

CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 67

APRIL 1981

NUMBER 2



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CALIFORNIA FISH AND GAME

VOLUME 67

APRIL 1981

NUMBER 2



Published Quarterly by
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

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SHARK ATTACKS IN CALIFORNIA AND OREGON, 1926—1979¹

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Analysis of 47 unprovoked shark attacks (45 in California and 2 in Oregon) since 1926 has clarified aspects of shark attacks on humans, especially by white sharks, *Carcharodon carcharias*. Eighty-seven percent of the victims were interviewed and precise details of these attacks are available. Data of attacks on skindivers were compared with skindiver effort and catch derived from California Department of Fish and Game surveys of skindivers conducted in 1960 and 1972. Information on victim activity, location of attacks, time of day, seasonal occurrence, water visibility, depth and temperature, species of sharks involved, attack patterns of sharks, and degree of injury to the victims is presented. Possible shark attack motivation is discussed. The principal attacking species from Point Conception and San Miguel Island northward was the white shark.

There appears to be an increase in the frequency of shark attacks both in California north of Point Conception and in Oregon. This increase may be due to the increase of prey marine mammal populations and a concomitant increase in the white shark population. The frequency of shark attacks in the 100-mile area between Año Nuevo Island and Bodega Bay is 10 times greater than the frequency of attacks over the remainder of the California coastline. Contrary to the findings of world-wide shark attack data analysis, northern California attacks occur more frequently in clearer water at temperatures less than 60°F. We found no correlation of attacks on spear-fishermen with speared fish. No shark attacks occurred in either California or Oregon in kelp beds; most of the attacks were on freediving skindivers who were looking for abalone. There were four fatalities—three swimmers and one skindiver.

INTRODUCTION

Those people seeking exotic flora and fauna to observe, photograph, research, and harvest have found the marine habitat an exciting new world to invade, but this invasion of the sea has not been without hazard. Most dangers encountered by skindivers and boaters are accepted as part of the endeavor, as are the dangers of bicycling, skiing, flying, etc. However, the hazards of shark attacks, as rare as they are, have not been accepted calmly and have probably inhibited many individuals from participating in marine water contact activities. Shark attacks present humans with a most terrifying experience, i.e., being attacked and possibly eaten in a physical element in which they cannot easily escape.

Even before the recent shark "horror" movies, there has been concern about shark attacks, such as in Australia, when swimming and surfing became popular in 1919 (Coppleson 1958). The horror stories of shark attack victims from ships sunk during World War II triggered world-wide anxiety among swimmers and

¹ Accepted for publication August 1980.

those involved in the newly developed sports of surfing and skin diving. In 1957 and 1958 there was an unprecedented number of attacks in South Africa waters (Smith 1963; Davies 1964) and, in this same period, there appeared to be an increase in shark attacks on both the Atlantic and Pacific coasts of the United States (Gilbert, Schultz, and Springer 1960; Schultz and Malin 1963). Llano (1957) posed questions and possible answers as to why sharks attack humans, analyzing reports of shark attacks and shark behavior throughout the world. In 1958, the American Institute of Biological Science and the Office of Naval Research initiated intensive research on sharks, including physiology, behavior, taxonomy, and a collation of world-wide shark attack data (Gilbert 1960). Most of the results of subsequent studies appears in *Sharks and Survival* (Gilbert 1963a) and *Sharks, Skates and Rays* (Gilbert, Mathewson, and Rall 1967). Several popular publications related some of the findings, especially the information on shark attacks (Helm 1961; Matthiessen 1971; Baldrige 1974; Ellis 1976).

The results of research through the early 1970's yielded considerable data on physiology and taxonomy, but serious information gaps on shark behavior persisted. Ethological studies were initiated on some of the more important and easily observed species (Johnson and Nelson 1973; Myrberg 1976; Gruber and Myrberg 1977; Gilbert 1977). The spring 1977 issue of *American Zoologist* presented the goals and results of current shark research. There now is less emphasis on collection and analysis of shark attack information and more effort on behavioral and life history studies. However, until more descriptive behavioral studies are completed, especially on the more dangerous species such as the white; tiger, *Galeocerdo cuvier*; and bull, *Carcharhinus leucas*, sharks, continued and more detailed analysis of shark attack data is needed to determine cause and effect parameters of shark attacks. Anti-shark measures are apparently effective in South Africa (Smith 1963), Australia (Springer and Gilbert 1963), the Hawaiian Islands (Tester 1969), but for mainland North America we are still confronted with continuing shark harassment and attack.

The Navy's Shark Attack File (SAF) information (Schultz and Malin 1963; Schultz 1967) allowed little opportunity for those analyzing the data to interview the attack victims. Much of the information was available only from news clipping services. Another drawback was the lack of control data to determine cause and effect relationships between shark attacks and human activities, such as comparison of diving and swimming effort with frequency of attacks. Many of the general conclusions were based upon analysis of a collation of world-wide data, lumping together all shark species and geographical areas; however, we found that generalized attack patterns based on world-wide data may not be applicable to California and Oregon, where unique oceanographic conditions occur.

Shark attack data presented in this paper are unique because a majority of the victims were interviewed by the authors and comparative data of skin diving effort and activity are available from Department surveys in 1960 and 1972 (Miller and Gotshall 1965; Miller, Geibel, and Houk 1974).

SOURCES OF DATA

Shark Attack File records (Schultz and Malin 1963) listed 28 unprovoked shark attacks for California from 1926 through 1962. Perry Gilbert (Mote Marine Laboratory, pers. commun.), submitted updated California SAF records through

1975, totalling 46 attacks. Of these 46 attacks we considered 16 to be special cases, provoked, or unconfirmed (Appendix I). In addition, California Department of Fish and Game files included information on 17 additional unprovoked attacks through 1979. In all, we considered 47 attacks on humans to be valid, unprovoked attacks for California and Oregon (Appendix II).

Initially, we reviewed the SAF data to determine whether an attack was provoked or unprovoked; part of this process was to locate as many of the victims as possible, even if they had been previously interviewed by other fisheries researchers. Twenty-seven (57%) of the victims were interviewed by the authors, 13 were interviewed immediately after the attacks by other researchers, and 1 was reported by Navy personnel; data for the remaining 6 attacks were available only from newspaper articles. Thus, 87% of the attack victims were contacted first hand in our analysis. This is compared with the world-wide SAF records in which 7.4% were from first hand interviews of the victims (Baldrige 1974). Details of eight California shark attacks on humans have been published in scientific journals (Bolin 1954; Fast 1955; DeWitt 1955; Collier 1964; Follett 1974; Collier, in press). Identification of the shark species was determined from tooth fragments, dentition patterns on the victims or their diving and surfing equipment, and by description of the sharks by victims and witnesses.

LOCATION OF ATTACKS AND SPECIES OF SHARKS INVOLVED

Shark attacks occurred irregularly from the Mexican border to Cannon Beach, Oregon (Figure 1). There are two general water regimes within these boundaries, each typified by characteristic fish assemblages. The cold-temperate zone (central California into Oregon) extends northward from San Miguel Island and Point Conception. The warm-temperate zone off southern California encompasses the inshore area south of Point Conception except for San Miguel Island. San Miguel Island is not totally within the influence of the warm southern California gyre and the fish populations at San Miguel are more similar to those along central California than those to the south. The southern range limits of 6 cold-temperate fish species are recorded at San Miguel Island (Miller and Lea 1972), whereas the northern range limits of 13 subtropical fish species occur at Point Conception, demonstrating the sharp, persistent demarcation of the two temperature regimes.

Recognition of these temperature regimes is important in the analysis of shark attacks since there appears to be dissimilar attack patterns in each of the two water masses, involving different shark species. It appears that most, if not all, the unprovoked attacks (Appendix II) from San Miguel Island and Point Conception northward may have been by white sharks whereas south of these areas the attacks may have been by sharks in families Carcharhinidae (requiem sharks), Sphyrnidae (hammerheads), and possibly Squatinidae (angel sharks). Of the 40 shark attacks in the cold-temperate zone (Table 1), 21 were by white sharks, 12 were presumably by white sharks, 5 were by large sharks of undetermined species, and 2 attacks were by sharks for which there was no description as to size or kind. Two of the seven attacks in southern California were reported by the victims to be by blue sharks, *Prionace glauca*, one by a hammerhead, *Sphyrna* sp., and one was most likely by a tiger shark, *Galeocerdo cuvier*. Shark species in three southern California attacks were unidentified.

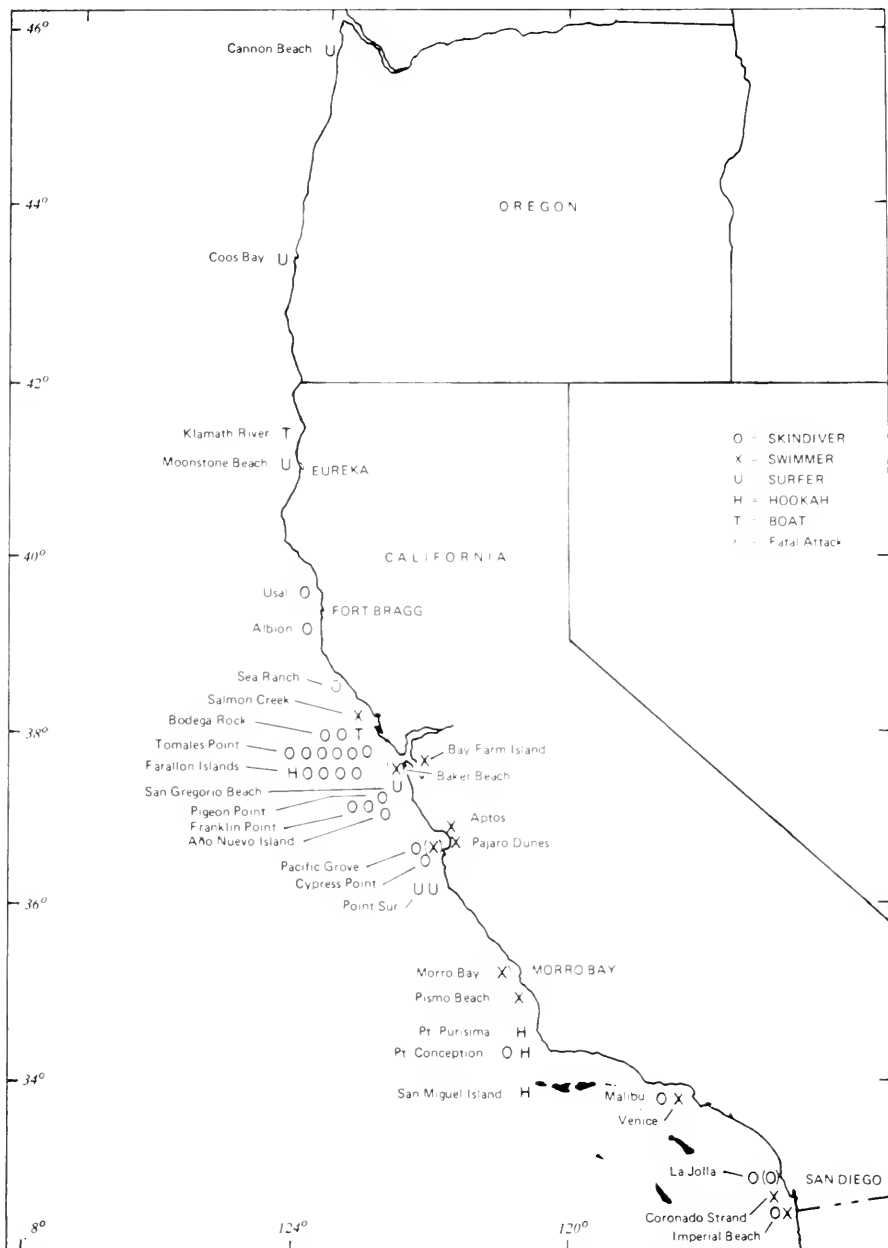


FIGURE 1. Location of unprovoked shark attacks on humans and boats in California and Oregon. (Attack locations are in lower case, initial caps.)

The seven unprovoked southern California attacks occurred between 1950 and 1959. Four attacks took place during the exceptionally warm water years of 1958 and 1959, indicating a possible abnormal influx of subtropical shark species (such as the tiger shark, which is rarely seen in southern California).

TABLE 1. Number of Unprovoked Shark Attacks on Humans Per Year in the Cold-Temperate (N) * and Warm-Temperate (S) * Water Regimes of California and Oregon by Victim Activity, 1926–1979.

Year	Swimming			Skindiving			Hookah Surfing		Totals		
	S	N	Total	S	N	Total	N	N	S	N	Total
1926	-	1	1	-	-	-	-	-	-	1	1
1950	1	-	1	-	-	-	-	-	1	-	1
51	-	-	-	-	-	-	-	-	-	-	-
52	-	1	1	1	-	1	-	-	1	1	2
53	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	-	-
55	1	-	1	-	1	1	-	-	1	1	2
56	-	1	1	-	-	-	-	-	-	1	1
57	-	1	1	-	-	-	-	-	-	1	1
58	1	-	1	-	-	-	-	-	1	-	1
59	-	1	1	3	1	4	-	-	3	2	5
1960	-	1	1	-	1	1	-	-	-	2	2
61	-	1	1	-	1	1	-	-	-	2	2
62	-	-	-	-	2	2	-	-	-	2	2
63	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	1	1	-	-	-	1	1
65	-	-	-	-	-	-	-	-	-	-	-
66	-	-	-	-	1	1	-	-	-	1	1
67	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	1	1	-	-	-	1	1
69	-	-	-	-	2	2	-	-	-	2	2
1970	-	-	-	-	-	-	-	-	-	-	-
71	-	-	-	-	1	1	-	-	-	1	1
72	-	-	-	-	1	1	1	1	-	3	3
73	-	-	-	-	-	-	-	-	-	-	-
74	-	-	-	-	4	4	1	2	-	7	7
75	-	-	-	-	3	3	1	-	-	4	4
76	-	-	-	-	-	-	1	2	-	3	3
77	-	-	-	-	1	1	-	-	-	1	1
78	-	1	1	-	-	-	-	-	-	1	1
79	-	-	-	-	1	1	-	1	-	2	2
Total	3	8	11	4	22	26	4	6	7	40	47

* Cold-temperate zone encompasses San Miguel Island and Point Conception north into Oregon; the warm temperate zone is south of this area.

Another grouping of possible shark attacks may also represent yet another type of shark interaction with humans in southern California. Five of the southern California unconfirmed attacks (Appendix I) along with two of the confirmed listings (Appendix II) appear to have unique similarities. The attacking sharks were not observed, the attacks were along sandy beaches in shallow water, and the wounds were all minor. Five were swimmers (Appendix I: SAF #234, 849, and Baldean; Appendix II: SAF #243 and 845) and two were surfers (Appendix I: Caldwell and Mullimax). The attack on the two surfers (Los Angeles Times 1975) was guessed by a lifeguard to have been by "barracudas", but this is unlikely in that there has never been a confirmed attack on a human by the California barracuda, *Sphyræna argentea*. It is possible that some, if not all, of

these seven southern California cases could have been attacks by the Pacific angel shark, *Squatina californica*. This shark reaches 5 ft in length, is an inconspicuous, sandy bottom dwelling form with a skatelike body, and has small but sharp-pointed teeth that could cause the type of cuts and abrasions reported in these cases. These sharks can be quite aggressive (Limbaugh 1963; J. Fitch, Calif. Dept. Fish and Game, pers. commun.) and have been known to strike at skindivers and commercial fishermen when disturbed. In July 1980, Charles Sloan, (scuba diver, Mountain View, CA, pers. commun.), reported being bitten by an angel shark he unintentionally provoked. While swimming along a sandy bottom in 50 ft of water off Santa Cruz Island, Sloan struck something on the bottom with a flipper and a few seconds later an angel shark bit one of his flippers. The shark identification was positive. The dive was at night (2100) and several angel sharks were observed by other divers. The attack occurred on 9 February 1980.

The small sharks that "attacked the feet" of Davis (Appendix I) were identified by Davis as leopard sharks, *Triakis semifasciata*, leading to an alternate possibility that at least some of these unconfirmed attacks (see also the facial bumping of Adams, Appendix I) could have been by leopard sharks. Other possible causes of minor cuts and abrasions in the surf area are several species of stingrays or unseen hard objects which can often be encrusted with sharp barnacles.

Other than the possible attack on Baldean in 1978 (Appendix I), there has not been an unprovoked attack in southern California south of San Miguel Island since 1959, demonstrating the rarity of attacks in southern California. Attacks in the northern cold-temperate zone, on the other hand, appear to be increasing. Numbers peaked in 1974 and 1975 but attacks have continued each year through 1979 (Table 1). Attacks on commercial abalone divers using hookah diving apparatus (skindiving equipment with an air supply from an air compressor on a tending boat) and surfboarders were first recorded in 1972. During more than 20 years of hard-hat diving for abalone, involving hundreds of divers over much of central and southern California, there were no reports of harassment or attack by sharks on these divers.

Except for the attacks in the area between Año Nuevo Island and Bodega Bay (Figure 1), shark-human interaction along the California and Oregon coastline has been rare and apparently random. Of the 40 unprovoked shark attacks on humans recorded for the northern cold-temperate area, 21 occurred within the 100-mile section from Año Nuevo Island to Bodega Bay. In addition, there were two attacks on boats in central and northern California, one off the Klamath River in 1959 (Follett 1974) and one off Bodega Bay in 1952 (Caras 1964). Since 1926, there has been an average of 0.20 attacks on humans per linear mile of outer coastline (San Francisco Bay excluded) between Año Nuevo Island and Bodega Bay. Outside this zone in California, the number of attacks has been 0.02 per linear mile of coastline, including the Channel Islands. The greatest number of attacks has been around Tomales Point, where eight attacks have been recorded over a 17-year period; five attacks have been recorded at the Farallon Islands over the same period.

There is anthropological evidence to indicate that the highest incident of shark attacks on swimming Indians in California was off Marin and Sonoma counties. D. Travis Hudson (Santa Barbara Museum of Natural History, pers. commun.)

has noted that the only coastal Indian tribe making magical reference to sharks (a prayer before entering the water) was the Coast Pomo (Loeb 1926), the tribe just north of the Bodega-Tomales area. One of the hunting procedures of north coast Yuki Indians was to swim to offshore rocks to kill harbor seals and sea lions with spears and arrows and then tow the animals to shore (Gifford 1939).

One of the problems in previous shark attack analysis has been lack of data on frequency of shark attacks in relation to the number of humans in the water. In our study, the attack ratio of Saturday-Sunday-Holiday (SSH) to Weekday (WD) was 1.75:1; however, we do not have estimates of swimming intensity for SSH and WD. A 1972 skindiving survey (Miller, Geibel, and Houk 1974) supplied an accurate count of SSH and WD effort at nearly all skindiving access areas between Pismo Beach and Eureka. In 534 sampling days, totalling 12,245 skindiver interviews in which SSH and WD data were recorded in the same monthly periods, the mean values of all sampling units of SSH effort was 33.2 divers, whereas the daily mean values of WD effort was 2.9 divers. Thus, in the 113 SSH days in a year, a mean total of 3,747 diving days was expended, and in 252 WD days of the year there was a mean total of 752 diving days expended, yielding a SSH:WD ratio of diver use of 4.98:1. The ratio of SSH:WD attacks by sharks was 5.25:1.

Even though there is a strong correlation between the SSH and WD attack frequency and skindiving effort, there is no positive relationship between the total number of skindivers utilizing a particular area and the number of shark attacks there. Skindiving effort for 1960 (Miller and Gotshall 1965) and 1972 (Miller, Geibel, and Houk 1974) were collated by county from San Luis Obispo County north to the Oregon border. A comparison of shark attacks on skindivers in these counties demonstrates no positive correlation of attacks with the annual skindiving effort (Figure 2). The highest skindiving effort was recorded for Monterey County, but only two attacks on skindivers occurred in this county. The greatest number of shark attacks occurred at Tomales Point (Marin County) and Farallon Islands (San Francisco County), areas of the coast with relatively little skindiving effort. Shark attacks seem to occur consistently (although infrequently) at Tomales Point, the Farallon Islands, and near Año Nuevo Island, but appear to occur more randomly throughout the remainder of the coastline. There has not been an attack in California and Oregon within the canopy of a giant kelp, *Macrocystis pyrifera*, bed. There was one attack (Sloan, Appendix II) in a bull kelp, *Nereocystis leutkeana*, area near Año Nuevo Island. In this case the shark removed the flipper from a descending diver 20 ft below the surface near the edge of a bull kelp area in which the plants were scattered about 20–30 ft from each other, forming a sparse surface frond cover. There have also been several shark harassments reported and, in two separate cases, the divers who were being circled by a large shark (reported as whites) headed for nearby kelp beds. Once the divers entered the canopy the sharks were not seen again. That is not to say that sharks may not enter giant kelp canopies. California Fish and Game divers encountered several sharks (presumed to be soupfin sharks, *Galorhinus zyopterus*), well within a thick canopy of giant kelp on the bottom; however, this shark species has not been known to attack humans.

If skindiving effort increased in the areas of high attack incidence, it would be logical to assume that the number of attacks would rise in proportion. However,

Coppleson (1963) reported that there rarely were shark attacks in Australia at beaches where over a hundred swimmers were active. When attacks did occur at swimming beaches, it was usually the swimmers away from the concentration who were attacked. A comparable situation is reported for South Africa (Smith 1963). In California, except possibly for the attack on Pamperin at La Jolla (Appendix II), all skindivers were attacked in areas of relatively light annual skindiving use. No divers have been attacked or harassed in any of the over 100 spearfishing competition meets that have been held since 1956 at many different sites from San Diego to Fort Bragg. The highest concentration of skindiving effort in central and northern California occurs in Carmel Bay and along Cannery Row, Monterey. White sharks occur in these localities, but there has never been an attack on a human in these heavily utilized areas. The area of highest incidence of traumatized dead sea otters, *Enhydra lutris*, coming ashore with white shark teeth fragments in the wounds is in Carmel Bay (Orr 1959; Ames and Morejohn 1980). A similar situation appears to be the case with surfboarders. All the attacks on surfboarders have been in areas in central and northern California and Oregon that are lightly or rarely used by surfers. We are not indicating that if large groups of skindivers start utilizing the Tomales Point and Farallon Island areas that there might be fewer attacks in these areas, nor are we indicating that it would be safer to dive in these areas in a large group.

ACTIVITY OF ATTACK VICTIMS

We used four activity categories to classify attacks: swimming (includes body surfing), skindiving (which includes both freediving and scuba), surfboarding, and commercial abalone diving (hookah). The largest number of unprovoked attacks was on skindivers (Table 1), with 26 attacks (55 % of the total), followed by 11 attacks on swimmers (23%), 6 attacks on surfboarders (13%), and 4 on hookah divers (9%). Activities of skindivers reveal that abalone diving was the activity most associated with shark interaction in California (Table 2). In California only 4 of the 26 skindivers (15%) had taken a fish before being attacked. In a world-wide analysis (Baldrige 1974), there was a positive relationship of the presence of speared fish with shark attack.

TABLE 2. Activities of Skindivers Attacked by Sharks in California.

	<u>Abalone Diving</u>			<u>Spearfishing</u>			Other	Total	%
	<u>With</u>	<u>Without</u>	Total	<u>With</u>	<u>Without</u>	Total			
	abalone	abalone		fish	fish		Total	Total	
Freediving.....	7	5	12	2	1	3	2	17	65
Scuba	0	1	1	2	2	4	4	9	35
Totals	7	6	13	4	3	7	6	26	100
Percent of total skindiver activity.....	27	23	50	15	12	27	23	100	
Percent of total activity (47 attacks) ..	15	13	28	8	6	15	13	55	

When the percentage composition of skindiving activity recorded in 1972 (Miller, Geibel, and Houk 1974) is compared to the percentage of shark attacks by skindiver activity (Figure 3), abalone divers were attacked at a rate 2.5 times greater than their representation. Skindivers in training sessions were never attacked, although this category comprised 30% of all skindiving activity in the

study area. There was no apparent correlation with the possession of abalones and attacks.

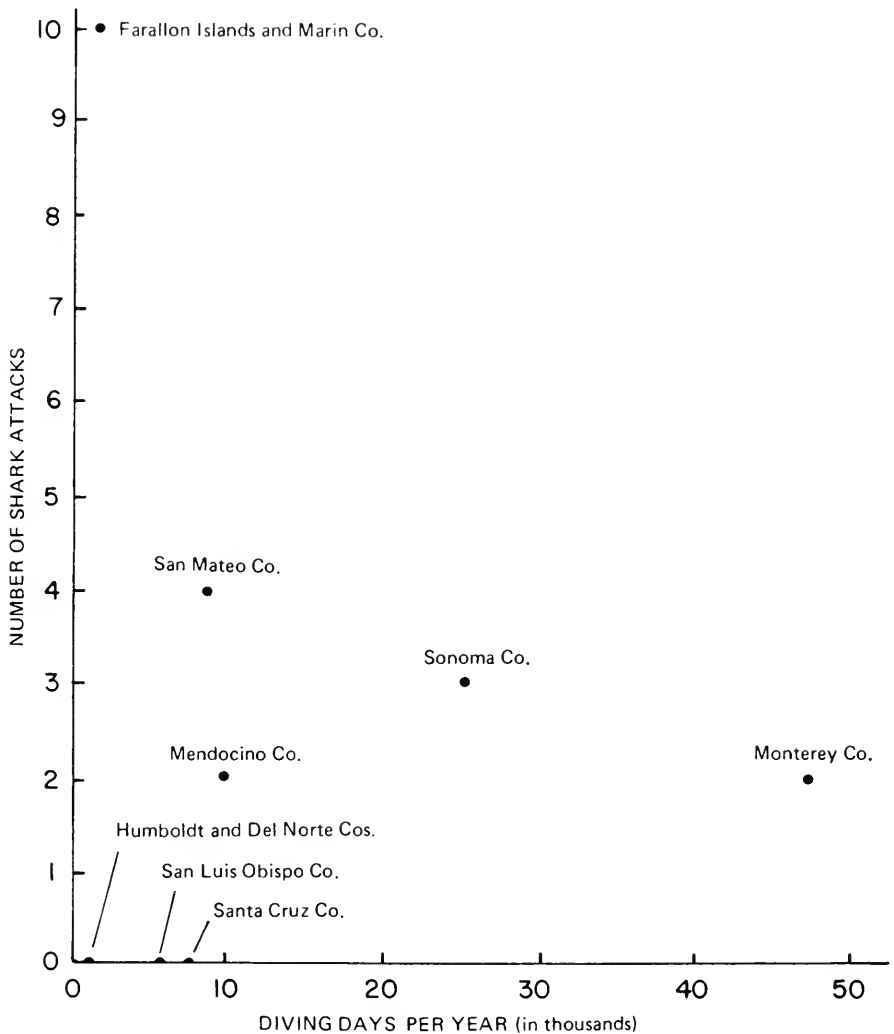


FIGURE 2. Number of unprovoked shark attacks on skindivers by central and northern California counties (1955-1979) compared to mean diving days expended by county (1960 and 1972 census data).

DEPTH OF ATTACKS

Attacks were over bottom depths ranging from 3 ft to 120 ft, with a peak depth range of 11 to 20 ft. There is no way to determine if these attack depth frequencies reflect shark distribution or behavior or represent the depths most frequented by the victims.

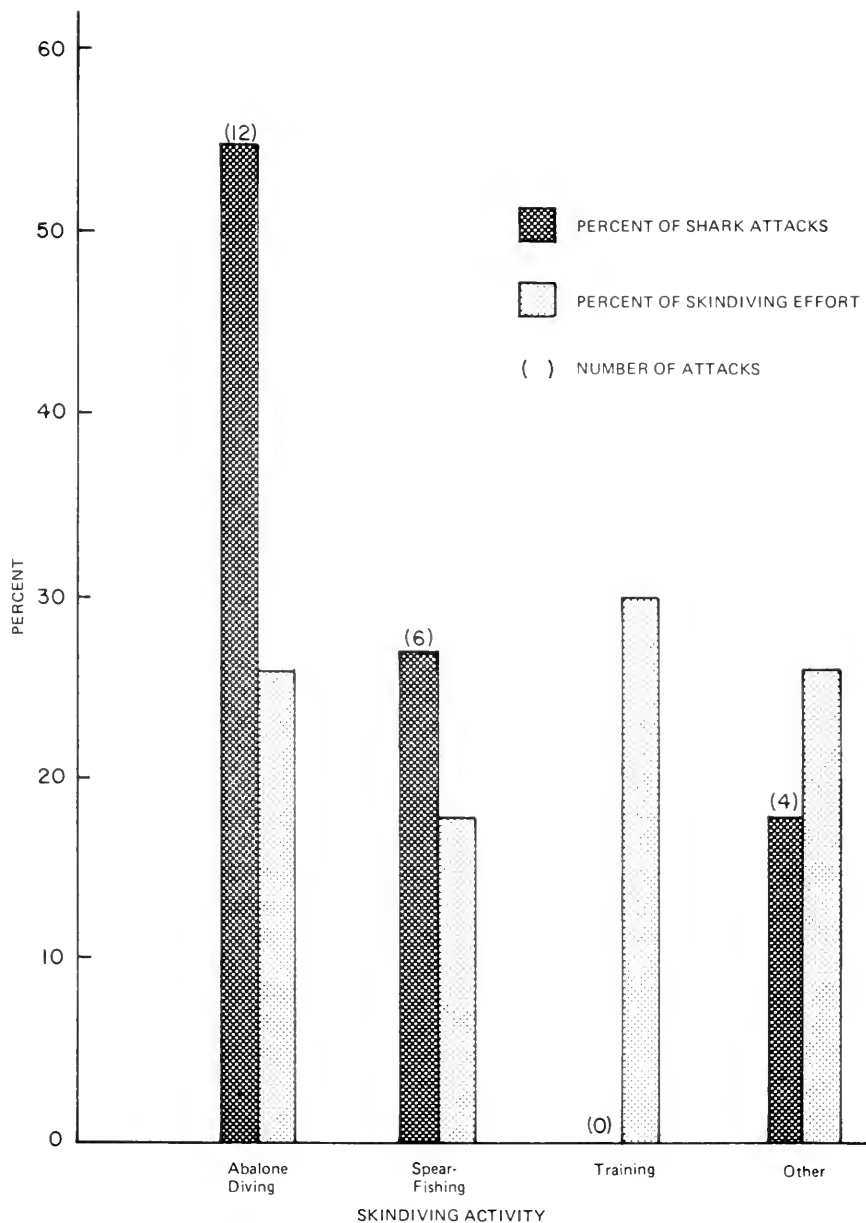


FIGURE 3. Percent and number of shark attacks on skindivers by activity compared to percent of skindiving hours expended in each activity.

A more meaningful presentation of attack depth data is the grouping of the number of attacks at or near the surface, at mid-depth, and at or near the bottom (Table 3). Seventy-nine percent of all victims and 76% of skindivers were at or

near the surface when attacked. In a world-wide analysis (Baldrige 1974), 90% of all shark attacks were at the surface, with only 31% of the world-wide attacks at the surface for skindivers. The high percentage of surface attacks for skindivers in California is probably due to the fact that 65% of the attacks were on freedivers who spend most of their diving time at the surface. In the 1972 skindiving survey, 49% of skindiving effort in central and northern California was by freedivers, demonstrating a greater tendency for freedivers to be attacked as opposed to those using scuba. Scuba gear cannot be used when taking abalones north of Yankee Point, Monterey County. Freediving for abalones in central and northern California thus results in a greater amount of diving time expended at the surface, where shark attacks are more likely to occur (Table 3).

TABLE 3. Number of Attacks at Surface, Mid-depth, and Bottom Categorized by Activity of Victims

Depth	Skindiving											
	Number				Commer- cial		Surf- boarding		Swimming		Totals	
	Free- diving	Scuba	Total	%	Abalone No.	%	No.	%	No.	%	No.	%
Surface.....	14	6	20	76	0	0	6	100	11	100	37	79
Mid-depth.....	1	2	3	12	1	25	0	0	0	0	4	8
Bottom.....	2	1	3	12	3	75	0	0	0	0	6	13
Total.....	17	9	26	100	4	100	6	100	11	100	47	100

WATER VISIBILITY

Water visibility is a difficult parameter to analyze because of the subjective nature of estimates made by the victims and witnesses. Shark attack data and skindiving survey results show shark attacks to occur frequently in clear water (20 ft or more visibility) north of Point Conception (Figure 4). Of the 21 attacks on skindivers for which we have data, 7 (33%) were in the 0 to 10 ft category, but 6 (29%) were in water visibilities of over 30 ft, which are relatively uncommon in central and northern California. Skindiver estimates of water visibility were recorded by Department researchers in 1960 and 1972, yielding 2,863 data points for all the major diving areas from Pismo Beach to Oregon. A chi-square test was used to compare these data with the subjective estimates of visibility reported by shark attack victims. Results were highly significant at the 99% level ($X^2 = 26.29$; 4 df), indicating that the actual number of attacks are not the same as the expected number of attacks.

Baldrige (1974), in his world-wide survey, points out that there is about a 50-50 chance of being attacked in clear water as opposed to turbid water. We could not compare our data directly with the SAF data because "clear" and "turbid" were not defined. If the dividing line of "clear" and "turbid" is arbitrarily set at 20 ft then, in California, 38% of the attacks were in "clear" water, with only 17% of the skindiving effort expended in this visibility category.

TIME OF YEAR OF ATTACKS

Shark attacks in California and Oregon have occurred in each month of the year (Table 4). All the attacks south of Point Conception were from June through November. Attacks north of Point Conception were scattered throughout the year, with a peak occurring from July through September. However, all the

attacks on hookah divers, surfboarders, and five of eight swimmers attacked in the northern area occurred from July through December. There is no obvious reason why most of the attacks have taken place in the latter half of the year. Even though there are predictable seasonable fluctuations in oceanographic conditions, marine mammal migrations, weather patterns and human activity, we do not know enough about shark behavior to reveal possible cause and effect relationships in seasonal trends. Blue sharks appear in large numbers off central and northern California during most of the summer and fall and the rare subtropical carcharhinids and sphyrnids (hammerheads) occur only in southern California. Little is known of the behavior of the white shark, the principal (and possibly only) attacking shark north of Point Conception.

TABLE 4. Shark Attacks by Month and Activity of Victims in Southern (S) and Northern (N) California.

	Swimming			Skindiving			Surf- Hookah boarding		Total		
	S	N	Total	S	N	Total	N	N	S	N	Total
January	-	-	-	-	3	3	-	-	-	3	3
February	-	-	-	-	1	1	-	-	-	1	1
March	-	-	-	-	1	1	-	-	-	1	1
April.....	-	1	1	-	1	1	-	-	-	2	2
May.....	-	2	2	-	3	3	-	-	-	5	5
June.....	-	-	-	1	-	1	-	-	1	-	1
July.....	-	1	1	1	4	5	2	-	1	7	8
August.....	-	3	3	-	2	2	-	2	-	7	7
September.....	1	-	1	-	3	3	1	2	1	6	7
October.....	2	-	2	-	2	2	-	1	2	3	5
November.....	-	-	-	2	1	3	-	1	2	2	4
December.....	-	1	1	-	1	1	1	-	-	3	3
Total	3	8	11	4	22	26	4	6	7	40	47

One data series for white sharks is available from daily commercial shark spotter logs kept by a pilot looking for basking sharks, *Cetorhinus maximus*, in Monterey Bay from 1948 through 1950 (Squire 1967). The data for this 3-year period were smoothed by a running average of three and plotted with comparably handled data on the number of shark attacks by month for central and northern California (Figure 5). There was a close relationship between the two frequencies, with strong peaks of white shark sightings in Monterey Bay and shark attacks throughout the area north of Point Conception during July and August. In spite of the obvious differences in data base between these series, it is tempting to assume some relationship between the increased seasonal abundance of sharks observed at the surface and attacks on humans.

TIME-OF-DAY OF ATTACKS

Time-of-day data are available for 37 of the 47 attacks. All the attacks were in the daytime, occurring fairly evenly between 0710 and 1830, with a slight peak from 1200 to 1500. These attack times probably reflect intensity of human activity.

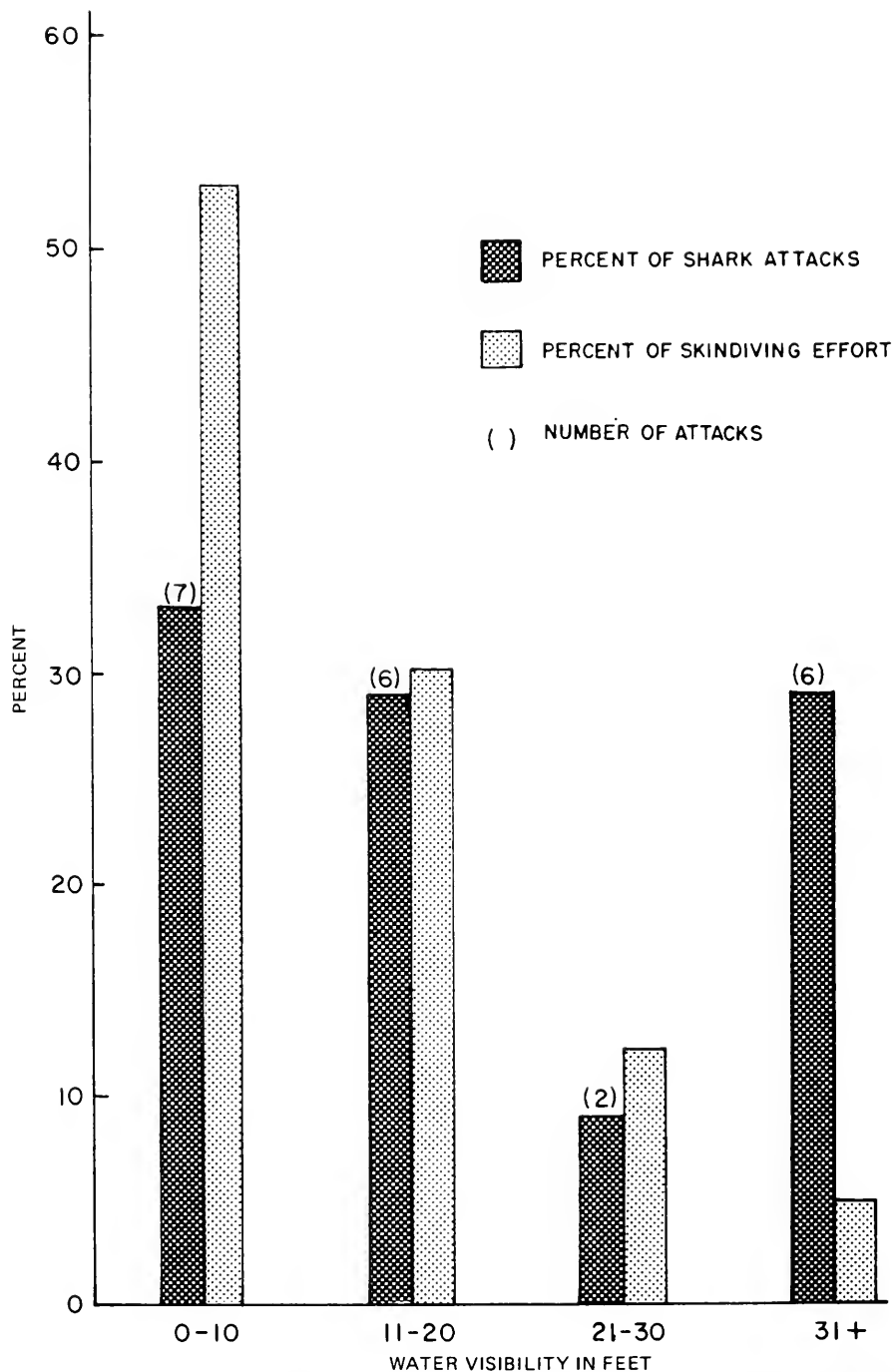


FIGURE 4. Percent and number of shark attacks on skindivers in 10-ft water visibility categories compared to percent of skindiving hours expended in each 10-ft category.

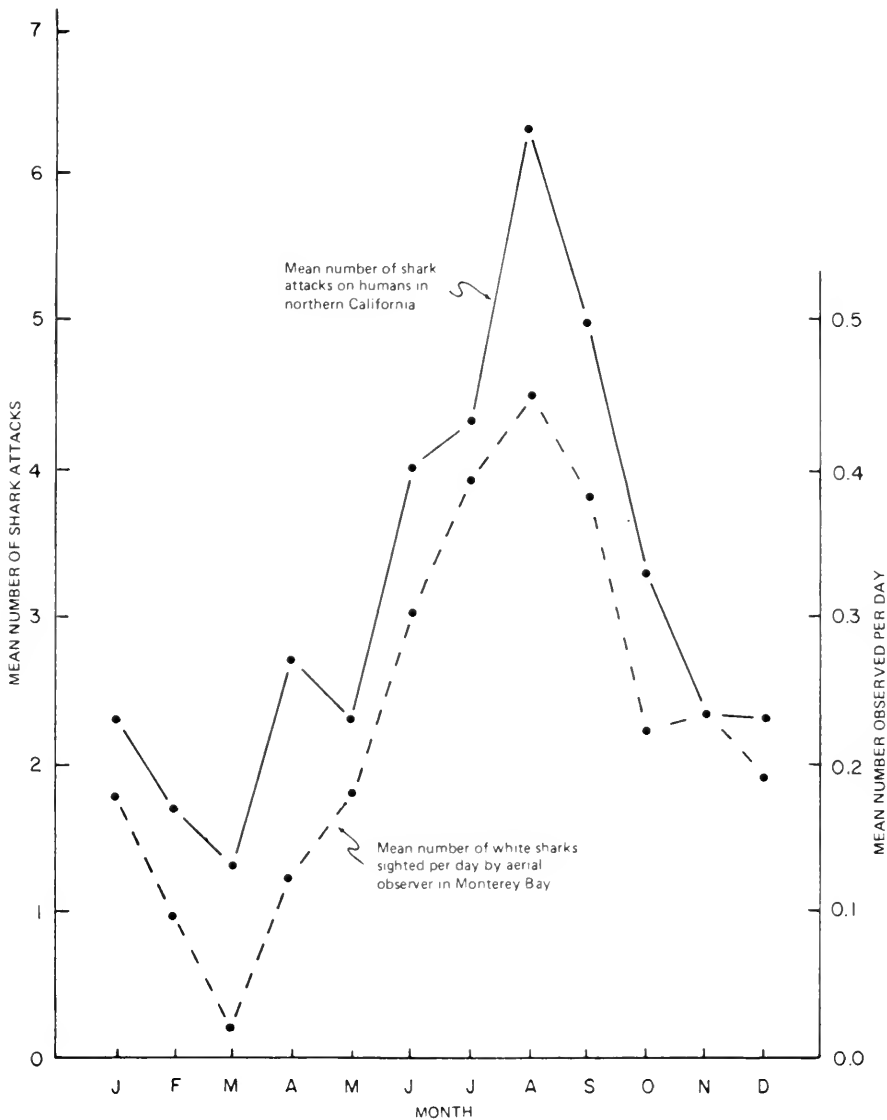


FIGURE 5. Mean number of shark attacks on humans north of Pt. Conception (1926–1979) compared to mean number of white sharks sighted per day by an aerial observer in Monterey Bay (1948–1950).

WATER TEMPERATURE

Water temperatures were measured after only 4 of the attacks; an additional 12 surface temperatures were estimated by victims and witnesses. That attacks occurred in all seasons in northern and central California is evidence that at least some white sharks are probably residential. World-wide attacks (Coppleson

1963; Smith 1963; Baldrige 1974) are skewed toward temperatures warmer than those encountered north of Point Conception. The southern California trend compares with the world-wide conditions, with most attacks occurring where surface temperatures are in excess of 65°F. In southern California surface temperatures at the scene of four attacks ranged from 60 to 70°F and northern California surface temperatures for 12 attacks ranged from 50 to 60°F.

SHARK ATTACK PATTERNS

Key data were the direction of the attack in reference to the victim, the ferocity or casualness of the shark, the number of bites on the victim, whether the wounds were from a "bite" or "slash", and the reaction of the shark to the victim's actions before, during, and after the attack. Attack patterns and their possible motivations can also be revealed from underwater studies (Limbaugh 1963; Nelson 1969; Johnson and Nelson 1973; Myrberg 1976; Gruber and Myrberg 1977). Other indirect sources of shark feeding behavior include stomach analysis (Strasburg 1958; Springer 1967) and observations of the commercial shark fishery (Springer 1967; Tester 1969). We do not intend to present a complete summary of current shark behavioral studies in this paper, but rather to present apparent shark attack behavior patterns for this section of the coastline and relate them to findings in various behavioral studies.

Direction of Attack and Extent of Damage to Victims

In only eight instances did the victim observe the shark before being attacked (Table 5), amounting to 19% of 43 attacks. Of the 42 attacks for which information is available, only three were frontal attacks on skindivers on the surface. Feet and legs were the parts of the body first attacked in 56% of the occurrences, followed by arms and hands (24%), and the torso (20%). A large majority of the wounds (65%) required extensive stitches, required hospitalization, resulted in permanent damage to tendons and nerves, or were fatal. The body was not cut by the shark on four of the victims.

Resistance of Victims and Behavior of Sharks

Evidence on whether resistance by the victim inhibited continued interaction by the shark is inconclusive. We could not determine whether eight of the victims (including the four fatalities) actually resisted (i.e., faced the attacking shark and engaged in aggressive activity by kicking at or striking at the shark). In some instances, it was not possible for the victim to resist because the shark did not remain in the area. For those who did resist, there was a slightly greater number of instances in which the shark remained in the area and attempted to bite rather than retreat. In 28 of the attacks (60% of the total) the sharks did not remain in the area (Table 6). In nine attacks (19%), the only bite was a prolonged grasp in which considerable damage was inflicted and which prevented the victim from resisting. In eight cases (17%), mostly involving swimmers, the shark inflicted more than one bite. Nineteen of the attacks consisted of one quick bite (16) or a slash (3), totalling 40% of the attacks. We defined a bite as a grasping of the victim with teeth of both upper and lower jaws; a slash was any wound or mark in which it was not possible to determine if teeth of both jaws were involved.

TABLE 5. Frequency of Occurrence of Whether the Victims Saw the Shark Before the Attack, the Direction of Attack in Respect to the Victim, the Area of Body First Hit, Whether the Victim Resisted, and Degree of Injury by Activity.

	<i>Skin- diving</i>	<i>Swimming</i>	<i>Surf- boarding</i>	<i>Hookah</i>	<i>Totals</i>
Shark Seen Before Attack:					
Yes	5	2	1	0	8
No	21	5	5	4	35
Unknown	0	4	0	0	4
Total.....	26	11	6	4	47
Attacked From:					
Rear	18	5	3	3	29
Side	5	1	3	1	10
Front	3	0	0	0	3
Unknown	0	5	0	0	5
Total.....	26	11	6	4	47
Area of Body First Hit:					
Feet-legs	19	3	2	1	25
Arms-hands.....	5	4	1	1	11
Torso	2	4	2	1	9
Unknown	0	0	1	1	2
Total.....	26	11	6	4	47
Victim Resisted Attack:					
Yes	16	3	0	2	21
No	9	4	3	2	18
Unknown	1	4	3	0	8
Total.....	26	11	6	4	47
Degree of Injury:					
None	2	0	1	1	4
Minor.....	9	2	2	0	13
Major.....	15	9	3	3	30
Total.....	26	11	6	4	47

TABLE 6. Attack Intensity and Patterns by Sharks by Victim Activity.

	<i>One quick bite or slash then departed</i>	<i>More than one bite</i>	<i>No second bite but attempted to bite again, or remained in area</i>	<i>One prolonged bite then departed</i>	<i>Total</i>
Skindiving.....	12	2	6	6	26
Swimming	4	4	2	1	11
Surfboarding	3	1	1	1	6
Hookah	0	1	2	1	4
Total	19	8	11	9	47
Percent.....	40	17	23	19	99

Forcefulness of Attacks

Most of the attacks were apparently slow, deliberate movements which could be described as an investigatory interaction of the shark with an "object". A typical attack in central and northern California was on a freediver who had been diving to the bottom several times, resting or slowly swimming on the surface and, without warning, had a flipper, foot or leg grasped by a shark. Shaking of the victim by the shark was reported in five cases. In 16 cases the skindiver fought back and, in about half of these encounters, the shark departed. Most of the victims were provided with immediate help from other divers in the water or in boats. In 23 cases, including 4 of the 5 attacks on surfboards, the attacks were forceful. The two attacks on boats (Caras 1964; Follett 1974) were forceful (the 14-foot skiff off Bodega Bay rammed and sunk and the 40-ft salmon troller receiving deep gashes in the hull above the water line). In two of the fatal cases, a swimmer (Savino, Appendix II) and a skindiver (Pamperin, Appendix II), the victims were apparently never released and were presumed eaten. The unconfirmed attack on a swimmer (SAF #417, Appendix I) off Dillon Beach (near Tomales Bay) may have also been by a large shark which carried the victim away. The Marin County sheriff's files showed the body was never recovered. Discussions with victims and the surgeons attending some of the victims revealed that in several cases severe damage to major arteries (and, in one case, the backbone) was narrowly missed. Several of the divers were extremely lucky to have survived.

POSSIBLE INCREASE IN WHITE SHARK ABUNDANCE

There appears to be an increased frequency in shark attacks within the past decade from Point Conception northward. The peak years of 1974 and 1975 have been followed by years in which one to three attacks have occurred on humans each year. This trend has continued although fewer divers are frequenting the Farallon Islands (Ainley 1979) and Tomales Point due to the notoriety of these areas as being shark attack localities. The senior author and other fishery biologists believe the population of large sharks in central and northern California is increasing. More frequent reports of sharks sighted and taken by commercial fishermen, sport anglers, and mammalogists confirm this belief. The senior author accompanied partyboat anglers to Año Nuevo Island during the 1958-1964 period. Angler's lines were occasionally harassed by blue sharks but not by white sharks. In recent years partyboat operators have reported they often move several times during a day to avoid white sharks. Partyboat, as well as sport skiff anglers off Año Nuevo Island report that white sharks will attack large lingcod, *Ophiodon elongatus*, when they are caught on hook and line. These large sharks will often surface and circle the boat, especially if fishing stops. Color photographs of the circling fish have confirmed these were at least two different large white sharks.

There have been more white shark attacks on sea otters in recent years (Ames and Morejohn 1980) and Burney LeBoeuf (Univ. of Calif. at Santa Cruz, pers. commun.) reports scarred, shark bitten elephant seals, *Mirounga angustirostris*, are commonly observed at Año Nuevo Island. Ainley (1979) notes that no attacks on pinnipeds were observed at the Farallon Islands from 1968 through 1972, but that from 2 to 12 attacks on pinnipeds, presumably by white sharks,

have been observed each year from 1973 through 1979 (D. Ainley, Point Reyes Bird Observatory, pers. commun.). Whenever it was possible to identify the pinniped being attacked, it was an elephant seal, and usually younger ones. Stomach contents of several large white sharks taken in southern and central California in recent years have contained remains of harbor seals, *Phoca vitulina*, and elephant seals. Elephant seal, harbor seal, and California sea lion, *Zalophus californianus*, populations have increased along the California coastline in the last 20 years, enhancing the food supply of large sharks. Harbor seals have reoccupied the Farallon Islands, with the first reproduction in recent years noted in 1974. Elephant seals first returned to the Farallones in 1959 but it was not until 1973 that the first pupping was observed. The elephant seal population has subsequently increased, with approximately 500 currently utilizing the Farallon Islands (D. Ainley, pers. commun.). Skindivers were attacked for the first time at the Farallones in 1962 and near Año Nuevo Island for the first time in 1974. All but two of the nearly 30 observations of sharks foraging on pinnipeds at the Farallones occurred during the winter, primarily December and January, when elephant seals return to the breeding grounds. The attacks on humans at the Farallones were from September through January, with four of the five attacks taking place from November through January. At nearby Tomales Point and Bodega Bay, attacks occurred during all seasons of the year, with four of the eight attacks occurring during April and May. There is a residential population of over 200 harbor seals in the Tomales-Bodega area.

MOTIVATION OF SHARK ATTACKS

Shark researchers debate the motivation of an attacking shark. Historically, we have assumed an attacking shark was feeding, but Baldrige and Williams (1969) and Johnson and Nelson (1973) report motivations other than feeding which elicit aggressive behavior in certain sharks. Agonistic behavior can be exhibited by posturing, which includes lowering of pectoral fins, arching the body, and swimming in figure-eight and S-patterns in front of the object being intimidated. These postures and displays warn an intruder to not approach further. Johnson and Nelson (1973) and other investigators have noted this behavior between sharks, as well as toward humans when the sharks were partially prevented by the divers from easy access out of a cove or cave in coral reef areas. Aggressive posturing can escalate into actual contact, sometimes a slashing with the upper teeth as has been observed in captive situations (Baldrige and Williams 1969) and in the wild (D. Nelson, Calif. State Univ., Long Beach, pers. commun.), or an outright biting attack.

The revelation that sharks may attack another shark, a human, and possibly a boat for other than foraging purposes has resulted in various interpretations of attack data on humans. Baldrige and Williams (1969) postulated:

"The possibility is therefore very real that a significant fraction of shark attacks on man may well be the result of aggressive behavior directed at the victims in an attitude of fighting rather than feeding."

They did not present detailed behavioral observations or criteria to differentiate agonistic and feeding patterns and unless the victim was actually eaten or severely wounded in a vicious attack, they apparently did not consider the attack to be feeding behavior: "If hunger motivated this and other similar attacks, then

the shark or sharks involved were certainly highly inefficient feeders." Ellis (1976) has also projected the exceptionally-efficient-predator syndrome to the white shark:

"The number of survivors of attacks by whites—about two out of three—seems to support the theory that the shark was not trying to eat the victim. . . . The white shark cannot be such an inefficient feeder that its prey, once in its mouth, escape approximately two out of three times."

Baldrige (1974) concludes his analysis of Navy shark attack data: ". . . 50–75 percent of all recorded attacks upon man were motivated by a drive or drives other than feeding." Considering the paucity of ethological information on the key species of sharks responsible for many of the attacks on humans, i.e., white, tiger, bull shark, and mako or salmon shark, *Lamna oxyrinchus*, this conclusion seems premature. This is especially so since Baldrige and Williams (1969) considered that any attack on a non-food item was not a feeding attack:

"Occasionally a shark will strike a surfboard or at the relatively flat skin of a boat. Surely, in these cases, the shark is not trying to eat the boats."

The implication that "attacks" on non-food items are not feeding behavior can be qualified. Strasburg (1958) relates:

"Pelagic sharks as a group are opportunistic feeders, commonly taking about any available food, and often ingesting articles of little or no nutritional value."

Some items found in shark stomachs include clothing, purses, and various other inedible items thrown over the side of vessels. There have been six surfboards attacked in California and Oregon and several others elsewhere in the world. Surfboards, about the size of large pinnipeds, silhouetted on the surface and propelled by the surfer's arms and legs, could be interpreted by a shark as something edible. Unlike most of the attacks on skindivers, shark interactions with surfboards have been quite forceful.

Sufficient observations have not been made to define a feeding attack on natural objects in the wild. There have been feeding patterns recorded on some of the larger tropical pelagic sharks. Limbaugh (1963) notes:

"Two distinct types of feeding behavior were observed in both the Galapagos and whitetip reef sharks. The most common pattern was to simply swim in and take the bait with varying degrees of speed. The other slightly less common method was to nose and/or maul a piece of bait as if they were playing with it. The former behavior was usually observed when more than one shark was in the area. A quick movement of another shark in the area, or even of a startled fish, triggered the behavior."

Springer (1967) relates similar behavior and mentions the buildup of interaction between members of a group of feeding sharks which can evolve into a feeding frenzy:

"Shark feeding appears to be an automatic process that always starts slowly and gathers momentum if a series of feeding stimuli occur. The solitary shark, predisposed to feed for whatever reasons, moves about investigating the environment, sometimes testing objects by bumping them with its snout. Occasionally, it makes short dashes after prey and, whether successful or not, returns to a leisurely inspection of the area. If another shark of similar size appears, setting up the possibility of competition for food, the bumping of inanimate or slow-moving objects is discontinued and these are taken

into the mouth for testing. When food is found, especially when more than one shark is present, the rate of swimming and attack by all members of the group increases. If the prey is large, and if its struggles produce a commotion in the water, the tempo and ferocity of the attack increase further."

The senior author has observed sharks foraging on small pelagic fishes floating on the surface after fish kills off Baja California. The sharks deliberately circled about, ingesting a few fish at a time, without much frenzy in their actions. Limbaugh (1963) reports similar feeding activity:

"The Galapagos sharks swam slowly to dead or injured fishes, almost stopped, and then bit or swallowed them. If several fish were after the same food, they raced for it, with the largest shark usually winning and the smaller ones taking the pieces. A whitetip reef shark made a quick rush at a fish, bit it in three pieces, and left two of the pieces behind."

These experiences cast doubt about the "efficient predator" concept for sharks. Possibly white sharks are opportunistic feeders as described for other species above and that they may not have a difficult time finding sufficient food along the California coastline with its present large populations of residential pinnipeds and fishes. Springer (1967) postulated:

"If we accept the proposition that sharks with plump livers that contain a high proportion of oil are well fed, we must conclude that sharks usually have little difficulty in finding enough food, despite annual and seasonal fluctuations in supply. . . . Sharks are able to go without food for long periods, . . . It does not greatly affect a shark's well-being to wait for the right conditions for feeding."

Nelson (1969) points out that older sharks become more cautious when approaching an unfamiliar object and will tend to more carefully investigate it. Limbaugh (1963) noted that almost invariably it was the younger sharks in an area that would be first to investigate the divers and approach much closer than larger members present. Thus, a general scenario of large shark feeding behavior appears to be one of cautious approach to items for investigation when by themselves with varying degrees of attack pressure invoked by the type of prey item. In addition to feeding interaction, agonistic behavior can be exhibited to other sharks and objects in its "territory."

Feeding attacks on marine mammals result in escape of some individuals. There are many records of sea otters and pinnipeds escaping an attack, evidenced by the number of these marine mammals observed dead with shark wounds, as well as from observations of living marine mammals with scars from shark attacks. Orr (1959) was first to note the sea otters attacked by white sharks in Carmel Bay. Through 1979, 61 sea otters that have been certain or near certain victims of shark attacks, have been found dead or badly wounded on central California beaches; another 40 sea otters may have been lacerated by sharks (J. Ames, Department of Fish and Game, pers. commun.). Thirteen of the 61 yielded fragments of white shark teeth when necropsied and two others contained tooth fragments too small for identification. The occurrence of various pinnipeds with obvious shark attack scars indicates sharks are not totally successful when attacking fast moving objects. Sharks may *not* be efficient feeders because, in some shark families, a nictitating membrane can cover the eye when the shark nears an object. The white shark does not have this membrane.

However, the junior author noted in the film *Mysteries of the Deep* (by photographers Ron and Valerie Taylor) that, when a white shark neared an object, the eye rolled upwards and slightly backward, exposing a white opaque covering. This covering probably protects the eye in the same manner as the nictitans. Gilbert (1963*b*) considers the function of the nictitans to be protection from abrasion and mechanical injury to the eye. Thus, it could be possible that some sharks are blind in the last stages of an attack and moving objects may be able to escape encounters because of this.

The attack patterns on humans in this study are quite varied. Most of the attacks, especially on skindivers, were a deliberate grasping of a part of the body, usually the legs, and the occasional shaking of the victim. Only three attacks could be considered slashes; the remainder were bites, some of them quite forceful. We reached the general conclusion that most of the attacks resemble the feeding behavior of an isolated, large shark that appears to be investigating an object. In most cases the shark left, but in 32% of the encounters, the shark continued the attack until the victim escaped on a board, onto a boat, or through the surf onto the beach. Schultz (1967) reported that 94% of the unprovoked attacks in his world-wide analysis were by solitary sharks. All the attacks north of Pt. Conception were by solitary sharks (at least no other sharks were seen in the area at the time) and in southern California one attack by a blue shark occurred when a diver approached a feeding frenzy of about 15 blue sharks, with one of the sharks coming to the diver, biting his arm, then leaving when struck. All other attacks in southern California were by solitary sharks. In only one case, the hammerhead attack off La Jolla, did a shark exhibit an agonistic display at the diver. After biting the victim's thigh and then retreating after being warded off, the shark made several figure-eight patterns in front of the diver, then left.

It is little consolation to a skindiver or swimmer whether a shark encounter is investigatory, feeding, or "fighting." Many of the initial attacks we report resulted in major injuries and damage to the victims or their equipment. It would be dangerous for divers to think that if the shark is merely attempting to drive the intruder out of its "territory," there is less danger. Divers might then be tempted to swim in shark infested areas when they would not otherwise do so if they felt a shark was going to attack for feeding. Our survey demonstrates clearly that any attacking shark can be highly dangerous regardless of its supposed motivation.

SUMMARY

1. There have been 47 unprovoked shark attacks in California and Oregon since 1926. Skindivers comprised the largest group, with 26 attacks (55% of the total), followed by 11 attacks on swimmers, 6 attacks on surfboarders, and 4 on commercial abalone divers. The two attacks in Oregon were on surfboarders.
2. There appears to be a division of shark attack areas off California. Shark attacks in the area south of Point Conception and San Miguel Island were typified by shark species which are tolerant of warmer water. The attacks occurred rarely (7 out of the 47 total). Most have occurred during periods of abnormally warm water. Possibly all the attacks north of Point Concep-

- tion were by white sharks; attacks occurred during all months of the year. Of the 40 attacks in this area, 21 were by white sharks, 12 presumably by white sharks, and 7 by unidentified species.
3. A number of shark attacks in southern California may have involved the Pacific angel shark; however, species identification was unconfirmed or doubtful.
 4. Shark attacks appear to be increasing in the cold-temperate area north of Point Conception, with the highest numbers occurring in 1974 and 1975. It is possible that this increase could be associated with the increase in pinniped populations along the coast over the past 20 years. The elephant seal, which is a favored food item of the white shark, has increased dramatically during this period.
 5. Data from attacks on skindivers were compared with scuba diving effort and catch from two surveys conducted by the Department of Fish and Game in 1960 and 1972. There was a close relationship between the number of skindivers in the water in SSH and WD strata and the number of shark attacks in these strata; however, there was no positive correlation between the number of annual diving days expended by county and the number of shark attacks by county. Shark attacks have occurred repeatedly only in certain areas (the Bodega Bay-Tomales Point area, the Farallon Islands, near Año Nuevo Island, at Pt. Sur, and Pt. Conception). The mean number of attacks from Año Nuevo Island to Bodega Bay was 0.20 attacks/linear mile, compared with 0.02/linear mile for the remainder of California.
 6. With skindivers, there was no strong correlation with the presence of speared fish (only 4 of the 26 skindivers attacked had speared fish); most of the skindiver attacks occurred on abalone divers. Nearly 80% of all attacks were at the surface. There were no attacks within *Macrocystis* kelp beds.
 7. There was no correlation with depth; attacks occurred over bottom depths ranging from 3 to 120 ft. In southern California attacks occurred in temperatures of 60°F or greater. Attacks in central and northern California occurred in temperatures at 60°F or less.
 8. There was a highly significant number of attacks in very clear water, especially by white sharks.
 9. No attacks occurred during nighttime; attacks during daytime ranged from 0710 to 1830, with a slight mid-afternoon peak. Even though attacks occurred during every month of the year, a majority occurred during the July to September period.
 10. Only eight of the victims observed the shark before being attacked; and only three attacks were frontal attacks. Sixty-five percent of the wounds were considered major. There were four fatalities: three swimmers and one skindiver.
 11. The belief that large white sharks are extremely efficient predators has not been substantiated by our data. The escape of large numbers of marine mammals indicates large sharks may not be able to capture all fast moving prey they attack.

12. Hopefully, divers will not think that some shark attacks may be agonistic territorial behavior rather than feeding behavior and thus feel they are safer in shark infested areas. This survey demonstrates that any attack, regardless of motivation, can be highly dangerous.

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APPENDIX I. Unconfirmed, Provoked, Special case, and Drowning Victim Shark Attacks in California. (An "*" placed before the name denotes the attack was listed as unprovoked by Schultz and Malin (1963).

Unconfirmed Attacks

- "*man." SAF #234; 27 May 1952; Coronado Strand, San Diego Co. This attack was reported in Coppleson (1958). The only information available is: "Swimmer struck on foot by shark . . . not seriously injured."
- "*man." SAF #849; 30 August 1955; Venice Beach, Los Angeles Co. This is a hearsay report by a lifeguard in a newspaper article. There was no interview of the victim or witness of the attack on the swimmer. The injuries were "minor."
- "*girl." SAF #435; 1950's; Capistrano, Orange Co. A fisherman was quoted by a lifeguard in a newspaper article that an attack "took place here several years ago."
- W. Davis. SAF #1709; 5 July 1972; Laguna Beach, Orange Co. Davis could not be reached for confirmation of the attack. The SAF report quoted the skindiver: ". . . saw two small sharks (2-3 ft) cruising towards me. Before I could get out of the water they started attacking my fins and legs. I speared one of them and made the I.D." There was no indication that the victim was actually bitten by what he identified as leopard sharks.
- M. Caldwell. 4 October 1975; Seal Beach, Orange Co. This was one of two attacks (see Mullimax below) on two surfers at this spot within a few minutes of each other. The victims could not be reached for confirmation. Caldwell received a deep laceration on the leg. A lifeguard guessed the attack was by a barracuda but the surfer thought it might have been a stingray.
- J. Mullimax. 4 October 1975; Seal Beach, Orange Co. The surfer received one laceration which he thought was probably from a shark. The attacking animal was not seen.
- M. Baldean. 3 September 1978; Santa Barbara, Santa Barbara Co. This swimmer was bitten in 3 ft of water on a sandy beach. The attacking animal was not seen but shook the victim's leg before letting go. The victim could not be reached for confirmation. Injury was minor.

Provoked Attacks

- *C. Leeper. SAF #239; 21 September 1954; La Jolla, San Diego Co. Quoting from Coppleson (1958): "Shark brushed against leg. When it came near again he grabbed it and brought it ashore . . ." "Five-foot sand shark." There is no evidence that the swimmer was actually bitten, and if so it would be considered provoked.
- *R. Yeargin. SAF #242; 8 May 1955; Malibu Beach, Los Angeles Co. Only information is: "Hit a 6 ft shark on nose . . . right forearm injured slightly." There is no evidence that the skindiver was actually bitten.
- *D. Strand and two other lifeguards. SAF #244; 30 August 1955; Zuma Beach, Los Angeles Co. An investigation by Gene Helfman revealed the following: ". . . a lifeguard went out on a surfboard . . . when he got out in the water he found a thresher shark which he grabbed by the tail. The shark turned around and bit him." Two other lifeguards got into the act and were bitten while bringing the shark to the beach, where it was killed.
- *K. Harris. SAF #1059; 29 August 1962; Solana Beach, San Diego Co. Report in the SAF file states: ". . . he struck the shark with his pry bar to scare it away from an abalone bed . . . turned and bit Harris and hung on." This was a horn shark (*Heterodontus francisci*); known to be aggressive when hit or grabbed.

Special Case Attack

- *J. Adams. SAF #1030; 10 February 1955; Trinidad Bay, Humboldt Co. This was a skindiver with a bleeding nose. A leopard shark bumped the diver on the side of the face and was warded off when it approached again. There was no bite.

Drowning Victims

- *A. and B. Wilkes. SAF #967; 27 July 1935; Santa Barbara, Santa Barbara Co. These were drowning victims from a boat accident. The bodies were mutilated by sharks but there is no way of knowing whether the attacks occurred before or after the victims had drowned.
- C. Jahne. SAF #417; @ 1955; Drakes Bay, Marin Co. This was a drowning victim whose body was attacked by two sharks when being towed to shore. The story was related by a deputy sheriff to a reporter when investigating the drowning of McNeil (see below). This attack was reported by the deputy to have taken place "several years ago."
- T. McNeil. SAF #417; 13 June 1959; Dillon Beach, Marin Co. The swimmer disappeared after diving into a deep hole inside the main surfline. The body was never recovered after extensive search.
- M. Samut. SAF #1930; 25 April 1965; Pacifica, San Mateo Co. this was a surfer who drowned and his body was never recovered. Sharks were sighted in the area later that day.

APPENDIX II. Confirmed, Unprovoked Shark Attacks on Humans in California and Oregon.

- N. Peixotto. SAF #215; 8 July 1926; San Leandro Bay, Alameda Co.; lat 37°44'N, long 122°15'W. The swimmer and his dog were swimming off Bay Farm Island when a 5 ft shark first attacked the dog, then the swimmer. Injuries were serious and the victim was rescued with help from a boat launched from shore.
- R. Campbell. SAF #733; 8 October 1950 at 1200; Imperial Beach, San Diego Co.; lat 32°34.0'N, long 117°08.0'W. Victim was one of four swimmers (body surfing) treading water in 12 ft of water. Shark bit victim on leg then attacked a second time from in front. Victim kicked at shark on second attack and was apparently bitten on thigh; wounds were major. Aid to victim was immediate; a nearby lifeguard placed the victim on his board and brought him ashore. The shark was reported to be "large."
- Navy Diver. SAF #722; November 1952 at 1000; Imperial Beach, San Diego Co.; lat 32°34.7'N, long 117°08.4'W. This was one of 24 demolition team divers swimming towards shore on the surface in 100 ft depth. A reported 4.5 ft blue shark bit diver's flipper and foot from below and behind. The shark remained in area. The diver grabbed his knife and, along with a diving buddy, went toward the shark. There was no second attack. Wounds were minor.
- B. Wilson. SAF #236; 7 December 1952 at 1400; Pacific Grove, Monterey Co.; lat 36°37.6'N, long 121°54.8'W. The body surfer was treading water in 20–30 ft depth when a large white shark attacked from below then attacked a second time from in front. The victim was pulled below the water by the shark then was attacked again as the rescuers were towing victim to shore. Wounds were major and fatal.
- P. Jacobs. SAF #240; 6 February 1955 at 0900; Pacific Grove, Monterey Co.; lat 36°37.6'N, long 121°54.8'W. Skindiver was on the surface in 20 ft depth when a white shark attacked from behind, resulting in minor wounds to a foot and loss of a flipper and sock from the other foot. Victim had speared a cabezon and was swimming slowly on the surface. The shark did not return.
- E. Vaughters. SAF #243; 4 September 1955; Venice Breakwater, Los Angeles Co.; lat 33°57.6'N, long 118°27.4'W. The swimmer was attacked in 4–6 ft depths. There is no description of the shark which bit his foot while he was moving on the surface. Wounds were minor.
- D. Clark. SAF #246; 14 August 1956 at 1630; Pismo Beach, San Luis Obispo Co.; lat 35°08.3'N, long 120°38.6'W. The 10-yr old swimmer was in 3 ft depth when a large shark attacked from the side, resulting in wounds on thigh, side, and hand. Victim was rescued by girl nearby on a rubber raft and brought to shore. The shark was reported to be large, about "nine feet."
- P. Savino. SAF #249; 28 April 1957; Morro Bay, San Luis Obispo Co.; lat 35°22.5'N, long 120°51.6'W. The tired swimmer was being aided through the surf by a swimming companion when he revealed that something hit him. After seeing the victim hold up an injured arm, the companion lost sight of him. The body was not recovered.
- J. Allman. SAF #845; 12 October 1958; Coronado Strand, San Diego Co.; lat 32°41.1'N, long 117°13.0'W. The swimmer was near the jetty in 6 ft of water when bitten on his left arm, hips, and leg. The victim was helped to shore by a companion. There is no description of the shark.
- A. Kogler, Jr. SAF #372; 7 May 1959 at 1745; Baker Beach, San Francisco Co.; lat 37°48.0'N, long 122°28.6'W. The swimmer and his girlfriend were swimming parallel to the shore outside the surfline when a white shark struck the victim's shoulder and chest area pulling him under the water. His companion brought him to shore; attack was fatal.
- R. Pamperin. SAF #376; 14 January 1959 at 1710; La Jolla, San Diego Co.; lat 32°51.2'N, long 117°16.0'W. The abalone freediver was swimming at the surface in 30 ft of water when a large shark, most probably a tiger shark, grabbed the victim from behind or lower side. The initial (probably only) attack raised the victim partly out of the water; the shark then submerged and was seen with victim held between the jaws. The body was not recovered.
- V. Fleet. SAF #434; 28 July 1959 at 1830; La Jolla, San Diego Co.; lat 32°51.2'N, long 117°16.1'W. The freediving spearfisherman was swimming on the surface in 30–40 ft depths when attacked by a small hammerhead shark. The shark attacked the victim's left thigh, resulting in minor bites. The diver had speared a barracuda which was attached to his right side. After the initial contact the shark made three figure eight patterns in front of the diver, then left.
- J. Hay. SAF #554; 4 October 1959 at 1500; Bodega Rock, Sonoma Co.; lat 38°17.7'N, long 123°02.8'W. The abalone freediver was swimming on the surface in 15 ft depth when a white shark bit the diver's swimfin and pulled the diver under the water. After shaking the victim's flipper, the shark released its hold and swam away. The diver's foot was not cut.
- D. Fryling. SAF #620; 10 November 1959 at 1330; Malibu, Los Angeles Co.; lat 34°01.4'N, long 118°47.0'W. The lobster freediver was swimming on the surface in 40 ft depth when he approached a feeding frenzy of about 15 blue sharks. He attempted to swim toward shore but one of the sharks was in the way and bit the victim on the arm. The victim grabbed the shark by the snout and pried the jaws open.
- F. Gilbert. SAF #683; 24 April 1960 at 1400; Tomales Point, Marin Co.; lat 38°13.7'N, long 122°59.5'W. The abalone freediver was lying on the surface kicking lightly in 18 ft depth when a white shark attacked from behind, biting the victim's foot and swim fin. The victim boarded his rubber float and went to the skiff. The wounds were minor; the swim fin was lost.

- S. Theriot. SAF #686; 19 May 1960 at 1300; Aptos, Santa Cruz Co.; lat 36°57.9'N, long 121°53.9'W. The girl swimmer was one of four students swimming in 8 ft depth on a sandy beach. The victim was circled by a large shark, probably a white shark, then bit on the leg. Two nearby companions on a large inner tube and a fourth swimmer brought the victim to shore. Injury resulted in loss of leg below knee.
- R. Orr. 21 May 1961 at 0930; Tomales Point, Marin Co.; lat 38°14.7'N, long 122°59.3'W. The abalone freediver was attacked near the bottom in 25 ft depth. The victim saw the shark coming slowly toward him. The shark picked up speed and hooked the diver's suit from behind. Victim then came to surface and got on his inner tube; the diver's skin was not cut.
- D. Vogensen. SAF #917; 20 August 1961 at 1530; Salmon Creek, Sonoma Co.; lat 38°21.3'N, long 123°04.1'W. The swimmer was waiting for a wave to ride when he saw a large form approach him. The shark circled then bit victim in groin and on foot. Injuries to the foot were major; the shark was presumed to be a white.
- F. Pair, Jr. SAF #1001; 14 January 1962 at 1030; Farallon Islands, lat 37°42.1'N, long 123°00.5'W. The scuba diver was spearfishing (no fish had been speared by the victim) in 30 ft depth with about 20 other divers. A companion observed the large shark heading toward the victim who was on the surface, but the victim did not see the shark until it had bitten his leg from behind. The shark remained in the area to attack again but was fought by the victim who thrust his spear at the shark's snout. Leg wounds were major.
- L. French. SAF #1115; 11 November 1962 at 1345; Farallon Islands, lat 37°43.4'N, long 123°02.3'W. The scuba diver had just reached the surface when a white shark (tentative identification) bit the victim in the thigh and leg area, shook him, and dragged him below the surface. The victim then fought back with his speargun and the shark swam away. Injuries were major.
- J. Rochette. SAF #1247; 11 January 1964 at 1200; Farallon Islands; lat 37°41.5'N, long 123°00.0'W. The scuba diver had speared a rockfish and had just reached the surface in 50 ft depth when a white shark bit the victim's thigh and legs. The shark continued to attack for several minutes while being hit in the snout at least nine times by the victim. Injuries were major. Prior to the attack, one of the victim's companions was harassed by the shark. After the attack two other scuba divers were visited by the shark on the bottom but it left when they remained in a cavelike area.
- D. Barthman. SAF 1398; 22 January 1966 at 1000; Cypress Point, Monterey Co.; lat 36°35.0'N, long 121°58.7'W. The freediver spearfisherman (had not speared fish) was resting on the surface in 60-65 ft depth when a shark bit the diver's arm, then attacked his thigh and shook the victim. The victim struck at the shark with his speargun and it departed after the second attack. Injuries were major. The victim thought it could have been a blue shark, but the wounds indicated a small white shark.
- F. Logan. SAF #1569; 27 July 1968 at 1100; Bodega Rock, Sonoma Co.; lat 38°17.7'N, long 123°02.8'W. The abalone freediver was attacked by a white shark near the bottom in 20 ft depth. The attack was from the side, with the shark holding the victim's torso between its jaws and shaking. The pressure was intense and prevented the victim from moving. The weight belt was severed and presumed to be swallowed by the shark. After the prolonged bite the shark departed. Injuries were major.
- R. Colby. 20 July 1969 at 1300; Pigeon Point, San Mateo Co., lat 37°10.8'N, long 122°23.6'W. The abalone freediver was resting on the surface when a large shark (thought to be a white shark) bit the victim's foot and partially dragged the diver under. A companion saw the shark just before the attack. The first newspaper accounts reported this as a killer whale attack, but examination of the boot revealed razor-like cuts made by a large shark. Injuries were minor.
- D. Joslin. SAF #1647; 6 September 1969 at 1120; Tomales Point, Marin Co.; lat 38°14.5'N, long 122°59.7'W. The abalone freediver was nearing the surface in 25 ft depth when a large shark (presumably a white shark) bit the victim's leg and raised his body almost out of the water. The shark returned to attack again and the victim hit the snout area with an abalone iron; the shark departed. Injuries were major.
- C. Ward. 2 October 1971 at 1200; Sea Ranch, Sonoma Co.; lat 38°42.1'N, long 123°27.0'W. The scuba diver was observing along the bottom in 15 ft depth when a large shark grasped both legs of the victim in its mouth, released them, and then departed. Cuts were deep on one of the legs.
- H. Himmrich. SAF #1474; 28 May 1972 at 1430; Tomales Point, Marin Co.; lat 38°13.7'N, long 122°59.5'W. The abalone freediver was attacked while lying face down on the surface in 15 ft depth. The white shark seized the right thigh area, shook the victim, then released its grip. The victim was pulled immediately into a skiff; the injuries were major.
- K. Gray. 19 July 1972; Pt. Purisima, Santa Barbara Co.; 34°45.0'N, long 120°38.5'W. The commercial abalone fisherman using hookah gear was pinned on the bottom in 20 ft depth by a large shark (probably a white shark). The shark made several attacks before the diver could be pulled to the surface by the boat tender. Injuries were major.
- H. Kretschmer. 9 September 1972 at 1000; Point Sur, Monterey Co.; 36°18.0'N, long 121°59.0'W. The surfer was resting on his board in about 30 ft depth when a white shark attacked, destroying the board and resulting in major damage to one of the surfer's legs. The victim saw the shark approaching on the surface before the attack. This attack was reported to be by a killer whale but tooth marks in the neoprene suit proved this attack was by a large white shark.
- L. Hancock. 26 May 1974 at 1130; Tomales Point, Marin Co.; lat 38°13.0'N, long 122°59.6'W. The abalone freediver was attacked on the surface in 10 ft depth immediately after jumping into the water. The white shark

- bit his leg and the diver immediately grabbed the shark in both arms. The shark then broke free and remained in the area between the victim and the boat until the diver could be reached and brought aboard. Hospital treatment of wounds was necessary.
- R. Kehl. SAF #1725; 26 July 1974; Albion, Mendocino Co.; lat 39°13.7'N, long 123°47.1'W. The abalone freediver was descending when attacked at 20–30 ft in 40–50 ft depth by a white shark. The shark swirled in front of the victim, who struck its gill area with an abalone iron. The shark left. The diver's foot was slashed, resulting in minor injuries.
- R. Sanders. 5 August 1974; San Gregorio Beach, San Mateo Co.; lat 37°19.1'N, long 122°24.5'W. The surfer was lying on his board outside the surf when he observed a large shark heading toward him on the surface. The victim slid off the board but the shark slashed his hand. The shark held the surfboard, submerged with it, and upon releasing it, the board flew into the air. Injuries to the victim were minor.
- D. Webster. SAF #1726; 2 September 1974 at 1730; Franklin Point, San Mateo Co.; lat 37°09.0'N, long 122°21.5'W. Three scuba divers, Webster, Greenlaw (see below) and a third party were swimming on the surface toward shore in 30–40 ft depth when a large shark (probably a white shark) bit Webster on the foot and flipper then surfaced between the three divers. The shark came slowly to Greenlaw and slashed his hand when passing by. Injuries to both divers were minor.
- J. Greenlaw. SAF #1726; 2 September 1974 at 1730. (see Webster above).
- J. Holcomb. SAF #1727; 14 September 1974 at 1335; Farallon Islands, lat 37°45.8'N, long 123°05.8'W. The commercial abalone diver using hookah gear was attacked by a white shark near the bottom, which was 25–35 ft in depth. The initial attack was from the side, followed by another attempt to bite as the diver resisted by grabbing and hitting at the snout and mouth area. Injuries were major.
- K. Johnston. 28 September 1974 at 0720; Point Sur, Monterey Co.; lat 36°18.0'N, long 121°54.5'W. The surfer was sitting on his board in about 9–10 ft depth when a white shark attacked from the side, injuring the victim's thigh and lower abdomen and damaging the surfboard. Injuries were major.
- G. Johnson. 19 July 1975 at 1330; Point Conception, Santa Barbara Co, lat 34°26.6'N, long 120°28.5'W. The commercial abalone diver using hookah gear was attacked by a large shark (probably a white shark) on the bottom in 25–30 ft depth. The shark made five additional passes before the tender pulled the diver to the surface. A flipper was bitten; the diver's skin was not cut.
- R. Rebstock. SAF #1739, 23 July 1975 at 1430; Point Conception, Santa Barbara Co.; lat 34°26.6'N, long 120°28.5'W. The scuba diver went to the same location as G. Johnson above and was attacked by a white shark on the surface shortly after jumping into the water. The diver was going to dive for abalone. The attack was a forceful upward thrust, knocking the diver out of the water. Injuries were major.
- G. Brown. 9 August 1975 at 1330; Usal Creek, Mendocino Co.; lat 39°50.0'N, long 124°44.9'W. The abalone freediver was working out of a skiff with other divers. The attack by a white shark occurred when surfacing in 25–30 ft depth. The shark bit the victim's arm and the diver hit the shark in the belly area with his abalone iron; there was no second attack. Injuries were major.
- R. Buckley. SAF #1745; 6 December 1975 at 1200; Farallon Islands; lat 37°42.1'N, long 123°00.5'W. The spearfishing scuba diver, who had speared a lingcod, was attacked at about middepth in 40 ft depth by a white shark. The victim observed the attacking shark before contact and received a bite on one leg after the victim had dropped the spear with the fish. The victim did not resist and the shark departed after the initial attack. Injuries were major.
- M. Shook. 24 August 1976 at 1400; Coos Bay, Oregon; lat 43°21'N, long 124°21'W. The surfer was lying on the board attempting to catch a wave in 8 ft depth and noted a "bump" on the rear of the board. A few moments later there was a more forceful bump and the surfer looked back to see a large shark with the rear portion of his board in its mouth. The white shark pushed the board and diver along the surface and finally broke the end section off. The surfer then swam to the jetty with the broken section still tied to his foot. The surfer was not bitten.
- W. Kennedy. 18 October 1976 at 1230; Moonstone Beach, Humboldt Co.; lat 41°02.5'N, long 124°07.5'W. The surfer was bitten on the leg by a white shark in 8–10 ft depth. Injuries were minor. (Information from newspaper report and unpublished data supplied by Ron Warner, Department of Fish and Game, Eureka, and Ralph Collier).
- J. Worrell. 18 December 1976 at 0900; San Miguel Island; lat 34°04.3'N, long 120°22.6'W. The commercial abalone diver using hookah gear was attacked by a white shark when 15–20 ft under the surface in 35–40 ft depth. The attack was from behind, with the shark seizing the leg and buttock area. The air hose was severed, which apparently startled the shark; it swirled in front of the diver. The victim then hit the shark with his abalone iron and the shark swam away. Injuries were major.
- G. Friedman. 14 August 1977 at 1300; Tomales Point, Marin Co.; lat 38°11.5'N, long 122°57.8'W. The abalone freediver was nearing the surface in 35 ft depth when a white shark seized the victim's leg. Injuries were major.
- P. Dunah. 5 August 1978 at 1230; Pajaro Dunes, Santa Cruz Co.; lat 36°51.8'N, long 122°49.2'W. The swimmer was wading in 5 ft depth in the surf when he felt a tug on his leg. The minor lacerations on both sides of leg indicate a small shark.

- C. Sloan. 11 March 1979 at 1000, Año Nuevo Island, San Mateo Co.; lat 37°06.3'N, long 122°20.0'W. The scuba diver was observing about 20 ft below the surface in 30 ft depth when a white shark seized a flipper and spun him around. The shark then surfaced near the anchored skiff, then left. The diver's skin was not cut.
- K. Doudt. 26 November 1979 at 1030; Cannon Beach, Oregon; lat 45°50.3'N, long 123°58.3'W. The surfer was attacked by a white shark in 8 ft depth while lying on the board. The attack was forceful, with major injuries to the victim. There were repeated attacks on the board and victim.

HISTORY AND STATUS OF WILD PIGS, *SUS SCROFA*, IN SAN BENITO COUNTY, CALIFORNIA¹

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An interview survey of landowners, encompassing most of the wild pig range in San Benito County, was completed in 1976 as a pilot project in preparation for a statewide survey of the distribution, relative abundance, and management problems of wild pigs in California. Results of 8 man-months of effort indicate that approximately 7,000 wild pigs of domestic and wild boar ancestry now range over 54% of the county, primarily in woodland habitats. The annual kill from all sources in 1975-1976 was at least 2,200 pigs. Most landowners considered wild pigs as pests because of damage to rangeland, crops, and watering facilities. Control methods included hunting and trapping, but these efforts were successful in substantially reducing pig densities in less than 10% of the pig range. Paid recreational hunting occurred on the larger properties. There was little interest among landowners in providing free public access to hunters despite depredation problems by wild pigs.

INTRODUCTION

The term wild pig encompasses wild boar and feral hogs, both varieties of *Sus scrofa*. Feral hogs originated from domesticated stock but are free-living, are not under effective ownership of humans, and do not receive protection, care, or food as a deliberate gift from man (McKnight 1964). Feral hogs have existed in various parts of California since the Spanish introduced domestic swine in 1769. Wild boar, old world progenitors of domestic swine, were introduced into the eastern United States and subsequently into Monterey County in 1925 (Bruce 1941, Pine and Gerdes 1973, Mansfield 1978). Since then, wild pigs with a wild boar phenotype have dispersed both naturally and assisted by humans into many parts of California where they freely interbreed with feral hogs.

Although landowners and sportsmen have utilized wild pigs in California since they were introduced, wild pigs were not classified as a game mammal under the State Fish and Game Code until 1957. Since then, results of an annual postal questionnaire survey of 2 to 4% of hunting license buyers indicate that by 1975 approximately 24,000 hunters were annually harvesting over 30,000 wild pigs in 27 counties (Barrett 1977). Periodically, a questionnaire survey by Fish and Game personnel has been made to estimate the statewide wild pig population. An estimate of 27,500 was obtained for 1975 (Anonymous 1976). No detailed map of the distribution of wild pigs in the State has been published, but most pigs occur on private lands in oak woodlands or chapparal habitats (McKnight 1964, Barrett 1970, Nelson and Hooper 1976).

A proposal was made in 1975 by the University of California to carry out a

¹ Accepted for publication September 1980.

county by county survey of the distribution, abundance, economic status, and management problems of wild pigs, comparable to a previous survey of deer in the state (Longhurst, Leopold, and Dasmann 1952). This paper reviews the results of a pilot project in San Benito County to refine methodology for a statewide survey. San Benito County was chosen because: 1) wild pigs were reportedly increasing in numbers; 2) the reported hunter bag per unit area from 1971 through 1974 was relatively high; 3) most land holdings are relatively large; 4) most of the county is relatively open habitat (Isgrig 1969); and 5) it is relatively close to Berkeley. These characteristics were expected to maximize the efficiency of a pilot study.

METHODS

The survey was to involve four phases over a 3-month period. However, due to financial constraints, only three phases were completed. The first phase involved meeting with all those persons likely to have a general knowledge of the current distribution of wildlife throughout the county. Such persons included all Fish and Game personnel, the County Agricultural Commissioner, the County Trapper, and the University Extension Service, County Farm Advisor. These individuals were asked to outline portions of the county where they were relatively certain wild pigs did not occur.

The second phase involved: 1) compiling, from county tax records, a property boundary map on USGS 1:62,500 quadrangles for those portions of the county which might support wild pigs (only properties over 40 ha were included); and 2) instituting, in cooperation with the Farm Advisor's Office, a postal questionnaire survey of the 180 landowners whose properties had been outlined. This initial contact requested a minimum of information, primarily whether wild pigs had ever occurred on the property and whether the respondent would consent to a personal interview. A special effort was made to guarantee that all replies were confidential. Some respondents also provided information on population size, population trend, annual kill, and economic status at this time. Two weeks later we sent a reminder letter to non-respondents and by 4 weeks after the initial mailing we had received 117 responses (65%).

The third phase involved personal interviews, normally on the landowners' property. We reassessed our stratification of properties in light of the information derived from the postal survey. A number of smaller properties lacked pigs and were not considered further. Over the following 6 weeks, 80 landowners who had consented to be interviewed were contacted by phone to set up an interview date and subsequently visited. Interviews lasted from a few minutes to several hours, depending on the interest of the landowner. Two to four interviews were completed each day.

Each interview generally followed a standard procedure: a series of predetermined questions printed on a two-page interview schedule with space for notes (Figure 1); and a cell by cell analysis of the property using the USGS 1:62,500 quadrangles on which a 1000-m Universal Transverse Mercator (UTM) grid had been drawn. Together the interviewer and the interviewee judged whether each 1-km² cell: 1) had no wild pigs present at any time over the past 5 years (1971-1976); 2) had been visited by at least one wild pig but not regularly utilized (occasional range); or 3) had been regularly utilized by at least one wild

pig over the past 5 years (permanent range). Occasionally these determinations were adjusted by the interviewer after discussions with neighbors or hunters interviewed at a later date. Opinions were cross-checked whenever possible.

1.0 BACKGROUND	5.1 Predation on livestock wildlife
1.1 Name	5.2 Crop depredation
1.2 Address	5.3 Pasture or range rooting (acres per year)
1.3 Phone	5.4 Disease or parasite vector or reservoir
1.4 Property name and size	5.5 General nuisance attracting vandals, poachers
2.0 LAND USE	6.0 PIG HARVEST - REMOVAL (July 1975 - June 1976)
2.1 Crop type and acreage	6.1 Total kill or removal from property
2.2 Grazing system, AUMS	6.2 Location of kill \pm 1 km
2.3 Mining	6.3 Method, numbers or percent, income
2.4 Recreation	6.31 Paid hunting (local, city)
2.5 Residential density	6.32 Invitation hunting (friends, relatives)
3.0 WATER AVAILABILITY	6.33 Poaching
3.1 Kind (lake, reservoir, spring, well, creek)	6.34 Depredation shooting
3.2 Seasonality (semi-permanent, perennial)	6.35 Trapping (kill market)
3.3 Development history	6.36 Poisoning (methods)
4.0 WILD PIGS	7.0 NATURAL LOSSES - LIMITING FACTORS
4.1 None/ Occasional - Seasonal/ Generally present	7.1 Predators (map locations, trends)
4.2 Seasonality, movements	7.11 Mt. lion
4.3 Abundance (group size, total on property)	7.12 Black bear
4.4 Source (how and when did pigs arrive)	7.13 Bobcat
4.5 Kind of pig (color)	7.14 Coyote
4.6 Population in history and trends	7.15 Eagle (nests)
5.0 DAMAGE - NEGATIVE VALUES (dollars per year)	7.2 Limiting factors, competitors, foods, etc.

FIGURE 1. Interview schedule used in a survey of 80 landowners.

Most of the questions were straightforward and readily answered. Special attention, however, was given to the questions on population size and wild pig kill on the property for the period 1 July 1975, to 30 June 1976. This period was chosen in order to compare our results with those obtained by the annual questionnaire of hunting license buyers for the same dates. Throughout the interview these latter questions were double-checked and any inconsistencies clarified. Particularly useful in this regard was discussion of limiting factors, including predation. Again, crosschecking with neighbors and hunters helped clarify the situation. As always, a special effort was made to assure confidentiality of all information. Responses were never discussed with other interviewees or with anyone else except project personnel.

The fourth phase of the project could not be carried out because of insufficient funds and manpower. It was to involve a complete aerial reconnaissance of the known pig range in the county at the end of the dry season to determine if observations of trails and rooting or pigs themselves would substantiate the distribution pattern obtained through interviews. Additionally, ground transects were to be walked using a toe-point tally of rooted sites in sample areas of permanent pig range. Consequently, the following results are based solely on the accuracy of the information provided by respondents.

All information that could be quantified, other than names of property owners, was coded and entered onto magnetic tape for permanent storage. Two types of data files were constructed: 1) a property case file; and 2) a county-wide geographic grid file. Data for the latter file were derived from the field maps and the results of interviews regarding introduction date, population size, and annual

kill. In addition to pig distribution, the field maps provided geographic data on distance to dwellings, distance to water, land use, and habitat type for each 1-km² cell. These data were used to assess habitat preference.

All analyses were made on the CDC 6400 computer at the U.C. Berkeley Computing Center using existing programs (Nie et al. 1975) and a new set of programs designed specifically for geographic display and analysis of wild pig survey data.

RESULTS

Description of Respondents

Of 117 respondents, 4 (3%) were public agencies administering 24% of the county land area. The remainder were private landowners of properties ranging from 50 to 24,300 ha and averaging 2,025 ha. All properties over 4,050 ha within wild pig range were represented. Private land in the sample represented 56% of the county. The primary land use was livestock grazing (91%), recreation (5%), and crop production (4%).

History of Dispersal

The first pigs arrived in San Benito County with the Spanish at Mission San Juan Bautista in 1797, but we found no specific records of feral pigs prior to the 1870's. A few respondents believed feral pigs had existed on their properties since the time their ancestors ran domestic swine on the open range to utilize acorn crops. From the turn of the century until about 1955 all wild pigs were descendents of domestic stock and were localized in the northeastern, central, and southern portions of the county (Figure 2). The entire feral pig population was probably under 1,000. In 1964 there were only 246 domestic swine recorded in the county (Isgrig 1969).

Between 1955 and 1975, there was dramatic increase in wild pig distribution (from less than 8% to over 54% of the county). Three fourths of the 56 respondents providing information first noted pigs after 1955 (Table 1). This period coincided with efforts by several pig hunters and landowners to introduce wild boar from Monterey County to improve the sporting quality of the population. Comments by several landowners who suddenly discovered wild pigs on their property, and by certain hunters who personally released young wild boar, confirm that some of these introductions were outside the existing pig range (Table 2). It was also argued by several respondents that the wild boar type is more wide-ranging than the feral hog and dispersed at a more rapid rate in 20 years, even without assistance, than had feral hogs over the previous 80 years. Wild boar characteristics (particularly striped young) are now evident throughout most of the present pig range. Eighty-five percent of the respondents with pigs on their land had noted wild boar characteristics.

Our best estimate of the distribution of wild pigs in San Benito County in 1975-76 is based primarily on the judgments of landowners and several hunters and partly on our own interpretation (Figure 3). For example, where a small property that was not sampled was surrounded by known pig range we included the area. Permanent range includes those 1-km² cells in which pigs were believed to be permanent residents for some portion (usually the last few years) of the period 1971-76. Permanent range covered 21% of the county. Occasional

range includes areas where at least one pig had been seen during the same period, and totalled an additional 33% of the county. Thus the total pig range was estimated at 195,286 ha or 54% of the county.

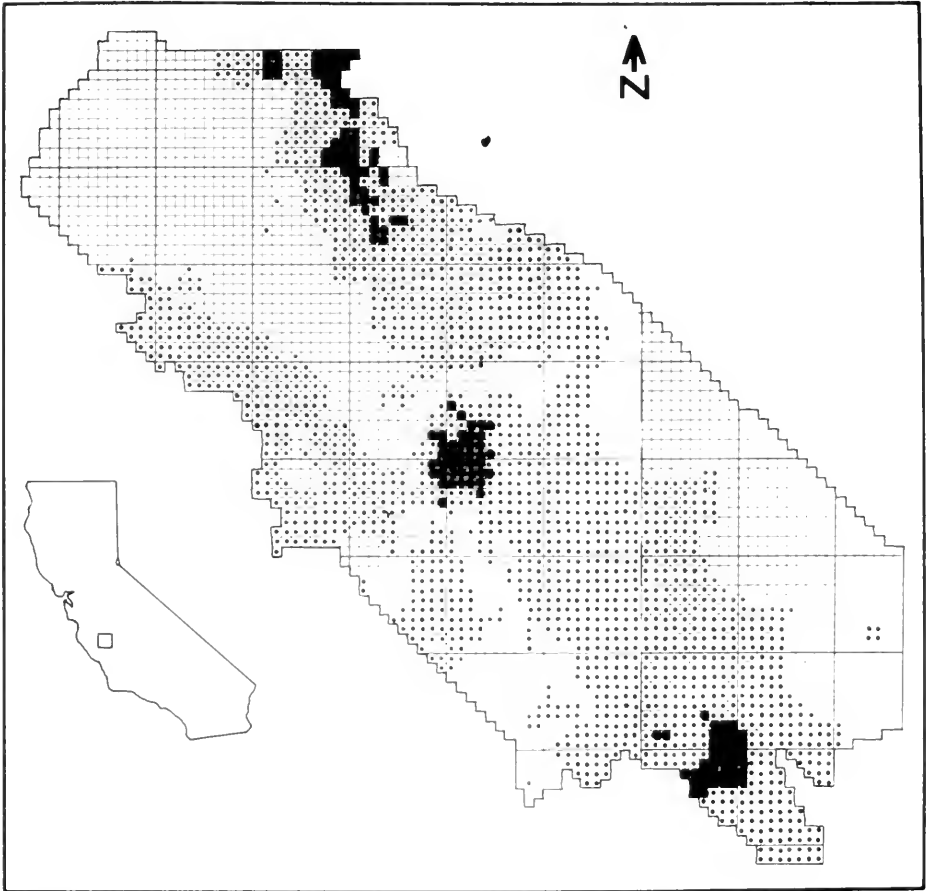


FIGURE 2. Feral hog distribution in San Benito County prior to 1955 (large dots) based on landowner interviewers. Small dots indicate current pig range.

TABLE 1. Opinion of Fifty-six Respondents Regarding the Period of Introduction of Wild Pigs Onto Their Land in San Benito County.

<i>Response</i>	<i>Percent</i>
1866-1875	2
1876-1885	0
1886-1895	2
1896-1905	2
1906-1915	2
1916-1925	0
1926-1935	4
1936-1945	4
1946-1955	9
1956-1965	26
1966-1975	49

TABLE 2. Opinion of Eighty Respondents Regarding the Source of Wild Pigs on Their Lands.

<i>Response</i>	<i>Percent</i>
Natural dispersal	53
Landowner release.....	11
Hunter release	4
Unknown	32

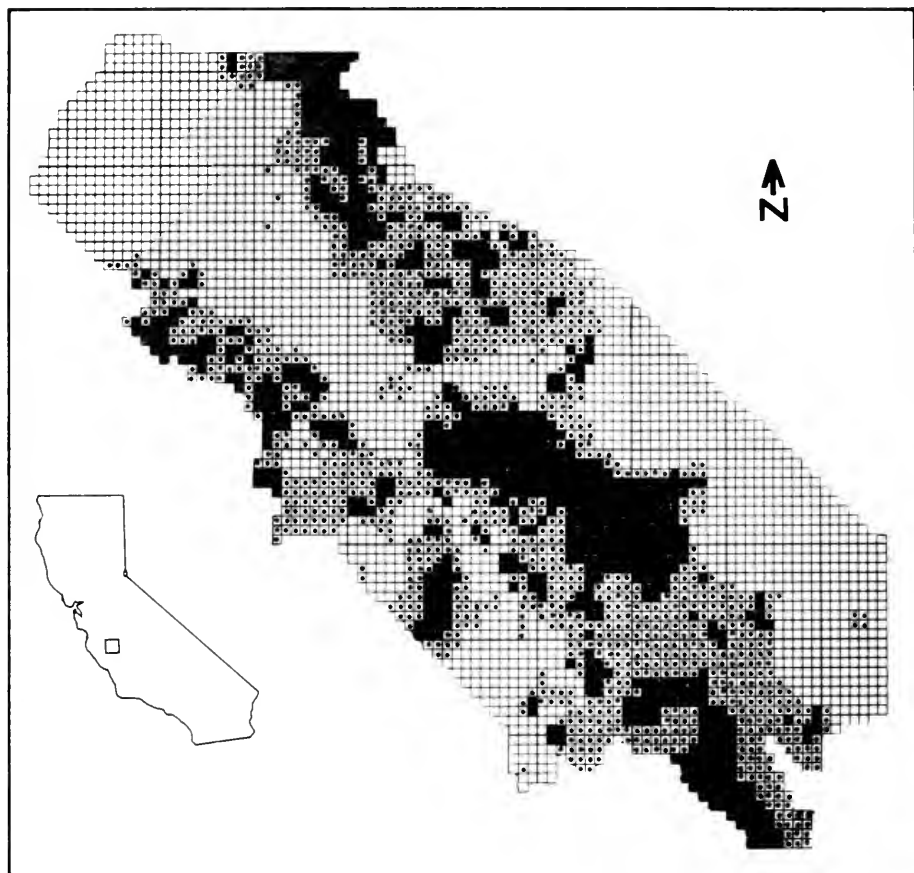


FIGURE 3. Distribution of wild pigs in San Benito County in 1975–1976, based on interviews with landowners, hunters, and our own judgement. Large dots signify permanent range and small dots signify occasional range.

Population in 1975–76

By calculating wild pig density estimates for all properties sampled, we estimated a total of 6,550 pigs on 182,077 ha of range. By extrapolating an average density of 3.5 pigs per km² to our estimate of 195,286 ha for occupied range in the county, we estimated there were 7,025 pigs in the county in 1975–1976. We believe this is a conservative estimate and does not account for suckling piglets. If only permanent range is considered for the same total population, a density

of 7.7 pigs per km² is obtained. This density is close to that estimated for similar habitat in eastern Tehama County (Barrett 1978). Our estimate is more than double the Department of Fish and Game estimate of 3,000 for San Benito County in 1975 (Anonymous 1976). Most respondents believed the population was currently stable or increasing (Table 3).

TABLE 3. Opinion of Forty-six Respondents Regarding the Population Trend of Wild Pigs in San Benito County in 1975–1976.

<i>Response</i>	<i>Percent</i>
Decreasing	9
Stable.....	43
Increasing	48

Limiting Factors

Many respondents did not have an opinion on which environmental factor (predation, water, cover, or food) was most important in limiting the distribution or abundance of wild pigs on their property (Table 4). Of those that did have an opinion, most believed that predation by humans in the form of hunting or trapping was more important than the availability of water, cover, or food. However, this opinion is not consistent with other information provided by the same respondents. Respondents recognized that mountain lions, *Felis concolor*, bobcats, *Lynx rufus*; coyotes, *Canis latrans*; and golden eagles, *Aquila chrysaetos*, might prey on wild pigs. However, none believed such predation was the limiting factor, although some argued that deer, *Odocoileus hemionus*, were limited by predators.

TABLE 4. Opinion of Eighty Respondents Regarding the Factor Most Limiting the Wild Pig Population on Their Land.

<i>Response</i>	<i>Percent</i>
Hunting or trapping.....	28
Water.....	14
Food	11
Cover.....	11
Unknown	36

We mapped all known permanent sources of water available to wild pigs within the occupied range. There was an average of 0.5 water sources per km². A density of less than one water source per 26 km² is probably necessary to limit the range of wild pigs (Barrett 1978). This may occur in a few parts of San Benito County, particularly in the dryer southeastern portion. It is unlikely, however, that water *per se* is a significant limiting factor within the present range.

We classified each 1-km² cell in the county into one of nine habitat types based on vegetation and land use information. Categories such as woodland—shrubland were utilized when two major habitats occurred in a cell and the second most important habitat comprised at least 30% of the area. Preference for each habitat was assessed by determining for each habitat type the percentage that was considered permanent pig range. Woodland and mixtures of woodland and other habitats are clearly preferred by wild pigs (Table 5). Woodland is comprised primarily of oaks (coast live oak, *Quercus agrifolia*; interior live oak,

Q. wislizenii; blue oak, *Q. douglasii*; valley oak, *Q. lobata*; canyon oak, *Q. chrysolepis*) and to some extent in the southeastern portion of the county, juniper, *Juniperus californica*. All these trees provide not only cover but also food in the form of mast. Portions of the county are probably unsuitable pig range because of inadequate cover.

TABLE 5. Preference of Wild Pigs for Designated Habitat Types in San Benito County.

Habitat	Percent of county	Percentage of habitat included within permanent wild pig range
Woodland	13	35
Woodland-shrubland	10	34
Woodland-grassland	32	31
Shrubland-grassland	5	18
Shrubland	3	17
Urban-suburban	1	7
Grassland.....	22	6
Grassland-agricultural	6	5
Agricultural-orchards	8	0

Mast, primarily acorns, is the single most important food of wild pigs in California (Pine and Gerdes 1973, Barrett 1978). Barley, oats, walnuts, prunes, and apricots are also utilized, resulting in conflict with agriculture. During the winter wet season, wild pigs utilize green forage and root for a variety of bulbs and soil invertebrates, thus coming into conflict with livestock production. We hypothesize that the availability of food is presently the most important factor limiting the abundance of wild pigs in San Benito County. Many respondents noted that the abundance of wild pigs had declined in years of drought and acorn crop failure.

Annual Kill

In response to questions on the type of human predation on wild pigs, most landowners indicated that hunting by themselves or with invited friends and relatives was the most common practice (Table 6). Poaching was apparently a very widespread practice, and it was of considerable concern to landowners, not so much due to loss of wild pigs but because of anxiety over potential damage to other resources. Many landowners simply shoot all wild pigs on sight (depre-dation hunting), a few regularly trapped pigs, and one had tried poison to control depredation problems. Several, including all of the largest landowners, had programs for paid recreational hunting. These programs were managed by employees or on a contractual basis with local guides. Fees ranged from \$10 to \$150 per day. Very few landowners said they would allow public hunting on their property without reimbursement even though wild pigs were generally considered pests.

By determining the kill density, including all sources of human-caused mortality, on each property for the period 1 July 1975 to 30 June 1976 and extrapolating over the total estimated pig range of 195,286 ha, we estimate a total kill of 2,206 (1.16 per km²). Properties under 400 ha averaged higher kill densities than larger

ones. A similar trend was apparent in the geographical data in that 1-km² cells with higher human densities were correlated with higher kill density.

TABLE 6. Opinion of Eighty Respondents Regarding the Sources of Human Predation on Their Lands in the Past Five Years.

<i>Response</i>	<i>Percent Frequency</i>
Invitation hunting.....	67
Poaching.....	58
Depredation hunting.....	36
Paid recreational hunting.....	14
Trapping.....	8
Poisoning.....	1

A comparison of our estimated kill of 2,206 with the legal kill in San Benito County for the same period estimated by the hunter questionnaire survey (Figure 4) revealed a discrepancy of 644 pigs. The estimated legal kill was 2,850 or 29% over our estimate. Hunter surveys generally overestimate the legal kill because hunters tend to exaggerate their success, thus this result is not unexpected. However, our estimate includes illegal and depredation kill in addition to legal kill. Our figure is probably an underestimate for two reasons. First, respondents tended to have difficulty recalling or estimating kill, and their estimates always increased with duration of the interview. Second, some substantial areas of public domain supported wild pigs, but we were unable to obtain any knowledgeable estimates of kill on these lands. It is likely that a good portion of the discrepancy between our estimate and the hunter survey estimate could be accounted for by the latter problem.

Kill as a Limiting Factor

Many respondents thought that all forms of human predation together was the main reason wild pigs were not more abundant in San Benito County. If one assumes that the estimates of population and kill by the respondents are accurate, and if one has independent information on the response of a wild pig population to cropping, it is possible to assess on a property-by-property basis whether or not the annual kill is substantially reducing the following year's population.

Information from several sources (Tipton 1977, Barrett 1978, Henry and Conley 1978, Barrett unpubl. data), including theoretical and empirical evidence, indicates wild pig populations can readily withstand annual harvests of 50 to 70% on a sustained basis. Our county-wide estimates for population and kill densities are 3.5 and 1.16 pigs per km², respectively, or a harvest rate of 30%. This is inadequate to control a wild pig population. On a local basis, we estimate wild pigs are being controlled (over 50% harvest) on only 7% of the occupied pig range (Figure 5). These calculations are inconsistent with the perception of many respondents that human predation is a major limiting factor in the county. To provide some perspective, one can calculate that given 0.08 households per km² of occupied pig range, and given that 60% of the pig population must be killed per year for control, then each household must take 25 pigs per year, or 2 per month. Few landowners were accomplishing this in 1975.

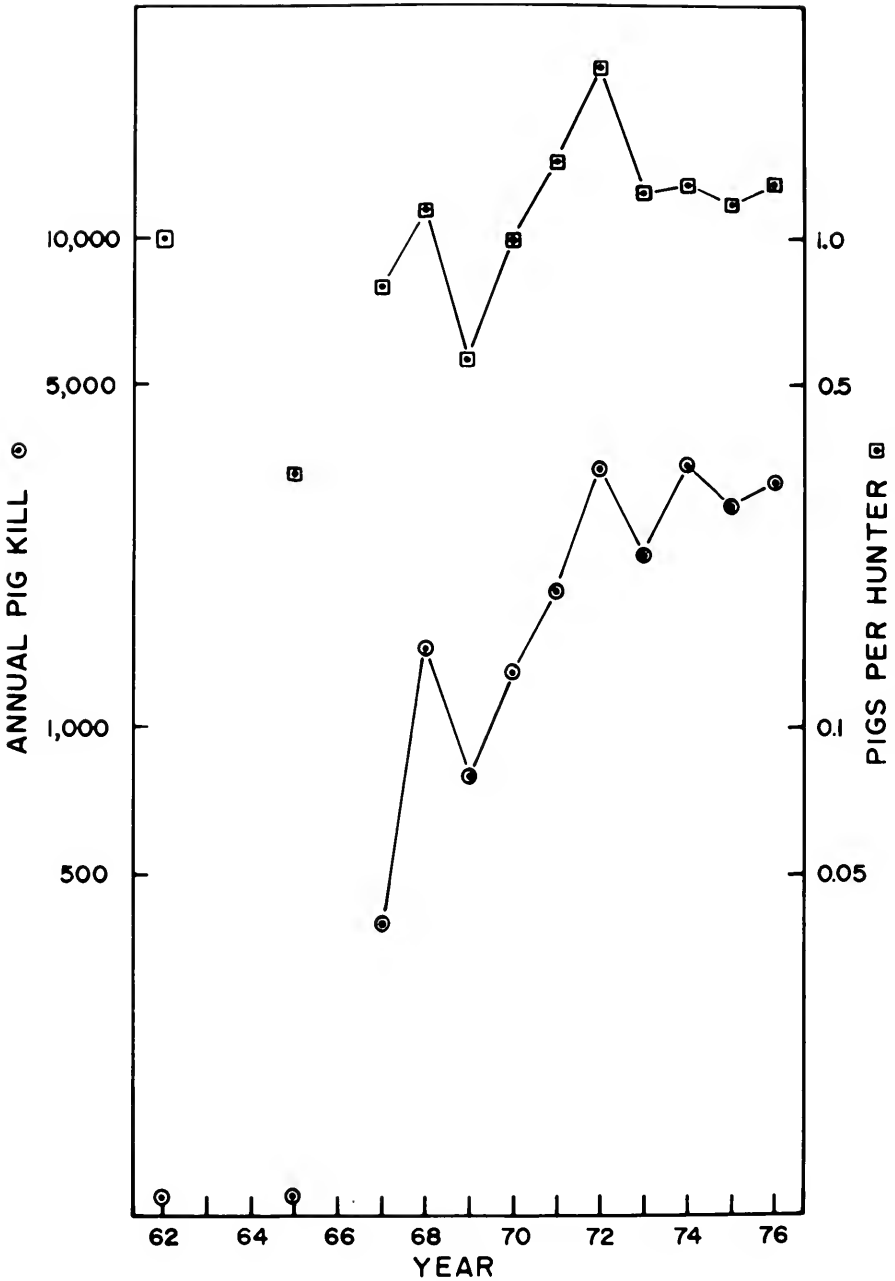


FIGURE 4. Trend in annual wild pig kill and hunter success in San Benito County based on a survey of 2-4% of hunting license buyers. San Benito County first appeared in survey results in 1962.

We should stress that the above calculations are for currently occupied range. Hunting and trapping are definitely important factors in limiting range expansion,

particularly around croplands and urban areas. In such fringe areas, dispersing pigs (usually boars) are regularly eliminated.

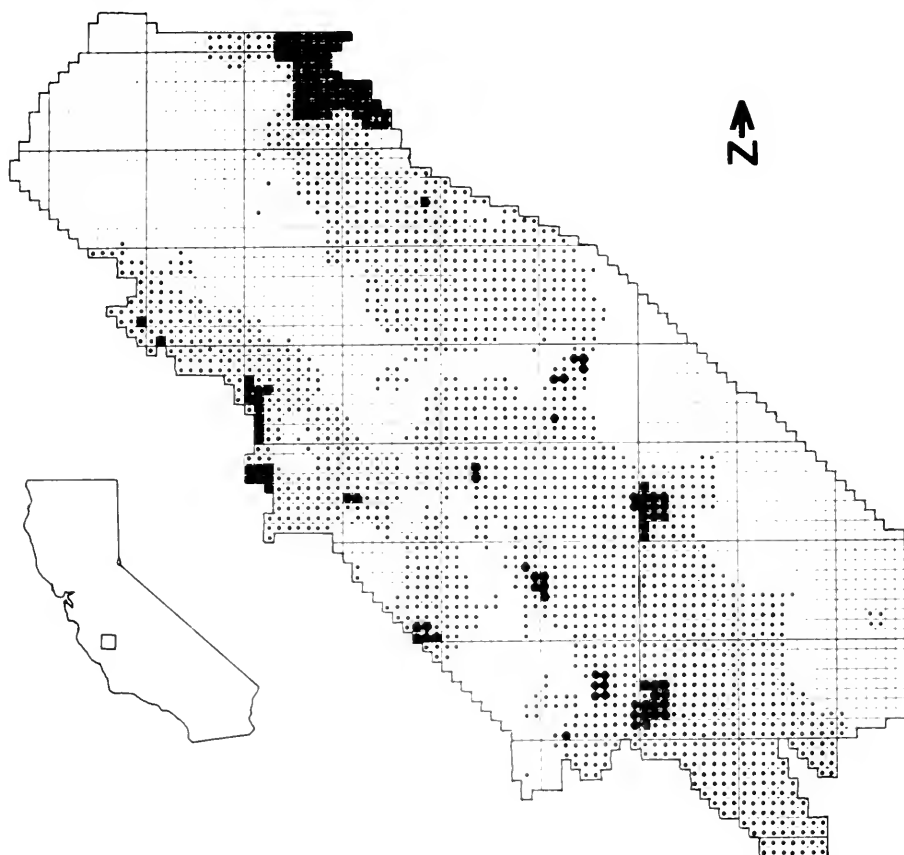


FIGURE 5. Localities in San Benito County where the 1975–1976 wild pig population (small dots) was apparently being cropped at a rate greater than 50% (large dots).

Economic Status

Interviewers were asked whether wild pigs on their lands were generally pests, assets, both (depending on the time and place), or had no particular economic significance. Nearly half of the respondents considered wild pigs definite pests (Table 7). Another 39% considered them pests under some conditions. Only 13% considered wild pigs assets or of neutral value.

TABLE 7. Opinion of Forty-six Respondents Regarding the Economic Value of Wild Pigs on Their Land.

<i>Response</i>	<i>Percent</i>
Pest	48
Both pest and asset	39
Asset	6
Neutral	7

Most problems caused by wild pigs resulted from their feeding on range and croplands (Table 8). Many accounts were recorded of pigs rooting up pastures, knocking down grain crops, and damaging vineyards and orchards. A third of the respondents had sustained damage to livestock watering facilities. A particularly serious example involved a boar which broke the float-valve off a water trough, allowing a large water storage tank to drain dry. Livestock had to be removed from the pasture as no other water was available that season.

TABLE 8. Opinion of Eighty Respondents Regarding the Negative Values of Wild Pigs on Their Lands.

<i>Response</i>	<i>Percent Frequency</i>
Pasture damage	69
Crop damage	50
Water source damage.....	33
Potential disease reservoir	4
Predator of livestock	3
General nuisance	57

Minor concerns included the possibility of wild pigs acting as reservoirs for livestock diseases and the possibility of boars killing lambs. A concern of over half the respondents was that pigs were a general nuisance in that they attracted poachers and sportsmen. Even though hunters might not set foot on their property, the likelihood of it (increased by the presence of pigs) was enough for many landowners to consider the presence of wild pigs a liability.

On the other hand, a few landowners were willing to overlook any negative problems because they were able to net additional income from the sale of pig hunting opportunities. Some of these people had even introduced wild boar to their property. Others, although they obtained some income from fee hunting, considered this simply a means to minimize the cost of controlling a pest. A few landowners had gone to considerable expense to fence portions of their property against pigs and other wildlife. It was not possible to estimate the dollar value (positive or negative) of wild pigs for the county as a whole from the responses obtained.

No respondents voiced concern for the possibility of wild pigs acting as predators or competitors with native plants or wildlife *per se*. However, when specifically asked, many agreed that there could be such interactions. Specific examples included predation on ground nesting birds such as quail, *Lophortyx californica*, and dove, *Zenaidura macroura*, although this could be compensated for as pig rooting enhances mullein, *Eremocarpus setigerus*, a preferred dove food (Grenfell, Browning, and Stienecher 1980). It was also suggested that pigs could reduce snakes and other herpetofauna.

CONCLUSIONS AND RECOMMENDATIONS

Although feral pigs have existed in San Benito County for over a century, efforts since 1955 by hunters and landowners to establish wild boar have resulted in a major expansion of wild pig range. The population and kill of wild pigs has increased as well. While this situation is looked upon favorably by hunters, most landowners consider wild pigs a liability. Owners of small pieces of property are generally capable of controlling wild pigs themselves and do not encour-

age public hunting on their land. Owners of larger tracts of land make use of the heavy demand for pig hunting in California by charging substantial fees for guiding hunters on their holdings. These fees are considered at least partial compensation for managing the hunters, as well as for depredations caused by wild pigs.

We consider this pilot project successful in that it has confirmed the feasibility of using personal interviews to obtain an overview of the status of wild pigs on a county-wide basis. The method provides information on economic status as well as distribution and abundance. We recommend the procedures developed here be extended over the entire state as soon as possible. However, we strongly recommend that future surveys include field checks to substantiate the distribution of permanent pig range.

ACKNOWLEDGMENTS

R. Lydon, San Benito County Farm Advisor, provided office facilities and executed the initial postal question survey. His respected position in the County was of critical importance to the success of this survey. M. Gering ably carried out most of the field work. M. Walraven assisted in developing computer programs and completing the data analysis. The California Division of Forestry provided access to facilities at the Bear Valley Fire Station. We would especially like to acknowledge the willing cooperation of landowners in San Benito County. The project was partially funded by U. C. Agricultural Experiment Station Project 3501-MS. Transportation was provided by the California Department of Fish and Game.

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SPAWNING BEHAVIOR AND REQUIREMENTS OF ALABAMA SPOTTED BASS, *MICROPTERUS PUNCTULATUS HENSHALLI*, IN LAKE PERRIS, RIVERSIDE COUNTY, CALIFORNIA¹

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Spawning behavior and requirements of Alabama spotted bass, *Micropterus punctulatus henshalli*, were studied by use of scuba in 1977 and 1978 at Lake Perris to determine which physical parameters might favor the propagation of this species over that of other black basses in California reservoirs. Spawning activity occurred almost entirely on rubble or large, flat rock substrates, in both sheltered and unsheltered areas, at depths between 0.5 and 4.6 m (\bar{x} = 2.6 m), and at temperatures between 14.5 to 23°C. Nesting cycles were successfully completed in 11 to 17 d. These data are similar to spawning data collected for other black basses; however, Alabama spotted bass displayed a tendency to spawn deeper and on more open or barren substrate, a definite advantage in some California reservoirs.

INTRODUCTION

A species of black bass, *Micropterus* spp., was sought that could spawn more successfully in California reservoirs during periods of fluctuating water levels and could maintain a sizable population where habitat, in the form of trees and brush, has deteriorated, leaving predominantly rocky or barren substrates. Spotted bass, particularly *Micropterus punctulatus henshalli*, appeared to be the most suitable for this purpose. They exhibit rapid growth, large size, and longevity in a lake environment (Gilbert 1973). They spawn comparatively deeply (Vogele 1975) and their fry develop faster, leaving the nest area earlier than largemouth bass, *M. salmoides*, fry (Carlander 1977). For these reasons, Alabama spotted bass were introduced into Lake Perris on 25 January 1974 (Brown, Aasen, and von Geldern 1974). Following successful spawning in 1974, studies were initiated to investigate various life history parameters, spawning requirements, and spawning behavior. Other black basses are absent in Lake Perris, thus precluding a comparative study in this impoundment.

DESCRIPTION OF STUDY AREA

Lake Perris is situated in a horseshoe-shaped basin closed on its western side by a 3.2-km earthfilled dam. It has approximately 16 km of shoreline and a surface area of 809 ha. Two kilometers of the northern shore have been graded (5:1 slope) and covered with sand to make swimming beaches (Figure 1). Two coves, approximately 2 ha each, were excavated in this shoreline for marina and boat launching areas. Both coves have 3:1 slopes and riprapped shorelines (2 km). There is a 2-ha natural cove near the southern abutment of the dam. This cove has about 1 km of shoreline; its sides are steep (3:1 slope) and covered

¹ Accepted for publication July 1980.

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with riprap and boulders. The substrate is primarily soft mud, although some areas in this cove have a sand and gravel bottom. The remaining shoreline of the Lake is decomposed granite or mud.

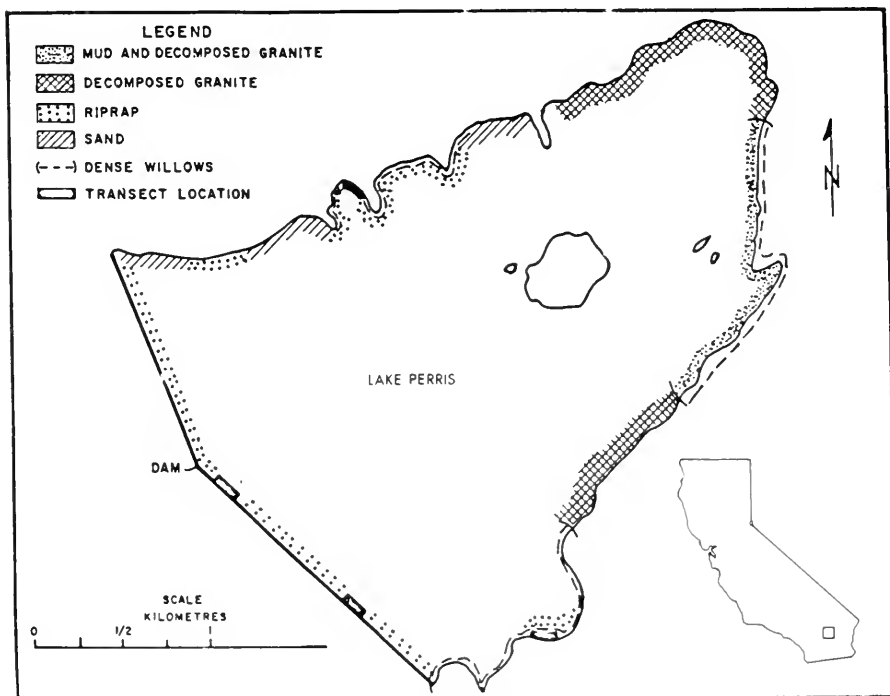


FIGURE 1. Lake Perris, Riverside County, showing substrate types and location of willows and study transects.

The upstream side of the dam is riprapped with rock ranging from 0.5 m to 1.5 m in diameter. Angler access ramps, composed of small rocks and gravel 5 to 10 cm in diameter, are situated at regular intervals along the upstream face. These ramps are approximately 5-m wide and extend from the crest of the dam to below the minimum pool elevation.

The Lake has a maximum depth of 35 m and a mean depth of 15 m. Surface water temperatures typically range from 10°C to 28°C. Water transparency, as measured by secchi disk, varies from 3 m in winter to less than 1 m in summer, averaging about 1.5 m. Lake stratification begins in late March and is complete by May; by early summer dissolved oxygen is almost totally depleted below the thermocline (usually 4 to 8 m below the water surface).

Lake Perris, a water supply reservoir that receives all its water via aqueduct, typically fills during November to April and drains from April through October. This pattern did not prevail, however, during the period of our study. During the 1977 spawning season, no water was released, and the water level dropped less than 20 cm, primarily due to evaporation. During the 1978 spawning season, the Lake received water from 1 April to 30 April and the water level rose 2.5 m. Beginning 1 May however, water release was greater than inflow and the water level dropped 1.1 m by the end of May.

During 1978, heavy growths of willows, *Salix* spp., developed in portions of the fluctuation zone, especially along the eastern and southern shores. Also, scattered plants became established along the dam face and in each of the coves, thus providing additional cover.

METHODS AND MATERIALS

Data relating to spawning behavior and physical parameters were collected using scuba equipment. In 1975 and 1976, cursory dives were made to identify substrate types and areas where the majority of spotted bass spawning occurred. Underwater observations were then conducted on a routine basis in 1977 and 1978. In 1977, diving began 18 March and was concluded 23 June. Eighteen dives were made: two in March, eight in April, six in May, and two in June. During the 1978 spawning season, 26 dives were made during the period of 13 March to 1 June: 7 in March, 11 in April, 7 in May, and 1 in June.

The study areas included four 100-m transects: two along the dam and one each in the marina cove and in the natural cove (Figure 1). At the dam, transect lines were placed on the bottom parallel to shore at a depth of 3 m, a depth arbitrarily selected to provide the divers with a fixed visual reference. These lines were anchored at each end and rocks were placed on them at various intervals to prevent their removal if hooked by anglers. At the coves, where angling pressure is more intensive, no lines were used. Instead, shoreline reference points identified the beginning and end of each transect.

Two divers participated in each dive. They entered the water at the beginning of a transect line or at a shore reference point, descended to depths of 3 and 4 m, respectively, and swam the length of the transect. Upon reaching the end of the transect, they ascended to depths of 1 and 2 m, respectively, and returned. This procedure permitted observation of the entire substrate at depths of 0.5 to 5 m.

Nests were marked for study by use of numbered floats. Each was attached to a transect line or anchored near a given nest. Weighted lines kept the floats underwater and prevented their removal by boaters or fishermen.

During each survey, divers recorded: (i) water temperatures at the surface and at 3 m, (ii) number of nests observed, (iii) depth of each new nest, (iv) condition of the nests (site cleaned, eggs present, eggs hatching, or fry present), (v) substrate type, (vi) orientation of nest to cover, (vii) presence or absence of fungus, (viii) extent of egg predation, and (ix) general behavior of the bass guarding the nest. A handheld thermometer was used for both surface and transect-depth temperatures. A Ryan recording thermograph anchored at 3 m was also employed.

The depth of a given nest was initially determined using a calibrated line or a diver depth gauge. Determination of substrate type and orientation to cover was done visually; substrates were classified as rock, rubble, sand, or mud. Orientation to cover was noted if the nest was within 1 m of a submerged object or overhanging rock. The presence of fungus on eggs and egg predation were also determined visually, but no attempt was made to quantify the amount of infection or predation on each nest. General behavioral observations were made both before and after the approach to a nest. Observations usually were made prior to disturbing the resident fish. In all cases, the diver remained motionless

on the bottom and as far from the nest as visibility would permit. In addition, it was necessary for the diver to control his breathing to avoid disturbing the resident fish; a slow, steady exhalation was less disturbing.

Data on nest size and number of eggs present were collected from five nests. Nest size was determined by measuring its greatest length and width. The number of eggs present was estimated by dividing the nest into quadrants. A 10 x 10-cm grid was placed in the center of each quadrant and the eggs under the grid counted. The ratio of the number of eggs within the grid to the area of the entire nest was used to estimate the number of eggs present.

In addition to the regular dives along the transects, random dives were made in other areas over various substrates. During these dives, only water temperature and the number and depth of nests were recorded.

RESULTS

Substrate Preference

Substrate types found in Lake Perris include mud, decomposed granite, sand, rubble, and large rocks (Figure 1). Preliminary dives made at various areas of the Lake in 1975 and 1976 suggested that spotted bass had definite spawning substrate preferences. Nests were seen only along the dam face where the substrate is composed primarily of large rocks with limited areas of rubble (angler access ramps). In 1977, spawning again took place primarily along the dam. Some nests were located, however, on gravel in the natural cove. Because so few nests were observed on substrates other than large rocks during 1975-77, no separation by substrate type was attempted. In 1978, nests were observed along the dam, in the marina cove, and in the natural cove. Nests were never seen along the sandy swimming beaches nor along the south and east shores, where the substrate is mostly mud or decomposed granite. A total of 64 nests was evaluated: 35 were found on rocks, 27 on rubble, and 2 on sand-gravel.

Orientation of Nests to Cover

In areas with scattered submerged vegetation, nests were frequently constructed under or within 1.0 m of cover; however, there was no apparent increased nesting density in areas with cover compared to areas without cover. For example, 2 or 3 willows per transect occurred along the dam and 8 to 10 per transect in both coves. However, the number of nests, 5 to 7 per transect, was approximately the same for each area.

Nest Depth

Depths of 24 nests measured in 1977 ranged from 0.5 to 4.6 m, with a mean depth of 3.0 m. In 1978, 64 nests ranged from 1.0 to 3.6 m, with a mean depth of 2.4 m (Table 1).

Spawning Season and Water Temperature

In 1977 and 1978, initial spawning activity, as identified by the movement of male bass into shallow water to clear nest sites, began in late March. At the onset of spawning activity in 1977, water temperatures at the surface and at 3 m were 15°C and 14.5°C, respectively. Eggs were first noted on 11 April, when the

temperature had risen to 17°C at both depths. The last new nest was found 6 June at a nest-depth temperature of 23°C. In 1978, males moved inshore when the surface temperature was 14.5°C. Eggs were first observed on 13 April at a surface and nest-depth temperature of 15.5°C. Water temperatures rose more rapidly in 1978 than in 1977; the last new nest was found on 19 May at a nest depth temperature of 22°C.

TABLE 1. Water Depth at Spotted Bass Nest Sites at Lake Perris

Depth (m)	Number of nests	
	1977	1978
0.0-0.5.....	1	
0.6-1.0.....		
1.1-1.5.....	3	1
1.6-2.0.....		5
2.1-2.5.....		16
2.6-3.0.....	5	15
3.1-3.5.....	7	8
3.6-4.0.....	7	16
4.1-4.5.....		3
4.6-5.0.....	1	
Total	24	64

Nest Size and Number of Eggs

Collection of data on nest size and number of eggs per nest was discontinued after five nests were evaluated because, in every case, the male bass abandoned the nest after disturbance. Sizes of the five nests ranged from 30 x 30 cm to 75 x 70 cm. The estimated number of eggs per nest varied from 3,000 to 14,000 (Table 2).

TABLE 2. Spotted Bass Nest Size and Estimated Number of Eggs at Lake Perris

Nest size (cm)	75x70	65x60	60x47	30x30	30x30
Number of eggs	14,000	8,900	7,500	6,300	3,000

Rate of Development

While it was difficult to monitor an individual nest completely through its development cycle because of egg predation, angler removal of adult bass, and abandonment, a sufficient number of nests were studied to determine a general pattern. Egg deposition occurred 1 to 3 d after the nest site was selected and cleaned. At time of deposition, the eggs were clear, but within 2 d turned opaque with a noticeable black spot. Hatching began on the fourth day and was completely by the fifth day. Sac fry remained in the nest 3 to 4 d before emergence. The yolk was absorbed within 2 d after the fry reached swim-up stage. Fry remained near the nest for 1 to 3 d, then moved into shallower water. Most of the fry schools observed away from nests were at depths of 0.5 to 1.5 m. Total elapsed time from site selection to departure of fry from the nest varied from 11 to 17 d (Table 3). The young remained in tight schools for approximately 2 wk or until they attained lengths of 2 to 3 cm.

TABLE 3. Sequential Rate of Nesting for Spotted Bass in Lake Perris

	<i>Prepa- ration</i>	<i>Incu- bation</i>	<i>Sac fry</i>	<i>Fry around nest</i>	<i>From nest site selection to fry leaving nest area</i>
No. of days.....	1-3	4-5	3-4	3-5	11-17

Nest Predation

Lake Perris also supports populations of green sunfish, *Lepomis cyanellus*, and southeastern bluegill, *L. macrochirus purpureus*. In 1977, green sunfish were approximately three times more abundant than bluegill; however, bluegill were the primary predators on bass eggs. Bluegill initiated all observed cases of egg predation. Green sunfish usually did not participate until five or more bluegill were actively feeding. Occasionally, spotted bass less than 15 cm in length were seen attacking a nest along with sunfishes. In 1977, approximately 25% of the nests observed experienced some egg predation. In 1978, the combination of comparatively fewer nests and a substantial increase in the number of bluegill led to noticeable predation on 50 to 60% of the nests. Nests built on flat rocks incurred the heaviest predation. Many of these were abandoned by the male bass, resulting in their complete destruction. Nests constructed on rubble were subjected to limited predation, and in most cases, the male remained with the nest.

Fungal Infections

The development of fungal infections was a prevalent condition affecting over 50% of the nests seen. The infections did not destroy all eggs and most nests produced some fry.

Adult Behavior While on the Nest

Following egg deposition, the male remained to protect the nest, usually swimming around and over the nest. Males were never observed "fanning" the eggs.

Males orienting to nests displayed a variety of responses to the approach of a diver. Some fled, while others remained with their nests. One of the more aggressive fish bit the senior author's thumb. Aggression toward fishes attempting to prey on the eggs similarly varied. Some males were completely successful in protecting their nests. In general, however, Alabama spotted bass nests appeared to be vulnerable to predation by bluegill. Frequently, bluegill were able to drive male bass completely from their nests. On other occasions, male bass simply stopped defending the nest and remained in the center of the nest while bluegill and other fishes fed freely on the eggs.

One male bass successfully completed two nests during a single spawning season. Within a week after the fry from the first nest had left the site, he had established a new nest 5 m away.

An apparent case of "fry adoption" was also observed. Two nests, separated by a large rock, had been built within 2 m of each other. They were prepared about 10 d apart and the first had swim-up fry while the other still contained

eggs. The male from the first was caught by an angler just after being checked by the divers. On the next day both nests were checked again. The second nest still contained developing eggs; no hatching had occurred, but a school of fry was present. The first nest was completely abandoned and, apparently, the fry had moved to the second nest and were accepted by the male. The male remained with the nest until the eggs had hatched and the fry had left the area.

Angler removal of male bass was noted on two other occasions. In each case the diver observed the fish being caught. Both fish were released, however, and both returned to their nests. One fish remained with the nest throughout the complete cycle; the other abandoned its nest within 2 d. Another fish that had been hooked by an angler was also sighted. When first observed, this fish had a single hook imbedded in its lower jaw and was protecting a nest with eggs. This fish remained with the nest until the fry left.

DISCUSSION

Spawning success is critical to a self-sustaining fish population and is directly affected by numerous environmental factors, including water level fluctuations and degradation of habitat. It has been suggested that the annual reservoir operation patterns and concomitant changes in littoral zone substrates have depressed largemouth and smallmouth bass, *M. dolomieu*, populations at a number of California reservoirs (C. von Geldern, Jr., Sr. Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.).

Lake Perris, like most California reservoirs, experiences an annual drawdown period that generally begins in early April when water temperatures typically reach a level conducive to black bass spawning. Drawdown at Lake Perris is less detrimental to the spawning of Alabama spotted bass, which spawned at a mean depth of 2.6 m, than it would be to smallmouth and largemouth basses, which generally build nests at an average depth of 0.6 m (0.15 to 2.0 m) (Carlander 1977).

Our underwater observations suggest that the presence of cover is of less importance to nest site selection of Alabama spotted bass than to other black basses, particularly largemouth bass; however, cover undoubtedly discourages predation on larval and juvenile basses.

Southeastern bluegill, the primary predators on spotted bass nests at Lake Perris, are not normally found in association with spotted bass in other California waters. It is not known if the considerable predation observed was related to the abundance of southeastern bluegill or an inability of spotted bass to adequately defend their nests against this predator. The latter is of particular interest if spotted bass are to be stocked at other California waters.

SUMMARY

Alabama spotted bass have become established in Lake Perris. Data collected during this study indicate that they should survive and reproduce in other California reservoirs. Basic spawning parameters are similar to those of largemouth bass and smallmouth bass, except that spotted bass spawn deeper. This factor alone makes these fish desirable for use in impoundments where a rapid spring drawdown usually occurs.

In addition, two other factors appear to favor spotted bass: their ability to spawn on barren, hard substrate, precluding the need for gravel, and less dependence on shelter at spawning sites. These conditions are prevalent features in many older California reservoirs.

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NOTES

CENSUS OF HARBOR SEALS, *PHOCA VITULINA*, IN SAN LUIS OBISPO COUNTY, CALIFORNIA, 1972-1973

The harbor seal, found along the entire west coast of North America, is generally wary in man's presence and "hauls out" (leaves the water to rest on rocks, sand, or mud) cyclically during low tide. Studies related to *Phoca* populations must take into account these behavioral patterns in order to obtain maximum population counts. Along the central California coast, population information is incomplete because studies have been designed primarily to census other pinniped species (Carlisle and Aplin 1966, 1971; Frey and Aplin 1970; Braham 1974; Mate 1977).

We conducted a baseline study dealing with harbor seal haul-out locations, population size, and pupping in San Luis Obispo County from November 1972 to April 1973. Also B. R. Mate (Assistant Professor, Oregon State Univ., pers. commun.) conducted two aerial surveys of the same area in June 1975 and 1976 during low tide. The results of our study and that of Mate's provide a basis for comparing the changes in harbor seal distribution between 1972 and 1976 in San Luis Obispo County.

Prior to taking population counts, we surveyed 138 km of coastline for harbor seal haul-outs (Figure 1). Land censuses were taken at least once a month during extreme low tides with the aid of a 30x scope.

We found 12 haul-out areas. All but one were on nearshore rocks or rocky shelves—areas subject to tidal action. The haul-out in Morro Bay, a sheltered estuary, was on an exposed mudflat. All haul-outs except those at Breaker Pt. and Seal Rock were protected from prevailing northwest winds and ocean swell by points of land or embayments.

Due to limited census data, three haul-outs were not included in our census analysis: Morro Bay (24 seals including 5 pups on 12 April 1973), Seal Rock just north of Lion Rock (32 seals on 2 February 1973), and Diablo Canyon Power Plant (0 seals, 2 November 1972). The Diablo Canyon haul-out was historically used by at least 50 seals before it was abandoned in June 1970 during power plant construction (Clifton 1971; Burge and Schultz 1973). However, *Phoca* have apparently reestablished the Diablo Canyon haul-out because Mate (pers. commun.) saw 143 seals on June 1976.

Harbor seals were gregarious throughout the winter in our study area (Table 1), which contradicts the findings of Scheffer and Slipp (1944).

The 6 December and 20 January land surveys were conducted during periods of storm. The inshore environment was extremely rough and the seals had limited access to their normal haul-out rocks. As a result, the counts were lower in all haul-out areas exposed to heavy wave action (Breaker Point, La Cruz Rock, Piedras Blancas, and San Simeon Bay). But in more protected areas (Cayucos Pt., Shell Beach, and Pirates Cove) the counts increased or remained stable. Bishop (1967) noticed that harbor seals in the Gulf of Alaska did not utilize haul-outs during a period of heavy surf.

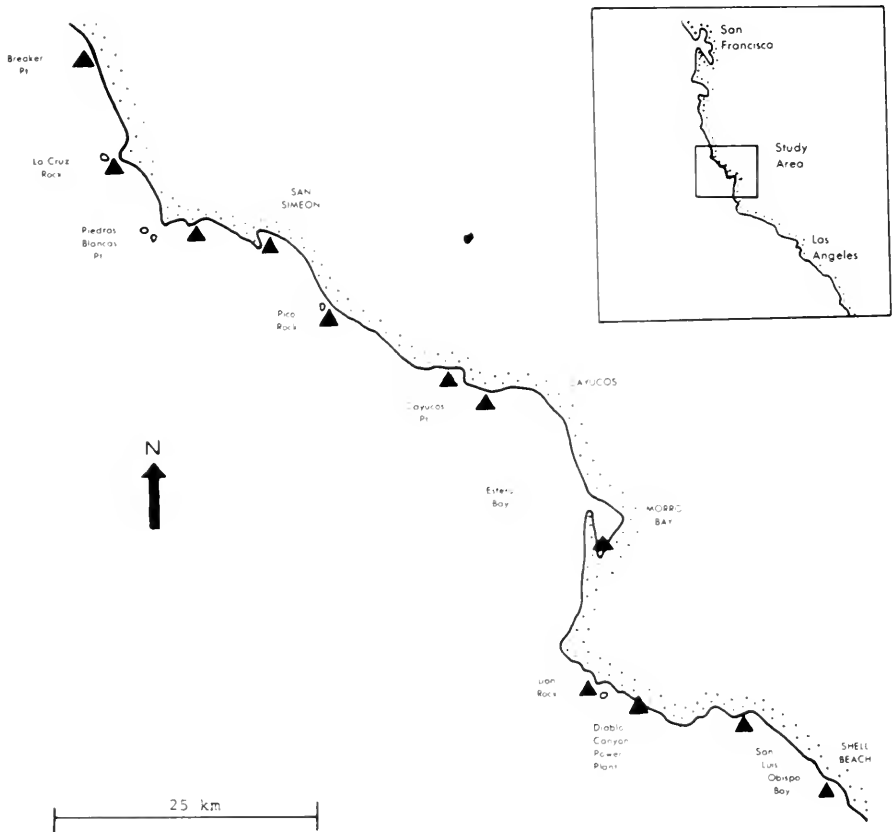


FIGURE 1. Harbor seal haul-out areas (▲) in San Luis Obispo County, California.

Even with ideal census conditions, the counts at specific haul-out areas fluctuated from survey to survey. This variation in numbers suggests strongly that individual seals regularly move from one haul-out to another. However, the total harbor seal population remained constant (between 400–500 seals) during the study. Although our data indicate that the population oscillated from a low of 267 seals on 20 January to a high of 518 seals on 15 February (Table 1), inclement weather, human disturbance, and incomplete surveys probably account for most of the changes in total population. Mate (pers. commun.) counted 618 seals on 10 June 1975 and 516 seals on 18 June 1976. His numbers are somewhat higher than ours but his aerial census work includes the Diablo Canyon area (100+ animals), which was censused only once during this study due to restricted access. These data suggest that the number of harbor seals in San Luis Obispo County has remained relatively stable between 1972 and 1976.

Spot surveys of haul-out areas indicated that the pupping season began in the last week of March. However, on 24 February 1972 an "orphaned" newborn pup was given to Dr. A. Roest (Prof. of Biol., California Polytechnic State Univ., San Luis Obispo, pers. commun.). No other pups were observed until late

TABLE 1. Number of Harbor Seals and Pups (in Parentheses) at Eight Haul-Out Areas in San Luis Obispo County, California, in 1972-1973. Dash Indicates Area Not Surveyed

Date	Haul-out areas								Total
	Breaker Point	La Cruz Rock	Piedras Blancas	San Simeon Bay	Pico Rock	Cayucos* Point	Pirates Cove	Shell Beach	
8 Nov	18	4 †	75	24	26 †	144	14	28	333
6 Dec †	16	15	51	5	29 †	192	20	33	361
4 Jan	31	59	74	25	69	155	-	-	413
20 Jan †	6	42	106	17	21	160	-	-	267
2 Feb	21	36	106	37	67	171	6	29	473
15 Feb	37	49	101	35	74	171	13	38	518
4 Mar	-	-	78	34	66	131	-	-	309
30 Mar	57	71	86	28(1)	67	132(4)	-	-	441(5)
14 Apr	15(3) †	43 †	64(6)	17(1)	71(6)	118(8) †	22(2)	21(2)	371(28)

* Includes two haul-outs in the vicinity of Cayucos Point

† Area disturbed by humans, seals in water

‡ Stormy weather

March. Pups were observed at all haul-outs except La Cruz Rock, where census data are incomplete for April. Since pups were observed at other exposed haul-out areas, it is suspected that they also occurred at La Cruz Rock. However, on 14 April, the date of the last observations, humans had frightened many seals off the rocks at La Cruz.

In other areas along the Pacific Coast, workers have noted seasonal movements of seals into large protected bays which serve as pupping grounds (Paulbitski and Maguire 1972; Loughlin 1973). This does not appear to be true in San Luis Obispo County, since pupping occurred at all haul-out areas in about the same relative proportions.

ACKNOWLEDGMENTS

I am indebted to T. Loughlin and B. Sullivan of Humboldt State University, A. Roest of California Polytechnic State University, and P. Kelly of the California Department of Fish and Game for their constructive remarks on the draft. I would also like to thank K. J. Rice for her technical assistance.

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A SLIDE RULE FOR LOCATING AND DECODING BIT VALUES ON SIX-BIT CODED WIRE NOSE TAGS

Coded wire nose tags (CWT) developed for use in juvenile salmonids by Bergman, et al. (1968) are coded with four words containing a maximum of six binary coded digits (bits) each. These words, one along each quadrant of the tag, need to be decoded into a decimal equivalent. A slide rule is described which helps decode them.

CWT coding systems use only two symbols, 1 (notch) and 0 (blank), signifying either a value or no value. The notches represent binary numbers ascending from right to left so that the first six notches on a CWT have the values 2^5 , 2^4 , 2^3 , 2^2 , 2^1 , 2^0 or 32, 16, 8, 4, 2, 1. A binary 1 or 0 indicates whether the value occupying that space is to be counted.

Notches are spaced 0.12 mm apart on coded wire and six bit data words are repeated every seven spaces, leaving one space (check) between words. Tagging machines randomly cut tags at about 1.07 mm. This ensures at least one complete word on each tag, but it also includes one or two bits from the following word. As a result, data words may begin at any point in the bit order, which will vary on successive tags. This makes decoding difficult. One of the four words on each tag is a masterword. It appears on all tags and enables the reader to align decimal equivalents with data bits in spite of random cutting. Using 1's and 0's the masterword for a six bit CWT may be written 0 0 1 1 1 111 (Figure 1). The decimal equivalents are 0 (check), 32, 16, 8, 4, 2, 1. The masterword is always blank at the decimal 32 position. The one-half interval mark between the 2 and 1 has no decimal value; it appears only in the masterword and is a convention adopted by the developers of the tag to prevent the masterword from being confused with a data word.

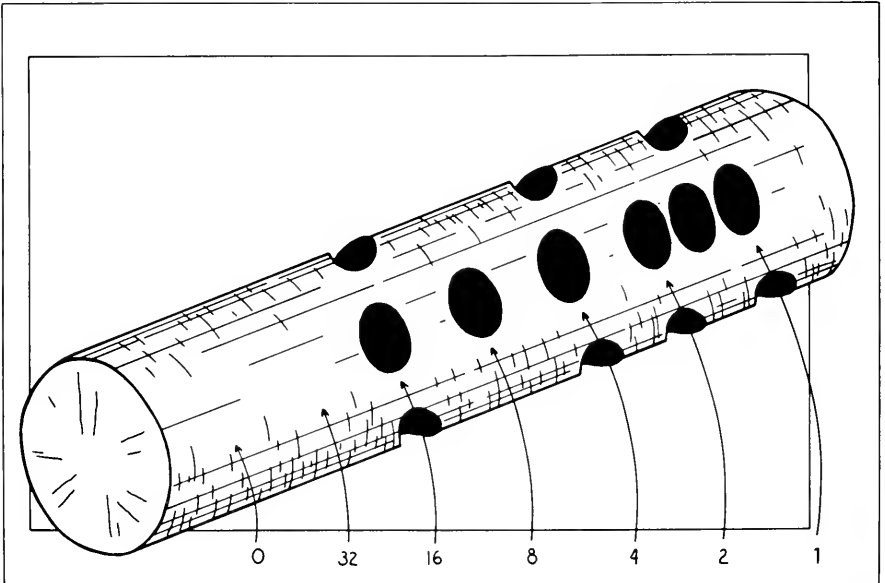


FIGURE 1. Six bit coded wire nose tag showing the masterword. Data words may be seen at the top and bottom.

The slide rule described here makes it easier to decode tags because it allows the reader to select the correct bit values from any combination of the masterword resulting from random cutting of the tag. It is easy to make and can be made in any convenient size (Figure 2).

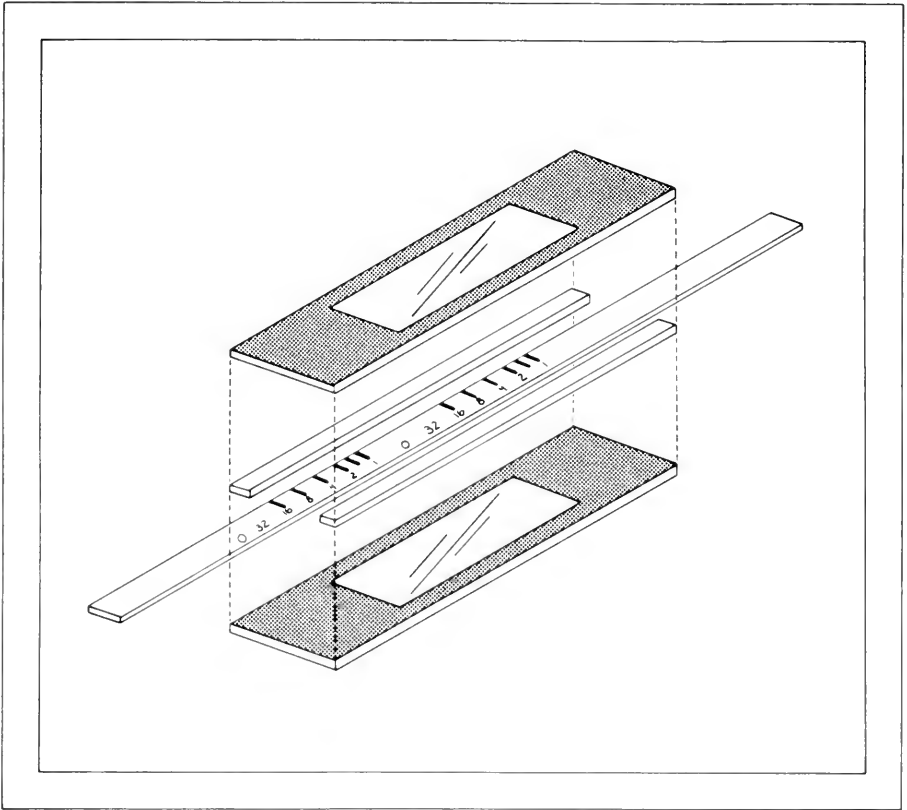


FIGURE 2. Exploded view of slide rule used to locate bit values for decoding randomly cut, six binary bit, coded wire nose tags.

To make the slide rule, print the masterword and associated bit values twice on each side of a plastic strip. On one side they should be printed in reverse order—a CWT is often reversed when placed on a pencil magnet for reading under a binocular scope and with a reverse scale the tag can be read in either position. We used a dry lettering transfer process to print on a 0.4-mm white plastic strip measuring 15 cm long and 1.3 cm wide.

The windowed slide was constructed from two pieces of 0.6 mm clear acetate 9 cm long and 2.5 cm wide. Using contact cement, the acetate was cemented together with narrow spacers along two edges. The spacers provide clearance in the middle for the plastic strip. The window was formed by painting all except a windowed area eight bits long on each side of the slide with a waterproof felt tip pen.

When using the slide rule, a tag reader first locates the masterword on a CWT. The white plastic strip is then moved through the window until the masterword shown on the rule matches that shown on the CWT. The bit values shown on the slide rule will be in the correct location for decoding the data words on that CWT.

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WOLVERINE, *GULO GULO*, RECORDS FOR THE WHITE MOUNTAINS, CALIFORNIA

Many authors have considered the wolverine to inhabit only the Sierra Nevada in California, extending as far as Walter Pass, Kern County (Grinnell, Dixon, and Linsdale 1937; Ingles 1965). In recent decades however, several authors have noted an increase in the number of wolverines being reported and expansion into new areas (Newby and McDougal 1964, Yocom 1973, Yocom 1974, Schempf and White 1977). These reported expansions may, in fact, be tardy recognition of the wolverines' actual distribution. The White Mountain Range in Mono County, California, is such an area. The purpose of this paper is to summarize known wolverine records in this area and to document a recent sighting.

The first known sighting of a wolverine in the White Mountains occurred during the summer of 1937 by O. Kenrlein on White Mountain Peak (Jones 1950). The elevation of the summit of this mountain is 4,343 m. Although Jones (1950) noted that this observation of a single animal was the first record for this range, no other data were presented. A search of California Department of Fish and Game (CDFG) records revealed no further information about this sighting (T. Blankenship, Wildlife Biologist, CDFG, pers. commun.; V. Koontz, Wildlife biologist, CDFG, pers. commun.).

The second sighting was made by Ted Wenzel in the 1960's at McAfee Meadow (Schempf and White 1977), but details of this report are unclear. The observer was positive of his field identification but was unable to document the date and time of observation (Ted Wenzel, pers. commun.). Also, no information is available on the number of wolverines that were sighted. McAfee Meadow is located approximately 5.8 km southeast of White Mountain Peak at an elevation of approximately 3,566 m.

The third observation of wolverines in the White Mountain Range occurred on 4 July 1977 when I observed two wolverines at 3,700 m elevation, 1.1 km north of Mt. Barcroft. This area is about 2.9 km west of McAfee Meadow and 4.8 km south of White Mountain Peak. I saw these wolverines in the late morning hours from approximately 137 to 160 m away, across a small drainage. The lead wolverine alternately bounded and walked across a snow bank approximately 23 m across. A second wolverine appeared on the edge of the snow bank, bounded across the snow, and caught up with the first wolverine. They were side by side briefly and it was apparent that the second wolverine was slightly smaller than the first. At the edge of the snow bank they entered a large talus field, where they slowed to a walk. As the wolverines traversed the slope, they stopped occasionally. They crossed approximately 115 m of talus before reaching a small ridge, where the smaller wolverine disappeared beneath a large boulder. The larger wolverine stopped at the boulder, looked back towards the talus slope and snow bank, and also disappeared beneath the boulder. Throughout my 8-minute

observation, both animals appeared unaware of, or unconcerned with, my presence.

These observations suggest that the boulder was a den site, but the site was not inspected because I did not want to disturb the animals. Their difference in size may indicate that they were of different age or sex. They were not antagonistic toward one another.

The three sightings reported here span 40 years, and all occurred within a 6-km² area. Thus, the Mt. Barcroft-White Mountain Peak area is a region of recent, and possibly historic, wolverine occupation. However, the wolverine apparently is rare in the White Mountain Range. Of three field studies that have been conducted in the White Mountains recently (Jorgensen 1975; Kovach 1978; Brightman, George, and Reinthal 1979; K. Ayres, U.S. Forest Service, pers. commun.), mine was the only one to yield additional records of wolverines or wolverine sign.

ACKNOWLEDGMENTS

I would like to acknowledge the assistance and help provided throughout this project by my former professors at Humboldt State University, S. W. Harris and, especially, C. F. Yocom. I would like to thank the biologists of the California Department of Fish and Game and the Inyo National Forest in Bishop for allowing me access to records and for their time and help.

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CALIFORNIA GRUNION, *LEURESTHES TENUIS*, SPAWN IN MONTEREY BAY, CALIFORNIA

California grunion range from Magdalena Bay, Baja California, to San Francisco Bay, California (Miller and Lea 1972), but spawning has not been documented north of Cayucos (Walker 1952). There have been rumors over the years of grunion spawning in Monterey Bay and no doubt they have, but because California grunion spawn after dark when most beaches are deserted, their spawning activity is rarely detected.

On 7 July 1978, at approximately 2300, grunion were observed on New Brighton State Beach, Santa Cruz County, by Park Ranger Steve Hansen. Ranger Hansen collected and saved some of these fish which were later identified by Robert N. Lea of the California Department of Fish and Game.

To verify whether grunion had spawned at this location, on 14 July, I accompanied Ranger Hansen to the northern end of New Brighton State Beach where he had collected the grunion 1 week earlier. After digging a short time, groups of grunion eggs were found buried about 15 cm below the surface of the beach.

This is the northernmost record of grunion spawning and extends the known spawning range 188 km to the north.

High tide on 7 July was 1.5 m above mean sea level at 2336 at New Brighton State Beach. Grunion were found on the beach about one-half hour before high tide. It is not known when spawning started or how long it lasted. Spawning normally begins after the tide has turned; however, the eggs were still buried in the sand a week later, indicating successful spawning. The next series of high tides on 21 July were 1.9 m above mean sea level and adequate to free these eggs from the sand.

The 12 grunion collected ranged in size from 164 to 190 mm TL and are deposited at the California Academy of Sciences, catalogue number CAS 42072.

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BOOK REVIEWS

Snake Venom Poisoning

By Findlay E. Russell; J. B. Lippincott Co. Philadelphia, PA; 1980; XIV + 562 pp.; illustrated; \$35.00.

When venomous snakes, snake bites, and treatment are discussed, the name Findlay Russell is brought up. In addition to being *the* expert on this subject, he has now demonstrated his ability to write. Subjects include: paleontology and phylogeny; identification, distribution, and behavior of North American venomous snakes; venom and venom apparatus; medical problems of snake bite; exotic species in the United States; and snakes in religion.

My only disappointment with an otherwise complete coverage was the absence of any discussion of the regulations regarding the importation and possession of exotic venomous snakes in the United States. For example, to minimize the potential establishment of exotic venomous snakes, the seven states of the Colorado River Wildlife Council have developed a common list of undesirable fish, amphibians, and reptiles recommended for prohibition. Most of the world's exotic venomous snakes, with the exception of indigenous species, are now prohibited by the member states.

Anyone who has any interest in snakes would benefit from this book. Those who would benefit the most are snake bite victims treated by physicians who have read the book. Problems resulting from improper treatment and first aid are vividly demonstrated both pictorially and with case records.

After reading the book, you will probably have the feeling that if there is anything Russell didn't cover in *Snake Venom Poisoning*, it probably isn't worth knowing.—James A. St. Amant

Pacific Coast Nudibranchs

By David W. Behrens, Sea Challengers, Los Osos, CA; 1980; 112 pp.; illustrated; \$24.95/hardback; \$14.95/softback.

For many of us, nudibranchs have been interesting and colorful organisms observed on dives or tidepool jaunts. The need for a complete guide to the group has been discussed for years and David Behrens has finally filled this void. *Pacific Coast Nudibranchs* is an outstanding work. The obviously photogenic subject matter lends itself well to the book's great visual impact but that is just the beginning. Following the familiar format so well utilized in *Pacific Coast Subtidal Marine Invertebrates* by the same publisher, the author has compiled a field guide to all described, and 25 previously undescribed, west coast nudibranch species. However, unlike many such guides, this work covers the subject in some depth.

The excellent photographs of each species are accompanied by a text detailing identifying characteristics, size, and range. A key to the opisthobranch orders, clear line drawings, a glossary, and a discussion of the anatomy of the group, offer the reader an opportunity to derive a much more than basic knowledge of the subject. The only lack that I could discern is the relative paucity of natural history notes. The inclusion of such material would, perhaps, have lent the book an even wider appeal. Also, material in the forward, which includes a review of nudibranch research from Linnaeus to the present, may best have been presented in the text. These very minor flaws serve only to point up the relative excellence of the work. The author, in his acknowledgement, suggests that his publication "may be the first product of open exchange and willing contributions from nearly every member" of the nudibranch fraternity. If this is the case the book reflects great credit upon them all. I heartily recommend it to all divers, tidepoolers, and students of marine biology.—John J. Grant

Wildlife Law Enforcement

By William F. Sigler; William C. Brown Company, Dubuque, Iowa; 3rd. ed.; 1980 403 pp.

Wildlife Law Enforcement is written in textbook form with a list of questions following each chapter. The book contains extensive lists of cited literature, recommended reading, and notes on case citations.

Information relating to the history of wildlife management and law enforcement, the role of law enforcement in management, history of European wildlife administration, Indian hunting and fishing rights, and chapters on State and Federal jurisdiction should be of interest to both management and enforcement personnel. Sections addressing the rights of individuals, collection of evidence, use of deadly force, search, the side arm, and arrest tactics are sure to stimulate wildlife protection officers. The information is current and well written. I do not agree with everything presented, particularly the sections on arrest techniques, but I find each and every section thought provoking and stimulating. Throughout the volume case histories are cited to back up points of law. All the cases cited are arranged in alphabetical order in an Appendix. Also in the appendices are pages of definitions, legal terms, and hypothetical problems with discussions.

If marine enforcement officers are looking for information relating to their specialized field, they will have to keep looking. Marine enforcement is not mentioned in the volume.

As a text, persons teaching wildlife enforcement classes would find the book very valuable. The book comprehensively covers a broad spectrum of subjects relating to wildlife enforcement. Even the most critical reader will find very few areas covered by the volume worthy of criticism. *Wildlife Law Enforcement* should be in the personal library of all professional wildlife protection officers.—*Kenneth D. Boettcher*

The Desert Bighorn—Its Life History, Ecology and Management

Edited by Gale Monson and Lowell Sumner for the Desert Bighorn Council; The University of Arizona Press, Tucson, Arizona; 1980:370 pp.; illustrated; \$14.95 paperback.

The Desert Bighorn Council was formed to meet and exchange information on the desert races of bighorn sheep. This group decided that a book was needed to bring together the existing knowledge about desert bighorn sheep and make it readily available. Putting a book together under multiple authorship is a monumental task. The editors deserve to be recognized for successfully accomplishing this. Even though it took several years to bring this book to completion, the editors have made sure that it is up to date and as complete as possible at press time. The Desert Bighorn Council's Technical Staff also reviewed all the chapters for accuracy and completeness and thus concurred in the material presented.

There are 22 chapters in this book and each one is illustrated with an appropriate pen and ink drawing of bighorn by Pat Hanson. I think any reader will find the chapter on the desert bighorn and aboriginal man fascinating and perhaps be surprised by the author's belief that primitive man may have hunted bighorn to near extinction in some places.

The chapter on mortality is interesting to everyone that has been following the recent losses of bighorn to scabies, chronic sinusitis, blue tongue, and pneumonia at various places in the southwest—all of these problems are deficiencies resulting from isolation-induced inbreeding, a factor working against the survival of small isolated herds.

The chapter on senses and intelligence and the anecdotes related there will be entertaining and perhaps give us a clue as to how wild sheep were domesticated long before written history.

Two chapters should be studied carefully: the impact of modern man and competition. The authors cite examples of bighorn coexisting with some competitive land uses. These examples should not be taken out of context, because when one studies the historic bighorn ranges where the animal has been extirpated, you find that sooner or later the bighorn disappear from ranges that are occupied by man or his domestic animals. The usurpation of bighorn ranges remain a major problem and the author emphasizes this in the chapter on habitat protection and improvement.

I believe this completely indexed book will become the "Bighorn Bible" and fingertip reference for recreationists and interested people from now on. Managers are going to use the wealth of information in this book and, over a period of time, bighorn are going to benefit from the efforts of the authors.—*Richard Weaver*



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