

PISMO CLAMS AND SEA OTTERS



by

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ABSTRACT

Sea otter foraging along Monterey Bay beaches and at Atascadero State Beach has precluded recreational Pismo clam fisheries at six major clamming beaches. Outside the sea otter's foraging range Pismo clam stocks are yielding good catches; apparently the stringent controls on the recreational fishery is adequate to maintain the State's Pismo clam stocks. Clammer interviews at Orange and Los Angeles County beaches and at beaches near Pismo Beach and Morro Bay and in Monterey Bay revealed the clam stocks to be on a healthy, sustainable yield basis. Exceptionally large numbers of small 1.5 to 3.5 inch Pismo clams were reported at all clam beaches surveyed north of Pt. Conception indicating good year class survival in recent years. Sea otters forage dense Pismo clam beds by moving along a "front", progressively foraging from one beach to the next, reducing the clams to low levels before moving on. Some sea otters continue to forage throughout the areas previously depleted by the larger aggregate moving northward, thus the large numbers of sublegal clams in the 1.5 to 3.5 inch size group in these intertidal and shallow subtidal areas are not expected to reach legal size in numbers sufficient to develop a recreational fishery. In Monterey Bay about 60,000 Pismo clams were removed or killed by human activity in the April 1974 to March 1975 period. A rough estimate of the Pismo clams consumed by sea otters during this same period in Monterey Bay is over 500,000 clams.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	1
ACKNOWLEDGMENTS	4
INTRODUCTION	5
STATUS OF PISMO CLAM STOCKS AT MAJOR CALIFORNIA BEACHES	5
MONTEREY PISMO CLAM SURVEY	11
Trench Transect Studies	11
Fifteen-minute Digs	13
Clammer Interview Studies	15
Description of Fishery by Beach Area	17
Potrero Road	17
Moss Landing Jetty Beach Road	17
Zmudowski State Beach	17
Palm Beach	19
Sunset State Beach - South Parking Lot	22
Sunset State Beach - North Parking Lot	27
Monterey Bay Academy	30
Hidden Beach	30
Manresa State Beach	30
Seacliff State Beach	30
PISMO CLAM MORTALITY IN MONTEREY BAY	32
Natural and Clamming Mortality	32
Estimate of Pismo Clams Taken by Clammers	34
Foraging of Pismo Clams by Sea Otters	37
Distribution and Numbers of Sea Otters and Number of Clams Consumed	44
SUMMARY	46
REFERENCES	49

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This collation and analysis of Pismo clam and sea otter information is truly the work of dozens of people who have worked many hours over many years collecting much of the data presented. We feel greatly indebted to all who have supplied data and given time to this study. We are especially indebted to John Fitch, the foremost authority on Pismo clam biology and population dynamics, for offering information and suggestions. The long series of trench transect data collected by Menlo Park and Long Beach office personnel was invaluable in relating present conditions to the past.

Menlo Park Laboratory personnel assisting in trench digs and clammer interviews in 1974 were Wendell Barnes, Kit Buckels, Patrick Collier, Richard Heimann, Tom Jow, Richard Nitsos, Lloyd Pawley, Phillip Swartzell, and David Thomas. Monterey office personnel contributed most of the time and effort on clammer interviews, clam shell censuses, and sea otter censuses. Jack Ames, James Houk, Kim McCleneghan, Glen Rothrock, Kenneth Boettcher, and Robert Grossi assisted on these surveys. Morro Bay office personnel Richard Burge and Theodore James participated in trench digs and clammer interviews in the Morro Bay and Pismo Beach areas. In southern California a large contingent of volunteers participated in the January clammer census under the direction of Melvin Odemar and David Ganssle. The intrepid interviewers facing the mass of clammers and bathers on the sunny beaches of southern California and to conduct aerial censuses were Robert Bell, Kathlene Bleich, Richard Dixon, Ellen Gleason, Peter Haaker, Robert Hardy, Therese Hoban, Everett Hogue, Phillip Lehtonen, David Ono, David Parker, John Sunada, and Vickie Wine.

David Zeiner from the Sacramento Marine Resources Branch office participated in the Monterey Bay census. Leo Singer, Warden Pilot of the Long Beach office, piloted the observation plane, and Warden Captain Gordon Cribbs assisted in setting up the clammer census for southern California. Nancy Durell typed the manuscript and Robson Collins and Robert Tasto did the editing.

Non-Department personnel also contributed to this publication. Mark Stephenson of the Moss Landing Marine Laboratory supplied much information on sea otter foraging and supplied a large series of biomass measurements of Pismo clams. Steven Shimek, University of California, Santa Cruz, imparted information on sea otter foraging habits; and Department of Parks and Recreation personnel supplied park attendance records and general comments about clamming activities. Judson Vandevere and others associated with the Friends of the Sea Otter assisted in clam shell censuses. Victor Morejohn and David Lewis of Moss Landing Marine Laboratory related information on sea otter distribution and behavior.

INTRODUCTION

In 1973 sea otters, *Enhydra lutris*, began foraging on Pismo clams, *Tivela stultorum*, in Monterey Bay near Moss Landing (Mark Stephenson, Moss Landing Marine Laboratories, pers. commun.) and at Atascadero State Beach (Wild and Ames 1974). Research personnel at Moss Landing Marine Laboratories recorded clam densities by means of randomly chosen plots from 1972 to 1974 at Salinas River State Beach (Potrero Road), Zmudowski State Beach, and Monterey Bay Academy beach. During the course of these studies they documented Pismo clam reproduction and densities and the arrival of sea otters in the Potrero Road area in April 1973, and noted subsequent changes in Pismo clam densities (Mark Stephenson, Moss Landing Marine Laboratories, pers. commun.). Most striking was the abundance of broken shells on the beach both inter- and subtidally soon after sea otters appeared. By September there were not sufficient clams present for clam reproductive studies at Potrero Road beach. Several more clam density surveys were made in 1974 by Moss Landing Laboratory personnel at Potrero Road beach, Zmudowski State Beach, and at Monterey Bay Academy (Figure 1).

In view of the importance of this depletion of Pismo clam stocks by sea otters at this important clamming beach, Department of Fish and Game personnel undertook a search of previously collected data on Pismo clams in Monterey Bay, and initiated collection of several series of data pertaining to sea otter distribution and numbers and effects of sea otter foraging on Pismo clam stocks in Monterey Bay. Additional data were collected on the status of Morro Bay and Pismo Beach Pismo clam stocks in December 1974 and January and February 1975. This report summarizes past data and presents the results of the 1974-1975 Monterey Bay and Morro Bay sea otter - Pismo clam interaction studies.

STATUS OF PISMO CLAM STOCKS AT MAJOR CALIFORNIA BEACHES

Evaluation of the effects of sea otter foraging on Pismo clams in Monterey Bay requires basic information of the status of clam stocks in Monterey Bay and the possible effects of heavy sport clamming pressure on these stocks. Pismo clam beds in Monterey Bay are at the periphery of clam distribution to the north and a comparison of the fishery and densities in Monterey Bay with comparable data from southern California beaches is essential to fully understand the nature of the relative effects of man and sea otters on clam stocks. In December 1974 clammer interviews were made at beaches in Monterey Bay and at Morro Bay and Pismo Beach to determine the relative abundance of various sized Pismo clams. In January 1975 an extensive survey was made of clammer effort and catch at Monterey Bay, Morro Bay, and Pismo Beach clam beaches and at certain beaches in Los Angeles and Orange counties.

The initial statewide survey was designed for December; however, exceptionally heavy swells pounded all the beaches from Monterey to Newport in December and abnormally poor conditions prevailed for clamming. Interviews were made in December at Monterey Bay, Morro Bay, and Pismo Beach area beaches, and in spite of the poor conditions there were fair amounts

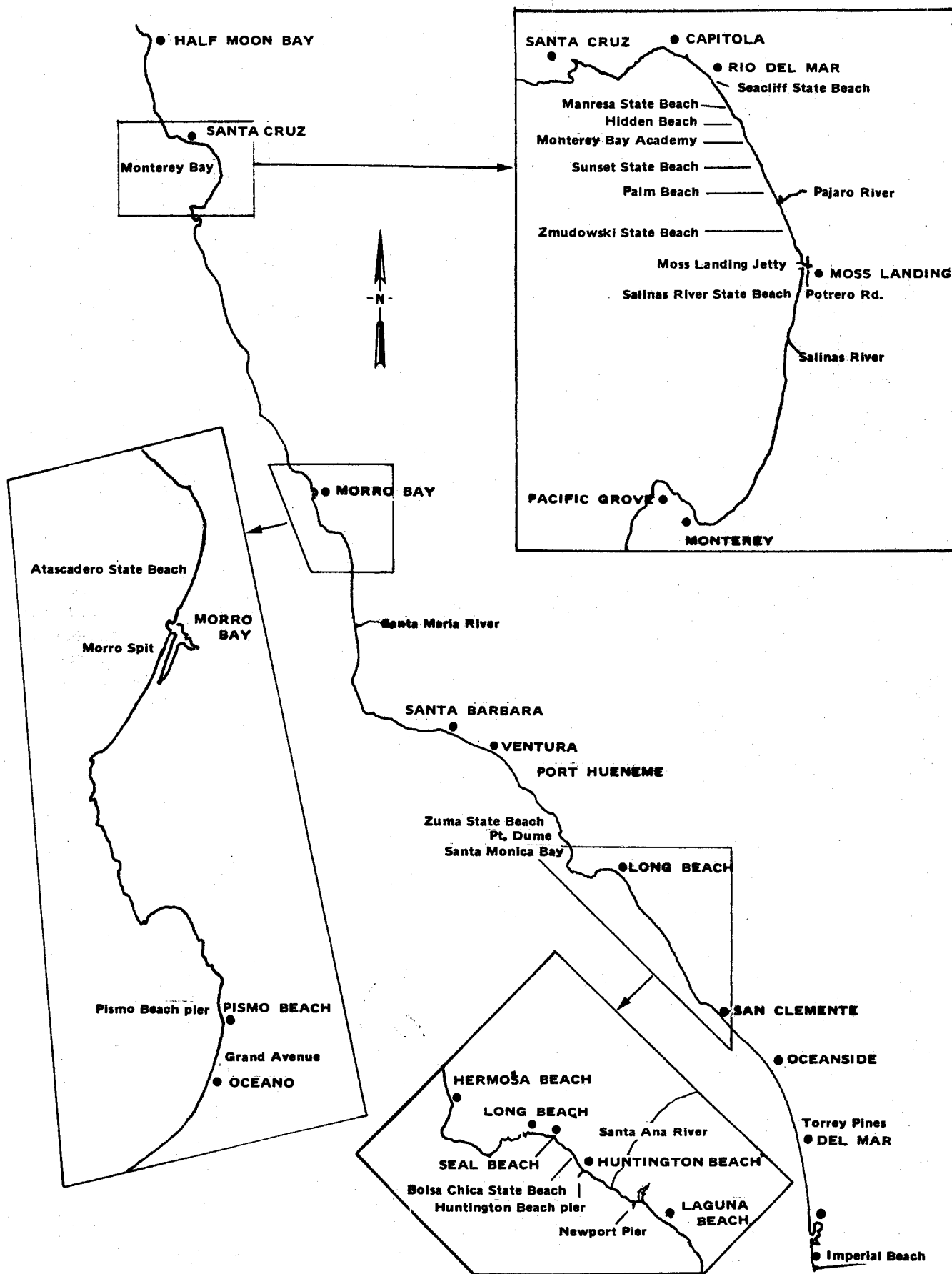


FIGURE 1. Cities and beach areas mentioned in text.

of clams taken at most beaches outside the sea otter's range, but virtually no clams were found at most beaches foraged by sea otters.

Sea otters began foraging along Atascadero State Beach in early 1973 and by fall of 1974 they had reduced the clam stocks to levels below that required to support a recreational fishery (Table 1). By January 1975 sea otters had not foraged at Morro Spit, but Dick Burge (Calif. Dept. Fish and Game, pers. commun.) reported substantial foraging of this area starting in late February 1975 as evidenced by presence of broken shells at low tide.

TABLE 1. Catch-per-day (C/D) and Catch-per-hour (C/H) of Pismo Clammers at Some Morro Bay and Pismo Beach Clamming Areas, December 1974 and January and February 1975.

	Atascadero State Beach		Morro Spit	Beach North of Pismo Pier		Grand Avenue		4 mi. S. of Oceano Ramp
	Dec 28	Jan 26	Jan 26	Dec 29	Jan 25	Dec 29	Jan 25	Feb 22
Clammers Interviewed	35	37	140	106	97	40	102	31
Hours	32.0	35.2	252.8	146.5	170.0	33.0	147.5	41.2
Legal	0	1	435	48	105	32	329	149
C/D	0.00	0.03	3.11	0.45	1.08	0.80	3.23	4.81
C/H	0.00	0.03	1.72	0.33	0.62	0.97	2.23	3.61
Sublegal	0	0	849	200	446	100	210	23
C/D	0.00	0.00	6.06	1.89	4.60	2.50	2.06	0.74
C/H	0.00	0.00	3.36	1.36	2.62	3.03	1.42	0.56

In the January 23-27, 1975, census excellent clamming conditions prevailed in southern California, fair to poor clamming conditions were present in the Pismo Beach - Morro Bay areas, and fair conditions prevailed in Monterey Bay. Twenty beaches were surveyed during this low tide period with most of the sampling effort expended on the lowest tide period on the weekend tides of January 25 and 26. Along with catch and effort data obtained from 2,564 clammer interviews aerial and ground counts were made to estimate total effort at many of the beaches. As in December, there was virtually no take of Pismo clams in the sea otter's range, but outside the sea otter's range fair to better than average yields were recorded (Table 2, Figure 2).

The highest clam-per-hour values were recorded near Newport Pier in Orange County, with high yields also recorded at Huntington Beach, Grand Avenue near Pismo Beach, Morro Spit, and in Monterey Bay at Sunset State Beach, Monterey Bay Academy, and Seacliff State Beach. There are other factors that may result in varying yields between beaches other than poor weather and heavy swells. In Monterey Bay the minimum size limit for Pismo

TABLE 2. Number of Clammers, Hours, and Numbers of Legal and Sublegal Pismo Clams Sampled and C/D and C/H Values at 20 Major Clamming Beaches during the January 23-27, 1975, Low Tide Period.

	<u>Clammers Interviewed</u>	<u>Hours</u>	<u>Legal Sized</u>			<u>Sublegal</u>	<u>Dates Surveyed</u>
			<u>No.</u>	<u>C/D</u>	<u>C/H</u>	<u>C/H</u>	
Monterey Bay Area							
Seacliff State Beach	33	60	152	4.61	2.54	5.46	26
Manresa State Beach	120	202	335	2.79	1.66	4.22	26
Hidden Beach	36	88	83	2.31	0.95	3.43	26
Monterey Bay Academy	123	253	465	3.78	1.84	7.18	24, 26, 27
N. Sunset State Beach	161	386	394	2.45	1.02	5.17	25, 26, 27
S. Sunset State Beach	103	199	28	0.27	0.14	0.76	25
Palm Beach	107	205	18	0.17	0.09	1.00	25
Zmudowski State Beach	58	101	2	0.03	0.02	0.02	24, 25
Jetty Beach	28	33	1	0.04	0.03	0.03	25
Potrero Road	60	87	0	0.00	0.00	0.00	23, 24, 25
Morro Bay Area							
Atascadero State Beach	37	35	1	0.03	0.03	0.00	26
Morro Spit	140	253	435	3.11	1.72	3.36	26
Pismo Beach Area							
North of Pier	97	170	105	1.08	0.62	2.62	25
Grand Avenue	102	148	329	3.23	2.22	1.44	25
Los Angeles County							
Hermosa Beach	20	46	39	1.95	0.85	1.85	25
Belmont - Long Beach	69	117	203	2.94	1.74	2.60	25
Seal Beach	90	133	269	2.99	2.02	1.94	25, 26
Orange County							
Bolsa Chica-Huntington Pier	585	707	826	1.41	1.17	0.21	25, 26
Huntington Pier-Santa Ana R.	495	830	2244	4.53	2.70	2.68	25, 26
Santa Ana R.-Newport Pier	100	158	677	6.77	4.28	2.05	25, 26

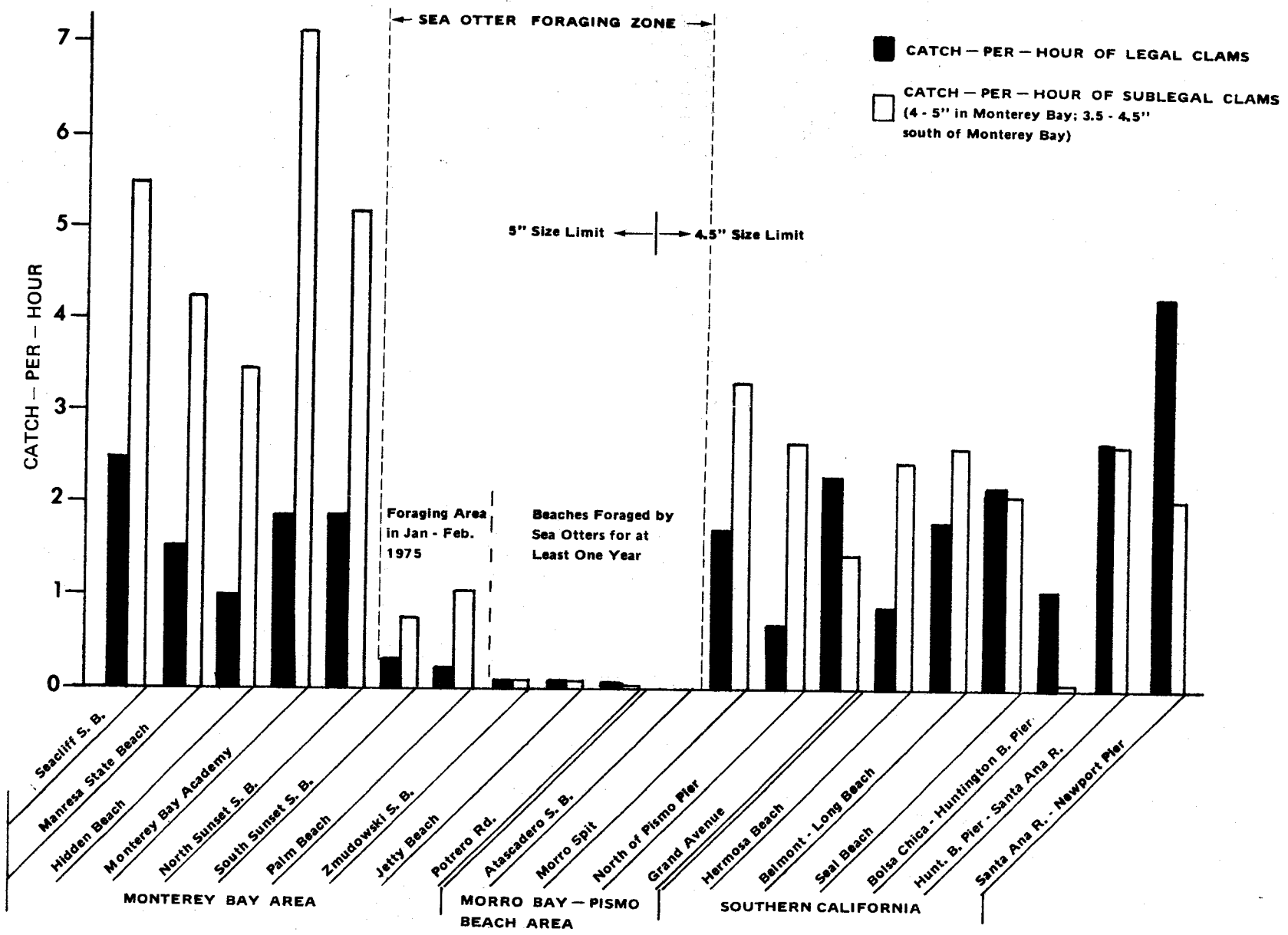


FIGURE 2. Catch - per - hour of legal and sublegal Pismo clams at 20 clamming beaches censused during the January 23 - 27 low tide period.

clams is 5 inches or 127 mm, whereas south of Monterey Bay the minimum size limit is 4.5 inches or 114.3 mm in greatest shell diameter. There is a closed season from May 1 to September 1 in Monterey Bay, but no closed season to the south. Skindivers commonly take Pismo clams at Pismo Beach, but seldom in Monterey Bay (Miller, Geibel and Houk 1974). In spite of these differences, clamming success was comparable in intensity and yield throughout the state and there appears to be no serious depletion of stocks, with some limit catches of ten clams per person taken at nearly all clam beaches by experienced clambers even during poor conditions. The beach area immediately north of Pismo Beach pier shows effects of heavy clamming use more than at other beaches; and low catches were recorded at Bolsa Chica State Beach, but it is not known whether low catches there were due to heavy use or to low natural stocks of clams.

The principal findings of this statewide clammer survey are that Monterey Bay clam stocks outside the sea otter's range were comparable in yield to that of beaches in the center of the Pismo clam range from Pismo Beach to Newport, that clamming effort has not caused depletion of clam stocks in Monterey Bay, and that except possibly for the beach north of Pismo Beach pier, Pismo clam stocks in California appear to be on a healthy sustainable yield outside the sea otter's range.

Minimum size limits, seasons, area closures, bag limits, requirement to rebury sublegal clams, educational programs outlining good conservation practices, elimination of commercial harvesting, and intensified enforcement of regulations have apparently reduced mortality of sublegal clams to where a good sustainable Pismo clam fishery can continue. The large numbers of sublegal clams within an inch of legal size in the Monterey Bay area (Figure 2) compared to the relatively smaller numbers of these sublegal clams at most beaches south of Monterey Bay, except for Morro Spit, can reflect two conditions. One is that the larger size limit of 13 mm (1/2 inch greater) retains more clams on the beach in Monterey Bay, whereas many of the clams from 114 to 127 mm (4.5 to 5 inches) are utilized at beaches to the south. The larger numbers of sublegal sizes to the north could also be, in part, due to relatively more recruitment, although Department trench transect data indicate no evidence of greater recruitment to the north. Exceptional recruitment of recent year classes was recorded at all clam beaches from Pismo Beach northward. Clammer interviews in Monterey Bay indicate higher densities of 38 to 89 mm (1.5 to 3.5 inch) clams compared to past years, with larger numbers also being reported by many clambers who have been utilizing these beaches for many years.

The effects of the December 1974 stormy period can be noted in the Pismo Beach data for December 1974 and January 1975 (Table 1). Catch-per-hour values increased from 0.97 in December to 2.23 clams in January at Grand Avenue, and in February during more optimum clamming conditions the catch-per-hour was 3.61 clams at the Oceano ramp area several miles south of Grand Avenue.

Even though this one statewide clammer census cannot as yet relate trends, it appears that except for one or two areas clam stocks are withstanding clammer pressure. At Bolsa Chica State Beach there appears to

be poor recruitment and at the beach north of Pismo Beach pier low catches of legal sized clams were noted. The low take near Pismo Beach pier is probably due to clammer use, inasmuch as relatively high numbers of sub-legal clams from 89 to 114 mm (3.5 to 4.5 inches) were reported by the clammers. Catch-per-hour values increased at Pismo Beach pier from 0.33 clams per hour in December to 0.62 clams per hour in January, but this latter value still represents poor clamming.

MONTEREY BAY PISMO CLAM SURVEY

Pismo clams have been utilized in Monterey Bay by man for thousands of years; first by aboriginals who used them for food and shell disc beads. However, Pismo clam shell fragments are apparently scarce in Indian middens of the Monterey Bay area and John Fitch (Calif. Dept. of Fish and Game, pers. commun.) reports Pismo clam shells present in southern California middens, but the shells are mostly from small sized clams. Weymouth (1923) states:

"It may be of interest in passing to note that apparently the Indians did not use the Pismo clam to any great extent, as far as can be told from an examination of kitchen middens near Oceano. On one mound examined there were numbers of young *Tivela* but no adults; no young or adults were noted in any other mounds."

Commercial clam harvesting was conducted until 1947 in California, but most of this activity was at southern California and Pismo Beach beaches (Fitch 1950). Statewide the sport limit is now 10 Pismo clams per day and in Monterey Bay the clams must be 127 mm or 5 inches in total length. There is a closed season from May 1 to September 1. There is public access to all Monterey Bay beaches, most of which are within state parks where parking and picnicking facilities are provided. Historically there has been little or no Pismo clamming in Monterey Bay south of the Salinas River because of lack of clams due to the coarseness of sand particles forming steep shorelines. Although Weymouth (1920) reported Pismo clams at Half Moon Bay, the beaches in the northern part of Monterey Bay are the northernmost Pismo clamming beaches in California.

The Department has conducted studies to determine the status of clam stocks in Monterey Bay over the years. These include trench transects, 15-minute digs, and clammer interviews. A summary of the results of these studies is presented.

Trench Transect Studies

Department transect data were not collected extensively in Monterey Bay before 1974 with data available only for 1953, 1966, and 1968. The trench transect (Fitch 1950) is dug along a line which is marked in segments 3 meters (9.8 ft) in length. A trench 0.15 m (6 inch) wide is dug along this line and each two segments represents a square meter of sand dug to a depth of about 0.2 m (8 inch). All clams dug are recorded by segment, measured, and aged. Sand dug from above the water line in the intertidal zone is thrown onto the beach and the clams are retrieved.

Below the water line to about knee depth the trench is probed with a garden fork and when a clam is struck it is dug out and collected. Trenches range in length from about 60 to 110 meters (197-361 ft) depending upon the steepness of the beach. The trench transect method was designed to measure recruitment strength of young clams and may not always adequately represent relative numbers of clams over 76 mm (3 inches) in largest diameter. Pismo clams are not evenly distributed laterally along the beach. There are dense clusters in some areas and in other areas there may be only scattered individuals. There is also a depth zonation by size with smaller sized clams more prevalent in the lower intertidal and shallow subtidal areas. This is due in part to the normal pattern of distribution (John Fitch, Calif. Dept. Fish and Game, pers. commun.), but may also be accentuated by heavy clamming effort in the shallower areas, thus lowering the density of larger clams where it is easier to clam. Subtidal areas outside the clamming zone contain dense populations of larger clams at most beaches. John Fitch (February 1975 letter) states:

"Off many of the state's sandy beaches, beyond the breaker line, Pismo clam populations are so dense they represent nearly virgin stocks. These offshore clams almost certainly are extremely important to annual recruitment, and thus are essential for the continued existence and well-being of our Pismo clam fisheries. At present, skin and scuba divers pose no threat to these offshore populations, but sea otters do.

"One such offshore bed of clams at Zuma Beach was censused during 1963. Between Point Dume and Lechuza Point nearly 2 miles to the north, at a depth of 15 to 25 feet there was a bed of Pismos 130 feet wide that contained an estimated 1,440,000 clams. Pismo clams also occur both inshore and offshore from this bed, but in lesser numbers Offshore beds of Pismo clams, some even more productive than Zuma Beach, are known to be present in other areas. The best of these beds are to be found off Morro Bay (south of Morro Rock), off Pismo Beach (south to the Santa Maria River), off Surf, off Santa Barbara (Hope Ranch), off Ventura (north of Ventura for several miles), off Hueneme, off Zuma Beach, in Santa Monica Bay (between about Venice and Torrance Beach), between Seal Beach and Newport Harbor jetty, in several coves off Laguna Beach (Irvine Cove, Emerald Bay, etc.), off San Clemente, and off Camp Pendleton, Oceanside, Del Mar, Torrey Pines and Imperial Beach in San Diego County. Prior to an invasion of sea otters, there were some excellent offshore beds in central Monterey Bay and off Atascadero State Beach."

Dives by Department personnel indicate that subtidal stocks along northern Monterey beaches are relatively shallow and not as extensive below 4.5 m (15 ft) as was described by Fitch for southern California beaches.

Because of the uneven distribution of clams along the beaches, transect data along Monterey Bay beaches are too few to disclose relative abundance of clams over 114 mm (4.5 inches) diameter; however, smaller sized clams, especially those below 76 mm (3 inch) diameter, are adequately represented

in these samples. The trench transect method can possibly be used to measure densities of clams larger than 3 inches but due to the scattered and often sparse distribution of these larger clams, more transects would have to be scheduled per year than have been previously dug. Good recruitment was revealed in the 1953 transect data, poor recruitment was indicated in the 1966 and 1968 transects, and good recruitment is represented in the 1974 transect data (Table 3). This recent good survival indicates that the level of clam densities along Monterey Bay beaches has been sufficient to take advantage of good survival conditions. Aging of clams over the past 20 years has revealed that there has been at least some recruitment entering the fishery from each year's crop with clams ranging from 26 years of age present in the fishery in 1968 and up to 29 years in 1974 (non-random sampling of sport catch). Thus, Pismo clam stocks in Monterey Bay have adequately withstood heavy sport take and the population has yielded good catches derived from an accumulation of recruitment from poor and marginal year classes as well as from strong year class strength. The present stocks of Pismo clams in Monterey Bay are comprised of two dominant size groups ranging from 38 to 89 mm (1.5 to 3.5 inch) and from 102 to 140 mm (4 to 5.5 inch) in length, with some clams measured to 173 mm (6.8 inch). The smallest size group is composed primarily of the 1969, 1970, and 1971 year classes (Table 4), whereas the larger sized group is an admixture of at least 14 year classes with legal sized clams primarily of the 11 and 12 year old 1963 and 1962 year classes. Apparently all year classes over the past 18 years are contributing to the stocks now with the 1964 year class contributing least to the population.

TABLE 3. Number of Pismo Clams Less Than 4.5 inches Per Meter² at Four Monterey Bay Beaches as Determined from Trench Transects.

<u>Year</u>	<u>Monterey Bay Academy</u>	<u>Sunset State Beach</u>	<u>Palm Beach</u>	<u>Zmudowski State Beach</u>
1953	--	--	4.00	--
1966	--	0.15	(0.08)*	--
1968	--	0.21	0.33	0.08
1974	2.55	1.86	2.91	0.25**

* Square meters dug not known; used average sized transect for computation.

**Trench dug after sea otters had been foraging for over a year's time.

Fifteen-minute Digs

Upon completion of the trench transect a "15-minute" dig is conducted subtidally at the end of the transect line to measure relative success in retrieving larger sized clams. Clams dug during this timed dig represent

TABLE 4. Size Composition by Age and Year Class of Pismo Clams Taken in Trench Transects and 15-Minute Digs in Monterey Bay, 1974.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
Year Class	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	
Size Interval in mm.																			
20-24	1	1																	2
25-29		3																	3
30-34		4																	4
35-39		3	2																5
40-44		3	3	2															8
45-49		6	4																10
50-54		8	9	3															20
55-59		1	11	3															15
60-64			8	6	1														15
65-69			12	8	5														25
70-74			12	11	1														24
75-79			5	16	5														26
80-84				4	5	3													12
85-89				3	9	3													15
90-94			2	2	6	2													12
95-99					5	1	2												8
100-104						3													3
105-109					1	3	2		1		1								8
110-114					4	4	1	1											10
115-119					4	6	1	2	7			2							22
120-124						2	2	3	2	2	1	3	2						17
125-129						2	3		3	1	5	3		3					20
130-134								1	1		6	4	1						13
135-139								1									1		2
140-144													1	1					2
145-149														1	2	1			4
150-154																	1	1	2
TOTAL	1	29	68	58	46	29	11	8	14	3	13	12	4	5	2	1	2	1	307

a catch-per-hour value. Greater numbers of larger clams are sampled in the 15-minute dig period than in the transect, and even though there is a high variability in numbers of clams collected, these digs do give an indication of the relative abundance of sublegal clams along the beaches (Table 5). The 1974, 15-minute digs at Monterey Bay Academy indicate that the majority of clams in the population are in the smaller 38 to 89 mm (1.5 to 3.5 inch) size group and that there are larger numbers of these small clams present now compared to late 1960's. The trench transect data revealed the same conditions. In both the transect and 15-minute dig series larger legal sized clams were either absent or were highly variable in number, thus neither method may yield reliable data to measure the relative abundance of legal sized clams in areas where stocks are low, as does the clammer interview data.

Clammer Interview Studies

In April 1953 Fish and Game warden J. O. Reim recorded 7,551 Pismo clams taken by 889 clambers at Palm Beach, yielding an average take of 8.5 clams per day or what would be equivalent to about 5 clams per hour, assuming clambers spent as much time gathering as many clams then as they do now at the better beaches. In 1968 and 1970 Department biologists kept records of their clam digging effort at Zmudowski State Beach, and in 1969 Jim Houk (Moss Landing Marine Laboratories student, now Department of Fish and Game) recorded clammer success at Jetty Beach. In January 1974 clammer interviews were conducted at Jetty and Zmudowski beaches and from October 1974 to February 1975 an intensive clammer interview survey was conducted to sample clambers at all Pismo clamming beaches in Monterey Bay. From January 1974 to February 1975 interviews were made of 1,935 clambers at 10 access areas. Numbers of clambers in each party, time spent clamming by each clammer, and number of legal sized clams taken were recorded. In addition, each clammer was asked how many clams within an inch of legal size were returned. This sublegal catch estimate is a subjective determination of how many clams are returned by clambers. Several errors are present in these data such as the ability of the clammer to guess how many clams were returned at the end of the day and, more important, being able to mentally recall the numbers of 4 to 5 inch clams when many more 1.5 to 3 inch clams were encountered. This smaller size group dominated the beaches in 1974; however, many of these clams were obviously small to the clammer and were not picked up, whereas 4 inch and larger clams were retrieved for measurement. These figures have proven reliable inasmuch as the abundance of the 4 to 5 inch size group reported by clambers declined relative to the catch of legal clams as the sea otter moved through each beach area. Also, clambers working in areas where sea otters have depleted the stocks of larger clams reported few clams larger than 4 inches but still reported an abundance of the smaller 1.5 to 3 inch size group in the lower intertidal zone, indicating they did differentiate between these size groupings. Apparently sea otters do not forage as heavily upon the small clams under 76 mm (3 inch) in the lower intertidal zone, or at least not until after the larger clams are depleted.

TABLE 5. Numbers of Pismo Clams Taken on Trench Transects and Average Number Taken per Hour During 15-Minute Digs at Four Beach Areas 1966 to 1974.

	<u>Legal Sized Clams, 5''+</u>	<u>4.5 to 5.0 Inches</u>	<u>Under 4.5 Inches</u>	<u>Total</u>	<u>Square Meters in Transect</u>
Monterey Bay Academy					
1974, March: transect	1	0	46	47	11.5
15-min. dig	0.0	4.0	6.7	10.7	
1974, June: transect	0	1	37	38	13
15-min. dig	2.0	2.7	12.0	16.7	
1974, December: transect	0	0	13	13	13
15-min. dig	1.0	6.0	11.0	18.0	
Sunset State Beach					
1966, January: transect	0	0	2	2	13
15-min. dig	1.3	2.7	4.0	8.0	
1968, January: transect	0	0	1	1	11
15-min. dig	4.0	6.4	8.0	18.4	
1968, December: transect	0	1	5	6	17
15-min. dig	2.0	5.3	4.0	11.3	
Palm Beach					
1966, January					
North: transect	0	1	1	2	13
15-min. dig	2.7	14.7	4.0	21.4	
South: transect	0	4	0	4	12
15-min. dig	4.0	7.0	4.0	15.0	
1968, December					
No. 1: transect	1	0	3	4	17
15-min. dig	2.0	1.0	1.0	4.0	
No. 2: transect	0	0	6	6	10
15-min. dig	5.3	5.3	2.7	13.3	
1974, December					
No. 1: transect	0	0	67	67	10
15-min. dig	0.0	0.0	12.0	12.0	
No. 2: transect	0	0	50	50	13
15-min. dig	0.0	0.0	6.0	6.0	
Zmudowski State Beach					
1968, December: transect	2	0	1	3	13.5
15-min. dig	6.7	4.3	0.0	12.0	
1974, June: transect	0	0	2	2	8
15-min. dig	0.8	0.0	2.4	3.2	

Stephenson ^{1/} noted a decline in this smallest group of clams after a year's foraging by sea otters at the Potrero Road area.

The beaches covered in this survey were: Salinas River State Beach (referred to as Potrero Road in text), Jetty State Beach, Zmudowski State Beach, Palm Beach, two beach access areas in Sunset State Beach, Monterey Bay Academy, Hidden Beach, Manresa State Beach, and Seacliff State Beach (Figure 1). Fifteen of the 48 days of low clamming tides (-0.4 ft and lower) in late 1974 and early 1975 occurred on weekends during good weather (except for heavy swells during two tide periods) resulting in above average clamming conditions during the survey period.

Estimates of clammer use in Monterey Bay were derived from instantaneous counts, estimates by Department of Parks and Recreation personnel, and counts made by samplers at major beaches surveyed. No limits of confidence can be given because these estimates are not computed from random counts. Estimates for all the beaches range from about 50 on the lowest weekday to about 1,200 for the maximum day of the year, November 29, 1974. The maximum estimate for the period from April 1974 through March 1975 is 15,000 clammer days.

The beaches south of the Pajaro River were lightly used throughout this period because of the lack of clams. The heaviest clammer concentrations during October and November were at Palm Beach. In December clammer effort shifted to more northern beaches as sea otters foraged on the clam stocks at Palm Beach and Sunset State Beach.

Description of Fishery by Beach Area

Potrero Road. Sea otters moved into this area in April 1973 and by September 1973 subtidal stocks of clams had been reduced to levels yielding only one large clam in 7 hours of diving compared to 20 large clams retrieved in an hour and a half of diving during the previous June. There are no clammer catch-per-hour values for the period before sea otters arrived. From March 1974 through January 1975 one legal clam and one clam between 4 to 5 inches were recorded in the sample of 120 clammers (Table 6). No clammers were present on four low tide periods because it became common knowledge that clam stocks were foraged by sea otters at this beach.

Moss Landing Jetty Beach Road. This clamming area covers about 2.5 km (1.5 miles) of beach from Moss Landing north jetty to Zmudowski State Beach access area to the north. Four clammers interviewed here in 1969 took 35 legal sized clams for a catch-per-day average of 8.7 clams. In January 1974, several months after sea otters had begun foraging the area, the catch-per-hour was 0.80 clams, but thereafter the take has not exceeded 0.07 clams per hour (Table 7). Six legal clams were taken by the 57 clammers interviewed between October 1974 and January 1975.

Zmudowski State Beach. This area is bordered by the Pajaro River to the north and is contiguous to the Jetty Road area to the south. In 1968 Department biologists took nine clams in 45 minutes during the 15-minute dig period, five of which were legal sized. On that day an additional 3

^{1/}Mark D. Stephenson. (Unpubl. MS) Sea otter predation on Pismo clams, Moss Landing Marine Laboratories.

TABLE 6. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Sized Pismo Clams at Potrero Road, November 1973 to February 1975.

	1973	1974										1975				
	Nov	Mar 6	Mar 7	Oct 15	Nov 12,14	Nov 29	Nov 30	Nov Total	Dec 28	Dec 29	Dec Total	Jan 23	Jan 24	Jan 25	Jan Total	Feb 23
Clammers	11	2	- No Clammers -		11	15	26	6	4	10	13	11	36	60	13	
Hours	*	1.0			16.5	19.0	35.5	7.0	4.5	11.5	14.0	24.5	48.0	86.5	14.0	
Legal	0	0			0	1	1	0	0	0	0	0	0	0	0	
C/D	0.00	0.00			0.00	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C/H	--	0.00			0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Sublegal	--	--			--	0	0	1	0	1	0	0	0	0	0	
C/D	--	--			--	0.00	0.00	0.16	0.00	0.10	0.00	0.00	0.00	0.00	0.00	
C/H	--	--			--	0.00	0.00	0.14	0.00	0.09	0.00	0.00	0.00	0.00	0.00	

*Not recorded.

TABLE 7. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Sized Pismo Clams at Jetty Beach, January 1974 to January 1975.

	1974					1975	
	Jan 8	Oct 15	Nov 29	Nov 30	November Total	Dec 27	Jan 25
Clammers	5	1	1	8	9	14	28
Hours	5.0	1.8	0.5	4.0	4.5	16.0	33.2
Legal	4	0	0	0	0	1	1
C/D	0.80	0.00	0.00	0.00	0.00	0.07	0.04
C/H	0.80	0.00	0.00	0.00	0.00	0.06	0.03
Sublegal	--	--	--	--	--	1	1
C/D	--	--	--	--	--	0.07	0.04
C/H	--	--	--	--	--	0.06	0.03

hours of sport digging by two biologists yielded 11 additional legal clams for an average of 4.27 legal clams per hour. Eighteen clammers took 44 legal clams for a catch-per-hour value of 2.12 clams in January 1974 (Table 8). Sea otters were beginning to forage this area in January 1974 and by October and November of that year the take was down to 10 clams for 79 clammers. Fourteen legal sized clams were taken by 148 clammers for an average take of 0.07 clams per hour from October 1974 to January 1975.

Palm Beach. This area is bounded by the Pajaro River to the south and is contiguous with the Sunset State Beach area to the north. Some clammers from Palm Beach and Sunset State Beach clam in the area midway, but essentially most of the clammers parking at Palm Beach clam in different areas than the clammers parked at Sunset State Beach south parking lot. Palm Beach has historically been one of the better clamming beaches in Monterey Bay. An average of 8.5 clams per day was recorded in 1953 at this beach, and the 1966 and 1968 15-minute dig data yielded higher density values than at Zmudowski and Sunset State Beaches for clams over 114 mm (4.5 inch) total length (Table 5). In October 1974 the highest catches per day and by hour of all beaches surveyed in Monterey Bay were recorded at Palm Beach. Sea otters had been foraging in the southern portion of Palm Beach since as early as June 1974, thus this beach area must have contained a large number of clams to have slowed the northern movement of sea otters for several months and for clammers to still take large numbers of clams in October. By December 1974, however, the clam beds became depleted by sea otters and catches fell to 0.45 clams per hour (Table 9; Figure 3). Data collected here in October, November, and December were separated into areas north and south of the

TABLE 8. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Sized Pismo Clams at Zmudowski State Beach, January 1974 to February 1975.

	1974									1975		
	<u>Jan 8</u>	<u>Oct 14</u>	<u>Nov 12</u>	<u>Nov 29</u>	<u>Nov 30</u>	<u>November Total</u>	<u>Dec 12</u>	<u>Dec 28</u>	<u>December Total</u>	<u>Jan 24</u>	<u>Jan 25</u>	<u>January Total</u>
Clammers	18	7	6	38	7	51	5	27	32	9	49	58
Hours	20.75	12.50	10.50	51.00	9.00	70.50	5.00	35.00	40.0	12.50	88.75	101.25
Legal	44	0	1	4	0	5	0	7	7	0	2	2
C/D	2.44	0.00	0.17	0.10	0.00	0.10	0.00	0.26	0.22	0.00	0.04	0.03
C/H	2.12	0.00	0.09	0.08	0.00	0.07	0.00	0.20	0.17	0.00	0.02	0.02
Sublegal	*	0	*	*	*	*	0	6	6	1	1	2
C/D		0.00					0.00	0.22	0.19	0.11	0.02	0.03
C/H		0.00					0.00	0.17	0.15	0.08	0.01	0.02

*Not recorded

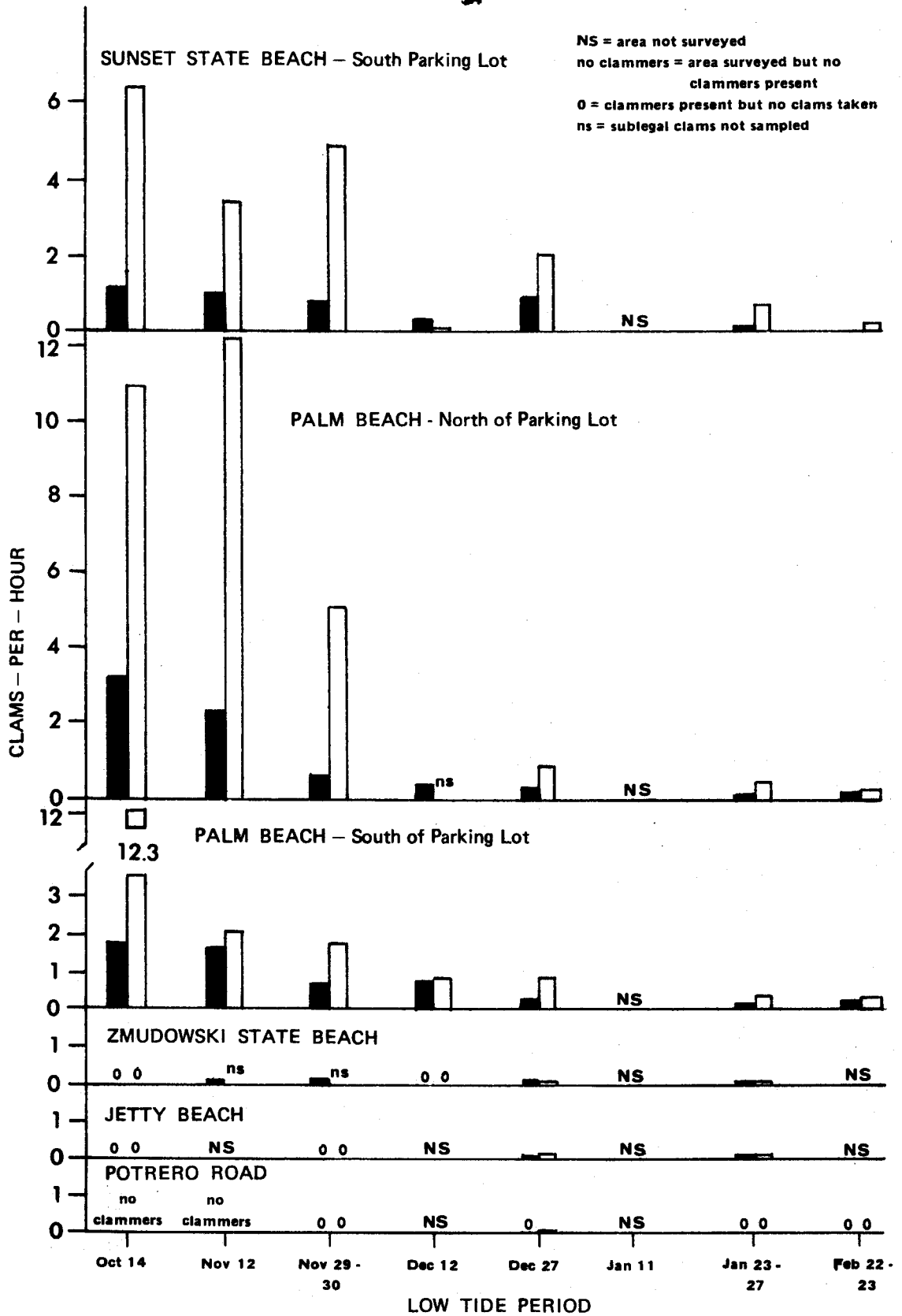


FIGURE 3. Catch - per - hour of legal and sublegal sized Pismo clams at six beach areas on eight low tide periods from October 1974 to February 1975.

TABLE 9. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Sized Pismo Clams by Monthly Totals for Palm Beach, October 1974 to February 1975.

	1974			1975	
	October	November	December	January	February
Clammers	42	99	33	107	22
Hours	87.3	184.8	68.5	204.5	56.0
Legal	257	197	31	18	11
C/D	6.12	1.99	0.94	0.17	0.50
C/H	2.95	1.07	0.45	0.09	0.20
Sublegal	647	817	38	205	16
C/D	24.9	10.21	1.27	1.92	0.73
C/H	11.45	4.86	0.58	1.00	0.29

parking lot (Table 10). These data document the movement of sea otters through the area showing the low values along the southern area where otters had been foraging previous to initiation of sampling and the rapid decline between each two week period north of the parking lot as sea otters moved into this area in November.

Sunset State Beach - South Parking Lot. Sunset State Beach encompasses the area between Palm Beach to the south and the private property at Monterey Bay Academy to the north. Within this state beach there are two access areas for clammers at the south and north boundaries. Sampling was conducted at both areas and there is little overlap of clamming activity between the parking lots. Clam stocks have historically not been as dense near the south parking lot area as at Palm Beach or at beaches to the north. In October there was essentially no sea otter foraging there, and the decline in catch and reporting of sublegal clams starting in late November due to sea otter foraging is clearly documented (Tables 11 and 12; Figures 4 and 5).

Legal sized clams declined from 1.36 clams per hour in October to 0.05 clams per hour by February 1975. The depletion of the 4 to 5 inch size group was equally dramatic, declining from 6.48 reported taken per hour in October 1974 to 0.54 per hour in February. February sampling interviews revealed large numbers of 1.5 to 3.5 inch clams still present in the intertidal zone. Children digging in the sand at low tide were finding these small clams and were using them as rocks to make patterns on the sand. There is some mortality of these small clams in this area due to gulls picking up these abandoned clams and dropping them from 30 to 50 ft heights to break the shell to consume the meat.

TABLE 10. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Pismo Clams at Two Areas at Palm Beach, October 1974 to February 1975.

	South of Parking Lot						North of Parking Lot						
	Oct 15	Nov 12	Nov 29	Nov 30	Nov Total	Dec 11	Oct 15	Nov 12	Nov 30	Nov Total	Dec 11	Dec 27	Dec Total
Clammers	20	18	24	20	62	12	22	16	21	37	8	13	21
Hours	45.5	34.75	40.75	38.25	113.75	19.50	41.75	33.50	37.50	71.00	24.00	25.0	49.0
Legal	82	53	30	22	105	16	165	71	21	92	9	6	15
C/D	4.10	2.94	1.25	1.10	1.69	1.33	7.50	4.44	1.00	2.49	1.13	0.46	0.75
C/H	1.80	1.53	0.74	0.57	0.93	0.82	3.21	2.12	0.56	1.30	0.38	0.24	0.31
Sublegal	187	38	102	44	184	15	460	444	189	633	*	23	23
C/D	20.78	4.22	4.25	2.20	3.47	1.67	39.30	27.75	9.45	17.58		1.77	1.77
C/H	12.47	2.08	2.50	1.15	1.90	0.83	11.10	13.25	5.32	9.17		0.92	0.92

*Not recorded.

TABLE 11. Catch-per-hour of Legal Sized Pismo Clams at Ten Monterey Bay Beaches, January 1974 to February 1975

	Seacliff State Beach	Hidden Beach	Manresa State Beach	Monterey Bay Academy	Sunset St. Beach		Palm Beach	Zmudowski State Beach	Jetty Beach	Potrero Road
					North Parking Lot	South Parking Lot				
<u>Legal Clams</u>										
January 1974	--	--	--	--	--	--	--	2.12	0.80	--
October	--	--	--	2.72	--	1.36	2.95	0.00	0.00	No clammers
November	--	--	--	2.60	1.35	0.98	1.07	0.07	0.00	0.03
December	--	--	1.32	2.23	1.45	0.50	0.45	0.17	0.06	0.00
January 1975	2.54	0.95	1.66	1.93	1.14	0.14	0.09	0.02	0.03	0.00
February	2.01	--	2.11	2.25	1.34	0.05	0.20	--	--	0.00
<u>Sublegal Clams</u>										
January 1974	--	--	--	--	--	--	--	--	--	--
October	--	--	--	--	--	6.48	11.45	0.00	--	No clammers
November	--	--	--	7.68	6.38	4.27	4.86	--	--	0.00
December	--	--	4.50	10.70	10.67	1.89	0.58	0.15	0.06	0.01
January 1975	5.46	3.43	4.22	8.86	5.53	0.76	1.00	0.02	0.03	0.00
February	9.04	--	3.61	16.51	5.40	0.52	0.29	--	--	0.00

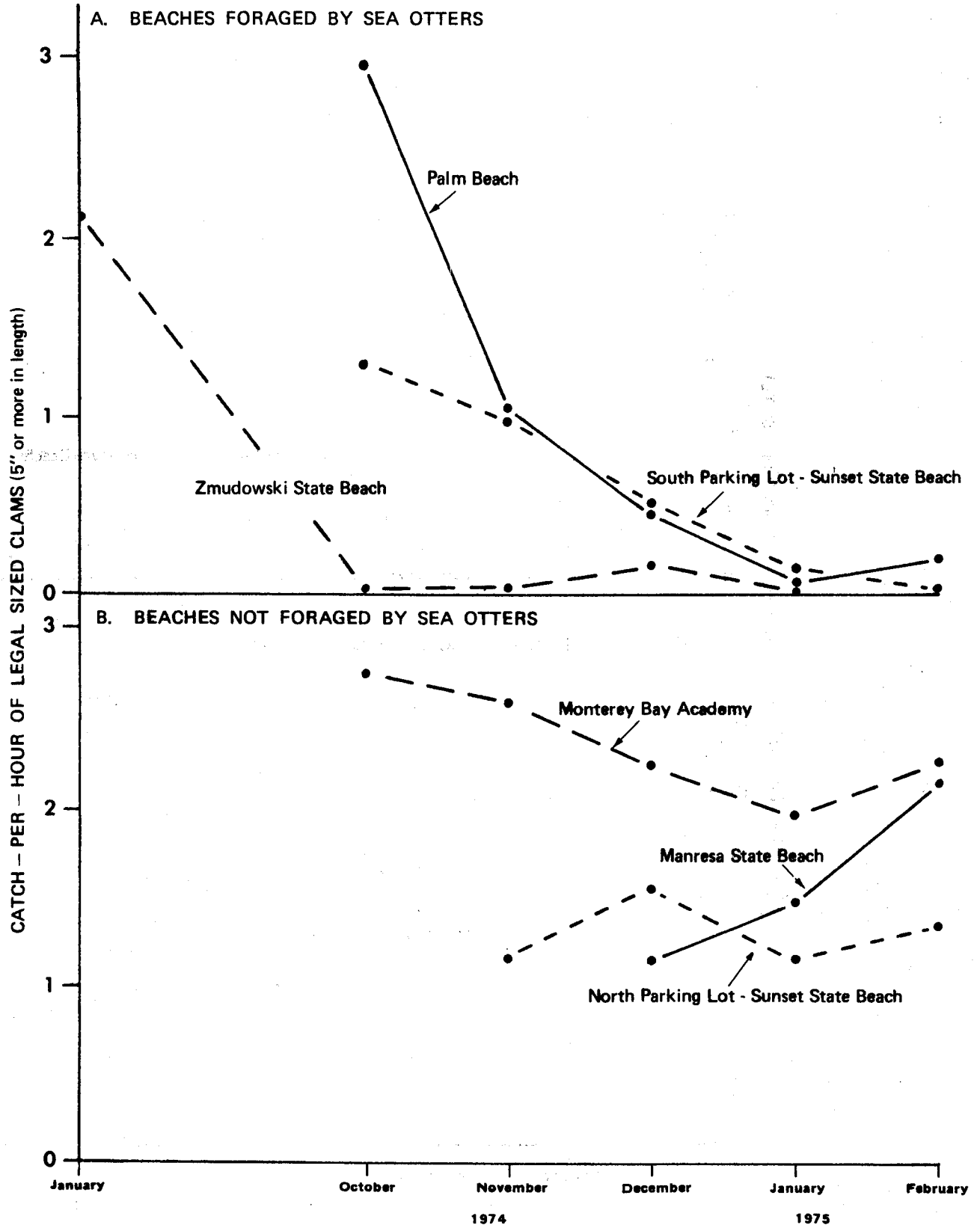


FIGURE 4. Catch - per - hour of legal sized Pismo clams at six beach areas in Monterey Bay January 1974 to February 1975.

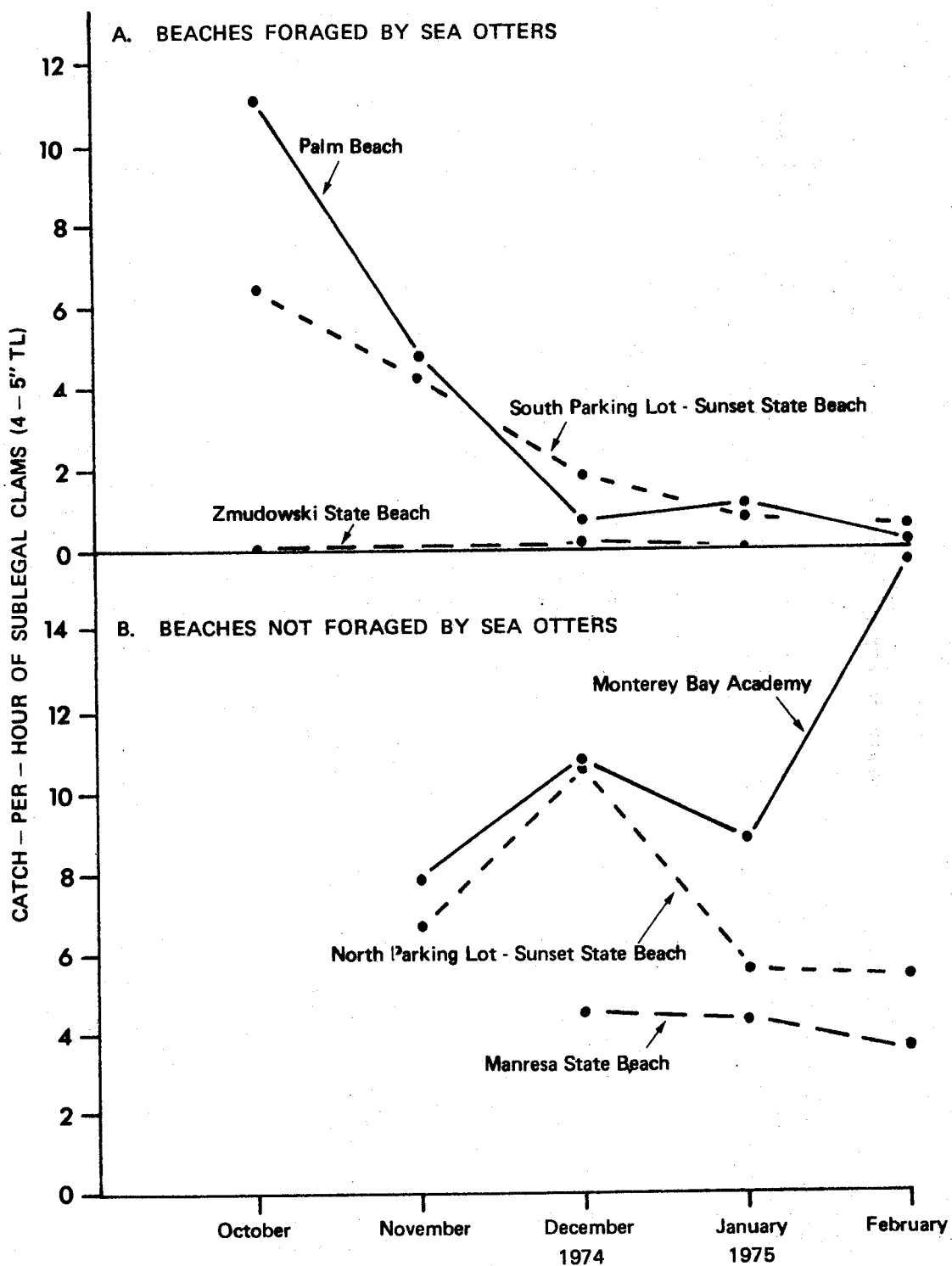


FIGURE 5. Catch - per - hour of sublegal (4 to 5 in. TL) sized Pismo clams at six beach areas in Monterey Bay, October 1974 to February 1975.

TABLE 12. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sub-legal Sized Pismo Clams at South Parking Lot of Sunset State Beach, October 1974 to February 1975.

	1974						1975		
	Oct 15	Nov 12	Nov 30	Nov Total	Dec 11	Dec 26	Dec Total	Jan 25	Feb 23
Clammers	12	27	40	67	14	37	51	103	55
Hours	25.7	63.8	65.0	128.8	21.0	77.5	98.5	198.8	121.0
Legal	35	70	56	126	9	40	49	28	6
C/D	2.92	2.59	1.40	1.88	0.64	1.08	0.96	0.27	0.11
C/H	1.36	1.10	0.86	0.98	0.43	0.52	0.50	0.14	0.05
Sublegal	149	221	329	550	4	182	186	152	63
C/D	13.55	8.19	8.23	8.21	0.29	4.92	3.65	1.48	1.15
C/H	6.48	3.47	5.06	4.27	0.19	2.35	1.89	0.76	0.52

Monthly averages of legal and sublegal sized clams per hour declined rapidly over the 3 month period from November to February indicating clam stocks were relatively less abundant here than off Palm Beach, where sea otters remained for over 6 months before moving into the Sunset State Beach area.

Sunset State Beach - North Parking Lot. This area has been one of the better clamming areas over the past years. In the 1966 and 1968 Department surveys the 15-minute dig data revealed good numbers of legal and sublegal clams (Table 5). Clammers were surveyed here in November 1974 before sea otters moved in and this area represents a good control area to determine the effects of sea otter foraging and effects of clamming activity on the stock of clams. Throughout the November 1974 to February 1975 period there was no significant change in either the legal or sublegal catches by clammers (Table 13). Legal sized clam catch values ranged from 0.99 clams per hour on January 26, when many novice clammers were encountered at this easily accessible area, to 1.88 clams per hour on December 11. Average monthly values show insignificant variation ranging from 1.13 in January to 1.45 clams per hour in December. Because of better clamming conditions, February catch values increased over those recorded in January, indicating the clam stocks had not been greatly reduced by clamming effort during this better than average clamming year (Figures 3, 4, 5, and 6).

TABLE 13. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Sized Pismo Clams at North Parking Lot of Sunset State Beach, November 1974 to February 1975.

<u>Date</u>	1974						1975					
	<u>Nov 29</u>	<u>Nov 30</u>	<u>Nov Total</u>	<u>Dec 11</u>	<u>Dec 27</u>	<u>Dec Total</u>	<u>Jan 12</u>	<u>Jan 25</u>	<u>Jan 26</u>	<u>Jan 27</u>	<u>Jan Total</u>	<u>Feb 22</u>
Clammers	23	66	89	22	31	53	14	18	129	14	175	34
Hours	49.0	121.5	170.5	48.0	50.0	98.0	31.3	49.8	312.0	24.0	417.1	84.5
Legal	82	149	231	90	52	142	81	58	309	27	475	113
C/D	3.57	2.26	2.60	4.09	1.68	2.68	5.79	3.22	2.40	1.93	2.71	3.32
C/H	1.67	1.25	1.35	1.88	1.04	1.45	2.59	1.16	0.99	1.13	1.14	1.34
Sublegal	396	647	1043	610	350	960	306	308	1550	61	2225	408
C/D	18.86	9.95	12.13	33.89	11.29	19.51	21.86	17.11	12.60	4.36	13.17	13.16
C/H	9.00	5.41	6.38	15.25	7.00	10.67	9.78	6.18	5.21	2.54	5.53	5.40

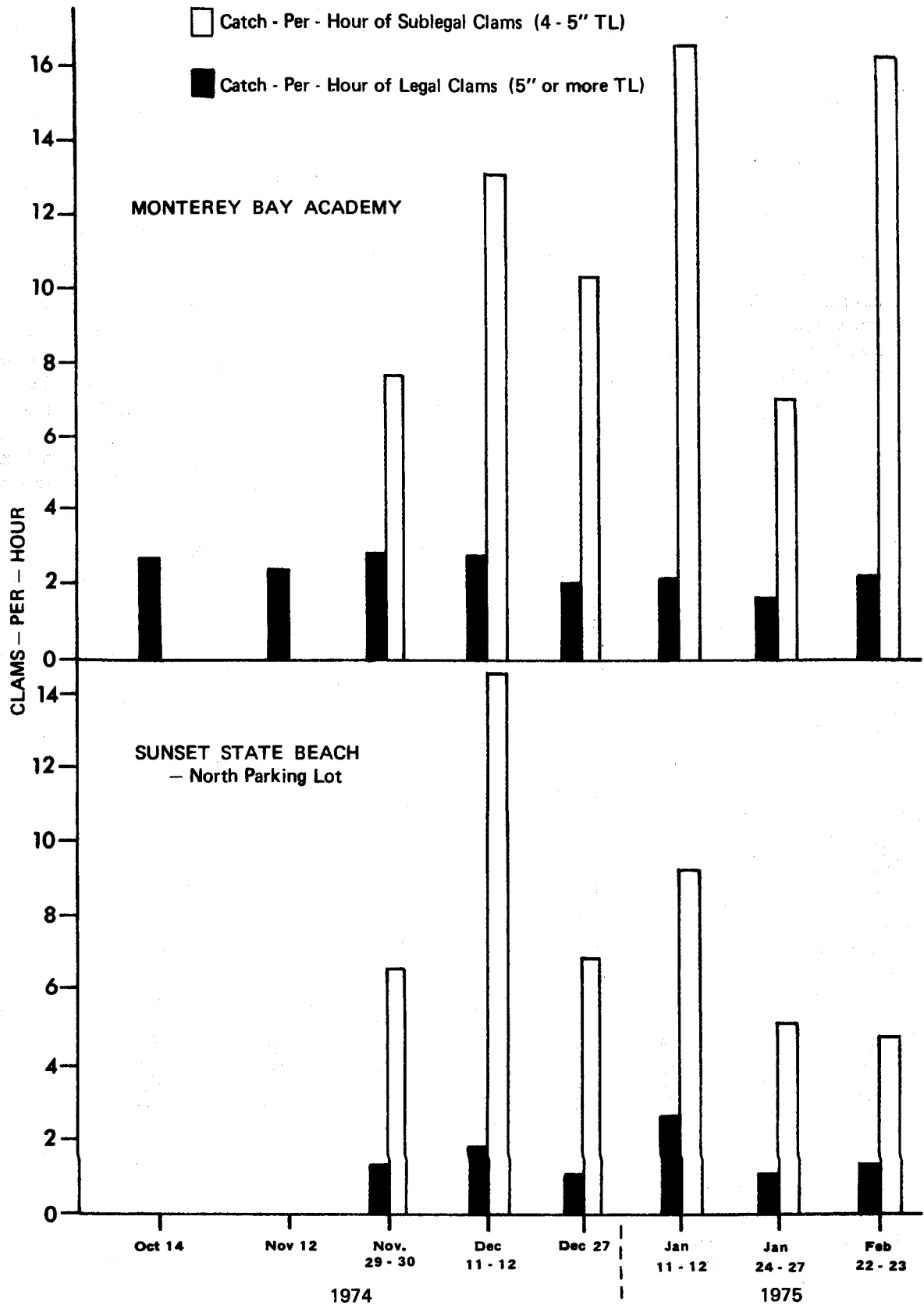


FIGURE 6. Catch - per - hour of legal and sublegal sized Pismo clams at Monterey Bay and the north parking lot at Sunset State Beach on eight low tide periods, October 1974 - February 1975.

Monterey Bay Academy. This area was not sampled in past years by Department personnel, but researchers at Moss Landing Marine Laboratories have been conducting random transect digs here since 1972. The Moss Landing Laboratory data (Stephenson, ms)^{1/} and results of the 1974 and 1975 Department trench digs, 15-minute digs, and clammer surveys disclose dense stocks of clams here, especially of the smaller sized groups. Catch-per-hour values remained near to or above 2.00 clams per hour throughout the October 1974 to February 1975 period. This area has also been a control to determine differential effects of sea otter and human take of clams at beaches being foraged to the south. There was a slight but not significant decrease from 2.72 legal clams per hour recorded in October to 2.25 clams per hour recorded in February (Table 14). Seven sea otters moved into the Monterey Bay Academy area in late January and possibly the lower catch values in February were a reflection of sea otter foraging. However, the sublegal size category did not decline in numbers, indicating the clamming pressure may have caused this small reduction in legal catch.

These data also indicate that a reported "large" take of illegal under-sized clams has not affected the stocks of sublegal clams at this beach (see page 32 for discussion of clam mortality).

Hidden Beach. This area is about midway between Monterey Bay Academy and Manresa State Beach, but receives less clammer effort because of its relative inaccessibility over dirt roads. Sampling was initiated here in January 1975 (Table 15) to document the change in clam catch and stocks if sea otters continue to move northward. Clamming was not as good here as at other beaches and sublegal stocks were below that of other beaches in Monterey Bay. However, January catch values were relatively low at nearly all Monterey Bay beaches, so this one sample may not adequately represent conditions here.

Manresa State Beach. This area was not surveyed until December 1974. There is relatively heavy effort here and this area will be the control area for Monterey Bay until the sea otters arrive; after which there will be virtually no more Pismo clamming in Monterey Bay. Catch-per-hour values of legal clams ranged from 1.32 in December to 2.11 in February (Table 15). An increase in catch and effort in January and February may have been in part due to the activity of more experienced clammers who abandoned their favorite clamming spots off Palm Beach and Zmudowski State Beach after sea otters foraged these areas. As at Hidden Beach, the density of sublegal clams in the 4 to 5 inch category appears to be less than at beaches to the south.

Seacliff State Beach. This beach was not surveyed until January 1975 when an average of 2.64 clams per hour was recorded (Table 15). There appears to be larger numbers of sublegal clams here than at nearby Manresa Beach.

^{1/} op. cit., page 17.

TABLE 14. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sublegal Pismo Clams at Monterey Bay Academy, October 1974 to February 1975

Date	1974							1975					
	<u>Oct 14</u>	<u>Nov 12</u>	<u>Nov 30</u>	<u>Nov Total</u>	<u>Dec 12</u>	<u>Dec 27</u>	<u>Dec Total</u>	<u>Jan 11</u>	<u>Jan 24</u>	<u>Jan 26</u>	<u>Jan 27</u>	<u>Jan Total</u>	<u>Feb 23</u>
Clammers	21	23	41	64	9	23	32	22	34	74	15	145	30
Hours	36.0	40.0	63.5	103.5	13.8	39.0	52.8	49.8	72.0	154.5	26.5	302.8	52.5
Legal	98	93	176	269	37	81	118	119	95	294	76	584	118
C/D	4.67	4.04	4.29	4.20	4.11	3.52	3.69	5.41	2.79	3.97	5.07	4.03	3.93
C/H	2.72	2.33	2.77	2.60	2.68	2.08	2.23	2.39	1.32	1.90	2.87	1.93	2.25
Sublegal	Not Recorded		484	484	180	385	565	865	369	1279	168	2681	867
C/D			12.10	12.10	20.00	16.74	17.65	39.32	10.85	17.28	11.20	18.49	28.90
C/H			7.68	7.68	13.00	9.87	10.70	17.37	5.13	8.28	6.34	8.86	16.51

TABLE 15. Catch-per-day (C/D) and Catch-per-hour (C/H) of Legal and Sub-legal Sized Pismo Clams at Seacliff State Beach, Manresa State Beach, and Hidden Beach, December 1974 to February 1975

Date	Seacliff State Beach		Manresa State Beach		Hidden Beach	
	Jan 26	Feb 22	Dec 29	Jan 26	Feb 22	Jan 26
Clammers	33	29	46	120	103	36
Hours	59.8	50.8	68.0	201.5	207.8	87.5
Legal	152	102	90	335	439	83
C/D	4.61	3.52	1.96	2.79	4.26	2.31
C/H	2.54	2.01	1.32	1.66	2.11	0.95
Sublegal	326	459	306	851	750	300
C/D	9.88	15.80	6.65	7.09	7.28	8.30
C/H	5.46	9.04	4.50	4.22	3.61	3.43

PISMO CLAM MORTALITY IN MONTEREY BAY

Natural and Clamming Mortality

Natural mortality other than by sea otters has not been studied in Monterey Bay, but results of observations by researchers in southern California are probably applicable to this area inasmuch as the same general physical conditions and species of predators are present except for the California corbina, *Menticirrhus undulatus*. Natural predation of small clams can be high as pointed out by Fitch (1950):

"Considering natural mortality it is not probable that more than 200 clams out of 1,000 one- or two-year old clams would ever reach legal size."

Included in natural mortality of small clams is predation by crabs, bat rays, sharks, and possibly other smaller surf frequenting fishes. Gulls pick up clams left exposed by storms and drop them to break the shell; and there is some predation by the drilling moon snail, *Polinices*. Only a few small Pismo clam shells collected on Monterey Bay beaches contained drill holes. A few gaped shells (halves entire, hinged together and meat gone) were observed, indicating minimal mortality from pollution, killing by hot sun's rays when exposed, or storm damage. Weymouth (1920) described storm damage at Pismo Beach:

"How destructive such changes may be, is seen in some winters when the heavy cutting surf washes out and rolls up the beach such numbers of the clams that windrows are found at high tide line."

However, Weymouth (1923) reports these natural disasters are infrequent.

Mortality of clams by man has been of some concern and as was pointed out above stringent legislation has been enacted to lessen mortality of young clams. Massive dieoffs of clams left exposed on the beaches near Pismo Beach were noted by Fitch (1950). Most Pismo clams can eventually rebury themselves, but if the day is hot several hours of exposure out of water can kill them. No such a dieoff has been recorded for Monterey Bay, so possibly temperature conditions were not damaging to exposed clams along Monterey Bay during the days when numbers of these clams may have been left unburied. Fitch (1950) wrote:

"In returning clams to deep water the recommended method is to throw the undersized clam into water which will be at least waist deep at low tide."

This suggestion is mentioned here to point out that clams can rebury themselves, and today, even though regulations require reburying of undersized clams, some clambers will still toss undersized clams into deeper water, thus keeping the clams from being eaten by gulls or washed up high on the beach during stormy weather. Weymouth (1923) points out that small clams can even rebury themselves when lying exposed on moist sand by manipulating their knife-edged foot. John Fitch (pers. commun.) reports that large clams over about 5.5 inches cannot rebury themselves even when covered by water and that apparently healthy large clams have been observed lying on their sides in deeper subtidal areas of southern California.

The heaviest mortality of sublegal clams by man is probably damage by clamming forks, and in a recent survey of clam shells at Pismo Beach, Morro Bay, and at Monterey Bay most of the shell fragments along Pismo Beach beaches were probably from this source followed by gull-dropped shells. There were only a few exposed clams on Monterey Bay beaches left abandoned by clambers or by children playing with small clams dug in the intertidal zone during low tide. Some of these smaller clams are picked up by gulls; however, this is not a major source of clam mortality. On January 27, 1975, on the fourth day of a prolonged series of low tides, 1,940 meters (1.2 miles) of beach area 50 meters (165 ft) wide, totaling 97,000 m² (116,011 yd²), was surveyed at low tide at Sunset State Beach to observe numbers of gaped shells due to possible clam mortality following this heavy clamming period. Ten gaped shells, four 4 to 5 inch live clams lying exposed on the sand, and one large live clam (123 mm) with a broken shell were tallied. The four exposed live clams were at the edge of a deep current eddy and may have been exposed by current erosion. Gaped shells averaged 0.0001/m² (one in 9,700 m²) and live clams averaged 0.00005/m² (one in 19,400 m²) in this 50 meter swath from the water's edge. Examination of the high tide zone did not reveal any concentrations of old or new gaped shells.

On February 22, 1975, a 6,400 meter (approximately 4 miles) by 50 meter (165 ft) swath was surveyed from Manresa State Beach to the south parking lot at Sunset State Beach. Gaped shells, live clams, broken gull-dropped shells, and the characteristic sea otter shattered shell fragments were tallied. Within this 320,000 m² (0.12 miles²) area from the water line and shoreward for 50 meters at low tide, 46 gull-dropped shells, 10 gaped shells, five live clams, and 65 "otter shells" were tallied. The "otter shells" are typically shaped fragments formed by the shell being pounded on its "edge" on another Pismo clam lying flat on the otter's chest. The two shell halves fracture, leaving the umbo and hinge ligament structures intact (Figure 7). In this survey gull-dropped shells averaged about 0.0001/m² (one in 6,950 m²), gaped shells averaged one in 32,000 m², and exposed live clams averaged less than one in 64,000 m².

Sea otter broken shells were common in areas being foraged, but those retrieved in the intertidal zone do not reflect the quantity of clams being consumed. Most of the foraging is done subtidally and only a small portion of clam shells fractured by sea otters would appear in the intertidal zone. Mark Stephenson (Moss Landing Marine Laboratories, pers. commun.) noted in the Moss Landing Pismo clam survey that more sea otter broken shells were evident subtidally than intertidally and that subtidally many of the sea otter broken shells were covered with sand. Many other large shell fragments of Pismo clams broken by sea otters were present on the beach, but only those with the ligament intact were counted as "otter shells". In the surveys at Pismo Beach and Oceano which are outside the sea otter's foraging range, one shell was found with this appearance within an area over a mile in length and about 100 yards in width. Possibly by some freak chance a gull-dropped shell may fracture in this manner. These characteristic shells were common at Atascadero State Beach, where sea otters had been foraging.

Fresh gull-dropped shells are readily identifiable. Usually all or nearly all the shell fragments are present at the impact area and the inner shell surface is encrusted with sand clinging to the bits of meat and mantle that may be left as well as to the sticky, unwashed inner shell surface. Most often one half of a gull-dropped shell is intact with the other half shattered into from two to six pieces. The largest gull-dropped shell measured 10.9 cm (4.3 inch) in total length; the average size was 7.6 cm (3.0 inch).

Estimate of Pismo Clams Taken by Clammers

A rough estimate of 15,000 clammer days was calculated for Monterey Bay in the April 1974 to March 1975 period. The total 1,935 clammers interviewed over the past year took 4,427 legal sized clams for an average of 2.29 clams per clamming day. This average is slightly biased to lower catch values, inasmuch as many of these clammer days were expended in areas foraged by sea otters and there was a disproportionately greater sampling effort at several of these sea otter foraged beaches. Outside the sea otter's foraging range the average catch-per-day by clammers was 3.16 clams. Using an average of 3.0 clams per day for the maximum 15,000 clammer days, about 45,000 legal clams were taken between April 1974 and March 1975 from Monterey Bay.

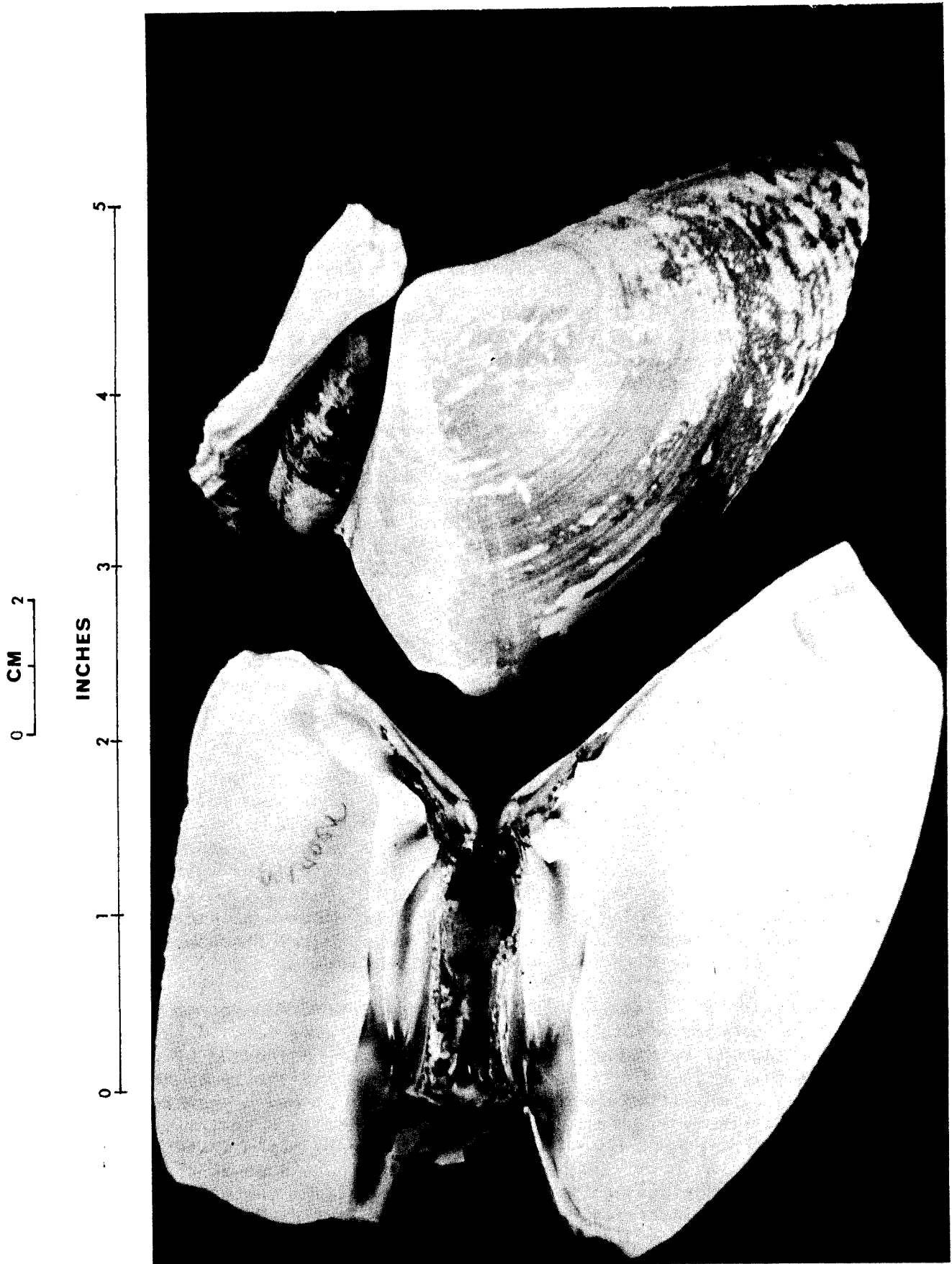


FIGURE 7. Characteristic fracturing of Pismo clam shell by sea otters.

Illegal sized clams were reported by many observers to be of considerable magnitude this year because of the many clams present just under legal size in the subtidal area. Marine wardens encountered overlimits and take of sublegal clams, but the magnitude of this take was not great enough to affect the stocks in any way and was certainly not as great as rumored. Warden Bob Grossi noted that about one clammer in 25 were in possession of illegal clams in September and October, but by February when clams were becoming scarce in sea otter foraging areas about 4 of every 25 clammers could be expected to possess illegal clams. Warden Ken Boettcher estimated that about 10% of the clammers in Monterey Bay possessed illegal clams and also related the increase in illegal operations as clams became scarce. There was also a greater than usual number of novice clammers present this year subsequent to Pismo clamming articles appearing in two major nationally distributed magazines. Many of these clammers did not even know how to dig for clams, what gear to use or what the regulations were. As a matter of courtesy, many inadvertent violations were not prosecuted and the illegal clams were returned to the sand. Warden Grossi (pers. commun.) reported the average overlimit per illegal clammer to be around two clams because most of the violators not cited possessed only one illegal clam. Some illegal possessions were of over 130 clams per party but these occurrences were uncommon. The average number of illegal clams possessed by clammers actually cited (62) by one warden was 6.3 illegal clams.

Using the high values for illegal operations of 4 clammers out of 25 being violators and each of these possessing an average of two illegal clams apiece, approximately 2,400 illegal clammers possessed around 4,800 illegal clams within the past year.

Some clams carelessly thrown onto the exposed sand may be picked up by gulls or die from other causes. The 4 miles of sandy beach covered on the February 22, 1975, shell census represented about half the clamming area of Monterey Bay, and if gulls dropped as many small clams outside this area as inside, then about 100 clams may be dropped each clam tide day by gulls. There were about 50 days of low tide periods within the open season last year, thus about 5,000 clams per year may be killed by gulls in this manner. Clam fork mortality is an unknown parameter for Monterey Bay, but from evidence at Pismo Beach, several thousand clams may be killed each year in this way in Monterey Bay.

Summarizing man caused mortality, there was a maximum of 45,000 legal clams taken, another possible 4,800 illegal clams removed, and about 5,000 clams left exposed by clammers and others that were picked up by gulls and dropped, totaling 54,800 clams killed directly or indirectly by humans, not counting clams killed by clam forks, run over by beach vehicles, or broken by non-clammers. Summing up all these possible mortalities, it may be suggested that around 60,000 clams were killed by man's activities in Monterey Bay in the April 1974 to March 1975 period. Some of these estimates are admittedly subject to question, but whatever the extent of human mortality, clammer interview data demonstrated clearly that the effects of all these activities did not adversely affect clam stocks in Monterey

Bay. Catch-per-hour values for both legal and sublegal sized Pismo clams were nearly the same at the end of the season as at the beginning at beaches outside the sea otter's foraging range, which were also the areas of heaviest clamming activity. The sharp decline in catches as sea otters moved into the Palm Beach and south Sunset State Beach areas are attributed solely to sea otter foraging and not to effects of clamming activity.

Foraging of Pismo Clams by Sea Otters

Evidence of sea otter foraging is readily visible at low tide periods by presence of large shell fragments and the typical "otter shells" described above. Accumulation of invertebrate hard parts of sea urchins, abalones, clams, and crabs has been cited by many observers (McLean 1962, North 1965, Rosenthal and Barilotti 1973), and presence of these remains are a reliable indicator of sea otter foraging. Clam shell censuses were made during May, June, November 1974 and January and February 1975 in Monterey Bay to delineate the areas of sea otter foraging. Observations of foraging sea otters was conducted during daylight hours to correlate with these shell collections.

The May 1974 shell fragment collection was designed to determine the best collecting methods. It was found that most of the newly broken shells were within 50 meters (164 ft) of the water's edge at low tide and there appeared to be certain areas where smaller worn pieces of shells would accumulate, whereas the newly broken shells with the periostracum still adhering were more scattered and in areas recently foraged. All whole shells and shell fragments of all species were collected from the water's edge to the high tide mark on one meter wide transects in May. In June a standard method was employed in which all Pismo clam shells were gathered from 50 meter long by 2 meter wide transects (164 by 6.6 ft) spaced each 100 paces from Manresa State Beach to south of Palm Beach. The shells in each transect were kept separate in plastic bags to be counted and weighed in the laboratory.

These samples of recently broken shells from Manresa State Beach to the Pajaro River revealed that within the sea otter's range the average weight of fragments where sea otters were foraging exceeded those outside the foraging range to the north, but that large fresh shells were still present south of the main aggregate (Figure 8). A few large fresh shell fragments were found in areas foraged as much as a year previously as at Jetty State Beach, indicating that some animals continue to frequent previously heavily foraged areas. Ground and aerial census observations confirmed this behavior with an isolated otter or sometimes two sea otters commonly observed foraging from the Salinas River to Sunset State Beach.

Not only is the average weight of shell fragments heavier in areas being foraged, but the number of newly fractured shell fragments is higher than outside the foraging range (Figure 9). The area from south parking lot at Sunset State Beach to Palm Beach was being heavily foraged in June 1974 and not only were the greatest number and largest average sizes of fragments found in this area, but the greatest number of small worn shells

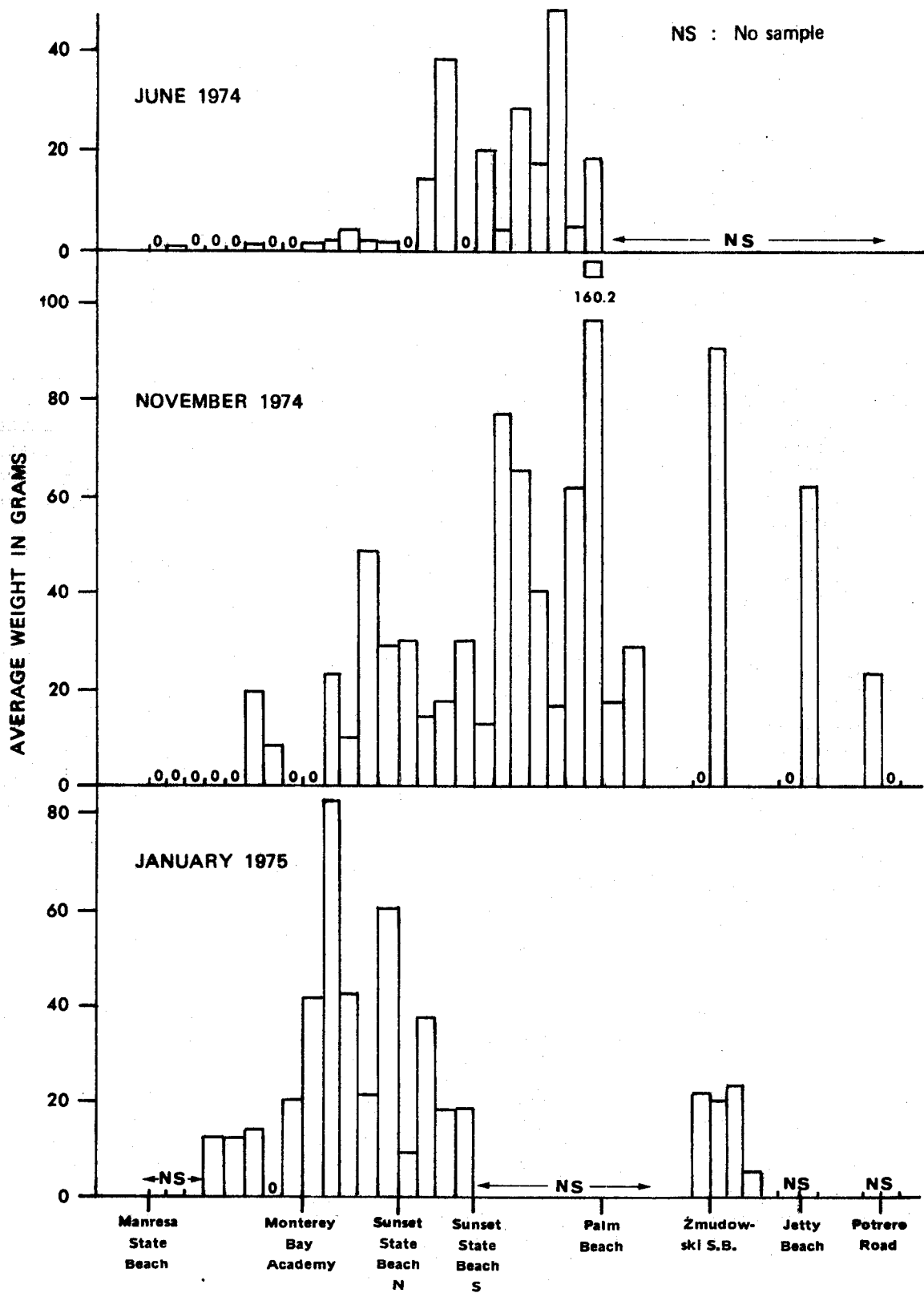


FIGURE 8. Average weight in grams of newly fragmented Pismo Clam shells per 400 yard segment from Manresa State Beach to Potrero Rd., June and November 1974 and January 1975. (Shells from each of 4 100m² transects were collated in each 400 yard segment).

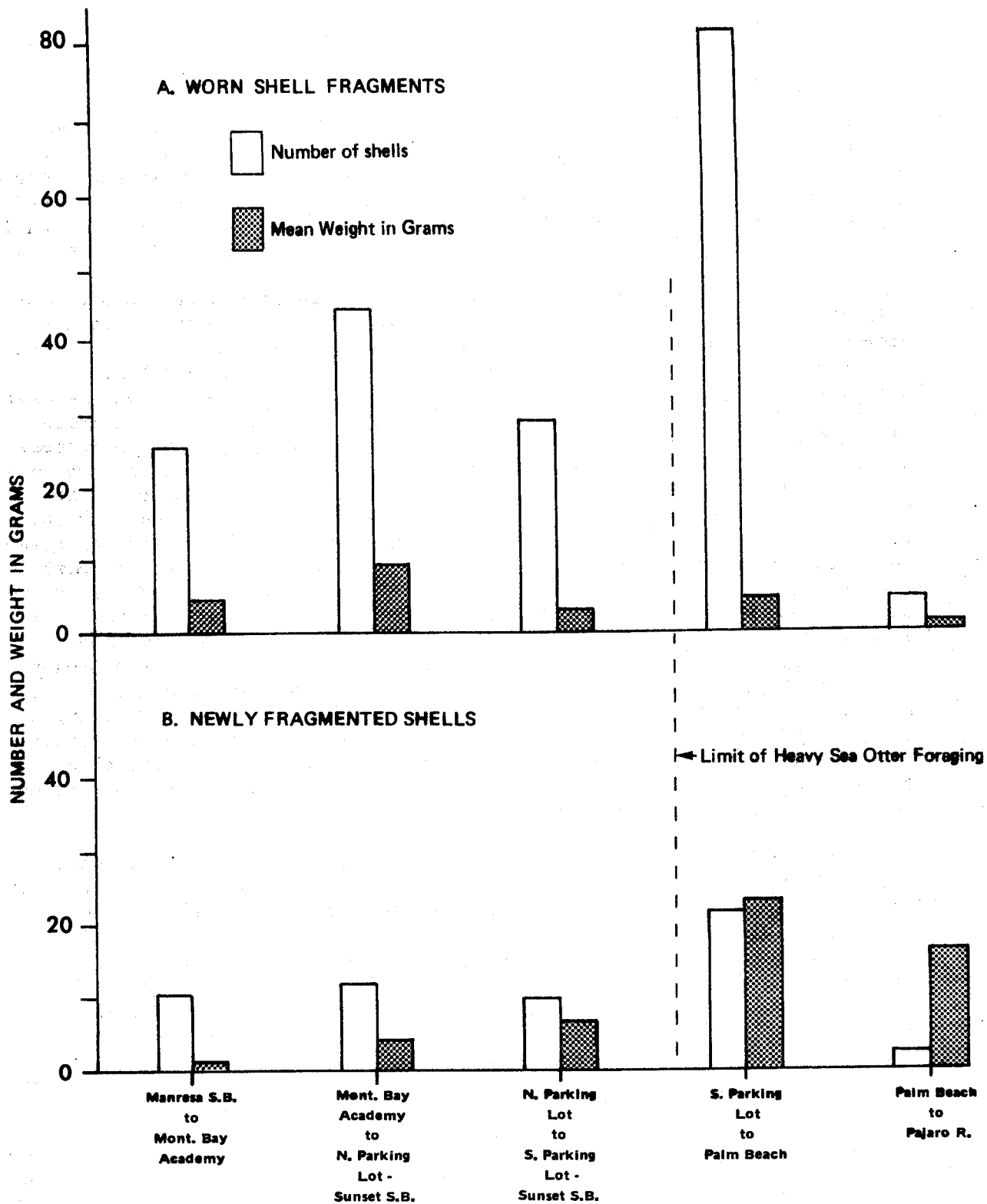


FIGURE 9. Number and mean weight in grams of worn and newly fragmented Pismo clam shells in five subareas of Monterey Bay in June 1974.

were recorded here. At this time there is no known relationship between the presence of this large number of small worn shells and sea otter foraging. Possibly these worn shells reflect the relatively dense clam population that has existed here. By January sea otters were observed foraging in the Monterey Bay Academy area and this shifting of sea otter distribution to the north was revealed in the shell fragment data (Figures 8, 9 and 10).

Shell fragment data and ground and aerial census observations demonstrate that the main concentration or aggregation of sea otters remains somewhat cohesive, at least when foraging, and instead of at first spreading out over the entire food-rich beach area from the Salinas River to Capitola, they have progressively foraged from south to north reducing clam densities to very low levels before moving into another dense clam area. This immigrating behavior somewhat parallels that displayed by sea otters as they moved progressively along rocky reef and kelp bed habitat from the center of their range. Along these Pismo clam beaches there are no kelp beds and reef areas yet the animals appear to be exhibiting some sort of transitional territorial or homing behavior that brings them back each day to where they foraged previously. Ground and aerial observations reveal that these sea otters forage primarily in the early morning and late afternoon periods with a few animals remaining in the surf area to forage throughout the day. Several observations made of the intertidal zone after a high tide early morning feeding revealed numbers of large broken shells with pieces of clam meat still attached. Two chunks of clam meat and viscera approximately 2.5 cm (1 inch) in diameter were found lying on the sand, and several gulls were beginning to pick up other scattered bits of clam meats. Gulls often remain with foraging sea otters along these beaches picking up scraps from the water near the otter, indicating not all meats are consumed from each clam by the otters.

After feeding, the otters swim offshore from 1/4 to 2 miles, where pairs of animals or from five to six may remain in close proximity to each other. Several more animals may be some 100 yards away with still other individuals or pairs resting from up to 1/4 to a 1/2 mile away. This loose aggregation has been noted on each of the aerial flights conducted in midday off Monterey Bay beaches and off Atascadero State Beach. The animals off Atascadero tend to remain closer to shore, most of them remaining within 1/4 mile of the breaker line. On days when observations were made during both morning and afternoon feeding periods, sea otters returned to the same area as foraged in the morning. Observing conditions are optimum in the morning in that the sun is at the observer's back and there is usually little or no surface wind action. Sun glare and heavy choppy seas present serious observing problems in late afternoon and in all cases where evening and morning observations have been made more animals have been counted in the morning period. The surf area covered during each feeding period by 20 animals or more extends for over at least a half mile to a little over a mile with most of the animals near the northernmost edge of the foraging zone. During a heavy freshwater runoff period in late January 1975 the Pajaro River deposited muddy water in the surf zone where otters had been foraging, and for 2 days no sea otters were seen

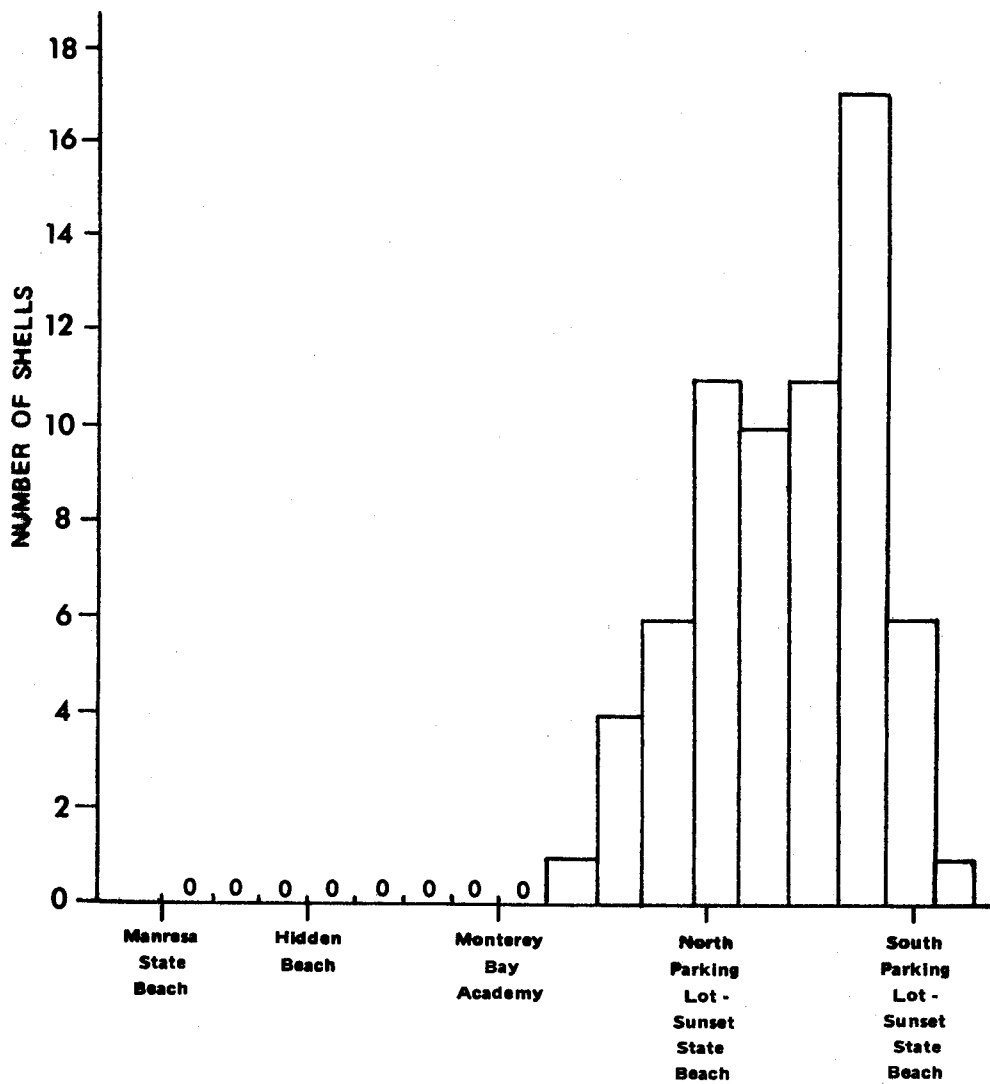


FIGURE 10. Number "otter shells" collected in 400 - yard segments from Manresa State Beach to Sunset State Beach south parking lot in January 1975.

foraging along the area from Manresa State Beach to Palm Beach. On the third day after the storm five sea otters were observed foraging in clearer water outside the breaker line several hundred yards and on the fourth day 22 animals had returned to the surf zone and had resumed foraging where they had foraged before the storm arrived; demonstrating again the unique behavior to return to a given spot along a long stretch of sandy beach. Clam shell fragment distribution suggests that when foraging at night the otters remained in the same area frequented during daytime, as no large numbers of "otter shells" were found outside the area where daytime foraging was observed.

To estimate the number of clams eaten by sea otters requires several assumptions that cannot be adequately tested. The parameters yielding this rough estimate include number of animals foraging between April 1974 and March 1975, the approximate size of the animals, the number of clams seen eaten per feeding period, the total amount of food consumed each day, distribution of the sea otters, and food items they consumed other than clams. The sea otters along the clam beaches appear to be immature independent animals, probably mostly males. These animals are exceptionally active compared to animals foraging in rocky reef and kelp bed areas and exhibit the typical behavior of young aggressive males. Kirkpatrick *et al.* (1955) and Malkovitch (1937) found that young animals consume more food per day by body weight than larger animals. Twenty to 30 pound (9.0 - 14.4 kg) animals consumed from 29 to 36% of their weight per day. Feeding experiments by these and other researchers indicate that an average sized animal of about 55 pounds consumes about 25% of its weight per day. Using a conservative average weight of only 40 pounds for the sea otters foraging along Monterey clam beaches and a 30% of body weight per day consumption of food, each sea otter consumes about 12 pounds of meat per day. Mark Stephenson^{1/} observed an otter of Moss Landing consuming 24 large Pismo clams in a 2 hour and 15 minute period in an incomplete feeding and 22 clams were observed consumed by a sea otter at Atascadero State Beach in a single incomplete feeding (Wild and Ames 1974). Assuming that sea otters forage twice each day, then at least 50 clams per day would be consumed by each otter at the rates of feeding observed above. Recent observations in Carmel Bay and off Monterey by Steven Shimek (Univ. Calif., Santa Cruz, pers. commun.) disclosed a feeding period during the middle of the night. It is not known, however, how many times an individual sea otter forages each day or night. Some observations indicate several feedings, but others possibly only one. This is a little known phenomenon of sea otter behavior and most likely the habitat being foraged and volume of items available may determine the number of times an otter feeds each day. It is known that sea otters in captivity consume from 36% of their weight per day as young growing animals and as little as 15% per day of their body weight as old mature animals and that animals in captivity and in the wild (Thomas Loughlin, Univ. of Calif., Los Angeles, pers. commun.) feed several times a day.

If a young 40-pound sea otter consumes shellfish meats at the rate of 30% of its body weight each day, then at least 12 pounds of meats would be required per day. Pismo clams measuring 4.5 inches total length, the average large sized clams in the subtidal area, contain an average of 67.4 grams (0.148 lbs) of meat. If a sea otter requires 12 pounds of meat per day,

^{1/} op. cit., page 17.

then at least 80 114 mm (4.5 inch) clams per day would be eaten. Twenty-five clams of this size would supply only about 4 pounds of food, so at this rate at least three feedings per day would be required for minimum daily requirements of energy. Pismo clams are the primary food item being foraged along these beaches. Mark Stephenson (Moss Landing Marine Laboratories, pers. commun.) noted in two separate foraging observations that 92.3 and 27.5% of food items by numbers were Pismo clams, the remainder being spiny mole crabs. On March 24, 1975, the senior author observed a foraging animal between 1800 to 1841 hours at Sunset State Beach north parking lot. Eleven Pismo clams were eaten during this period and one unknown small object was chewed, yielding 91.7% Pismo clam by numbers. Diving time of the 17 dives recorded for the 41 minutes averaged 37.2 seconds (range 16 to 69 sec.; S.D. 14.8 sec.). Five hours later at 2315 three sea otters appeared in the same area and began feeding. Only four nighttime dives were observed because of the close proximity of the three animals and the limited viewing ability of the light-intensifier scope. These dives ranged from 22 to 42 seconds, but these data are inconclusive inasmuch as longer dives may have been overlooked.

Pismo clam consumption probably represents around 90 to 95% of the sea otter's diet by weight along these beaches even though at times less than half of the items eaten are clams. About five large spiny mole crabs (48 grams mean total weight) contain an equal wet weight of viscera, egg mass, and "body" meat as the biomass of one 114 mm (4.5 inch) Pismo clam. The "body" meat of a spiny mole crab lies at the midventral line between the legs and is a dense layering of shell material and meat. The condition of the remains of a spiny mole crab eaten by a sea otter (Stephenson, Moss Landing Marine Laboratories, pers. commun.) indicates only the viscera and, if present, egg mass may be eaten by sea otters in that the legs were chewed upon but the meat not extracted and eaten. If only the viscera and egg mass were eaten, then about 10 large spiny mole crabs yield the same biomass of food as one 114 mm (4.5 inch) Pismo clam. Assuming that the "body" meat is consumed by the sea otter, if Pismo clams averaging 114 mm (4.5 inch) greatest diameter make up 70% of the diet by numbers and the remaining food items were mole crabs, then 91.8% of the food consumed by weight would be Pismo clams. If this body meat is not eaten then at 70% by numbers, Pismo clams represent 96.0% of the food consumed by weight.

Other evidence that Pismo clams are the preferred items sought along these beaches and that spiny mole crabs are incidental by preference is that spiny mole crabs are apparently about as numerous after the sea otter front has depleted the Pismo clam stocks and moved to new areas as before (Stephenson, op. cit., and Department of Fish and Game transect dig observations). A few sea otters continue to forage these depleted beaches and have been observed foraging on both Pismo clams and mole crabs. Assuming the "body" meats are eaten along with the viscera and egg mass a small 40 pound sea otter would have to consume at least 400 spiny mole crabs per day to meet its minimum daily energy requirements; assuming the food value of mole crabs is comparable to the value of food items used in energetics experiments. The large numbers of mole crabs present and the few numbers

of sea otters remaining indicates this food source alone is not sufficient to maintain a resident population of sea otters.

Assuming a young sea otter could actually exist on only 10 pounds of food daily and only large 114 mm (4.5 inch) clams were eaten, then at least 67 clams would be required per day. If 5% of the daily food by volume is of crabs, then 9.5 pounds of clams at 0.15 pounds per clam would total at least 63 large clams needed per day per sea otter. This is the lowest possible number of clams a sea otter must consume per day as determined from all the data known about sea otter food requirements.

Distribution and Numbers of Sea Otters and Numbers of Clams Consumed

Sea otter ground and aerial censuses have been made periodically over the year and a half that otters have been foraging Pismo clams in Monterey Bay. The first counts were made by Moss Landing Marine Laboratories staff, who counted a maximum of ten sea otters in June 1973 (Mark Stephenson, Moss Landing Marine Laboratories, pers. commun.). In December 1973 Department aerial census and ground truth observations by Moss Landing Marine Laboratories staff and students yielded an estimated concentration of about 20 sea otters foraging immediately north of Moss Landing jetty (Figure 11). As the animals moved northward their numbers gradually increased presumably as new wandering sea otters joined the foraging aggregate and remained with them. By December 1974 up to 28 sea otters had moved into the area off the north parking lot of Sunset State Beach. In late January 1975 Ancel Johnson and Ron Jameson (U.S. Fish and Wildlife Service, pers. commun.) counted 46 sea otters in the Sunset State Beach area. Subsequent to this observation a stormy period increased the turbidity of the surf area and for several weeks thereafter not more than 22 animals were counted in this area, although no total census of the entire bay out to 2 miles had been made to reveal the possible location of the other sea otters. Surveys made of the kelp beds to the north at Capitola and Santa Cruz failed to reveal any concentrations of sea otters, so either some animals remained outside the range of visibility of ground observers, scattered along the entire beach area to the south toward the Salinas River, or returned to the Monterey-Pacific Grove area. The sea otters that returned to the Pismo clam foraging area off Sunset State Beach came back to the area where they foraged before the storm and proceeded to continue their methodical foraging.

Sea otter censusing along sandy beaches is less accurate than when counting sea otters in kelp beds. The animals are more active when feeding and remain offshore in open water when resting. These pelagic resting animals are difficult to recognize from the air, because there are no reference points with which to orient observations. Ground truth comparisons reveal that aerial spotters observe from 1/3 to 1/2 of the animals present along sandy beaches. Observers from shore on the other hand often cannot observe animals farther from shore than one-half mile, so these shore counts are always minimal counts as not all animals feed at the same time. Ancel Johnson and Ron Jameson (U.S. Fish and Wildlife, pers. commun.) observed 46 animals foraging off Sunset State Beach on January 27, 1975. These observers remained in the foraging area for most of the day and were equipped with binoculars and a Questar spotting scope. Department ground

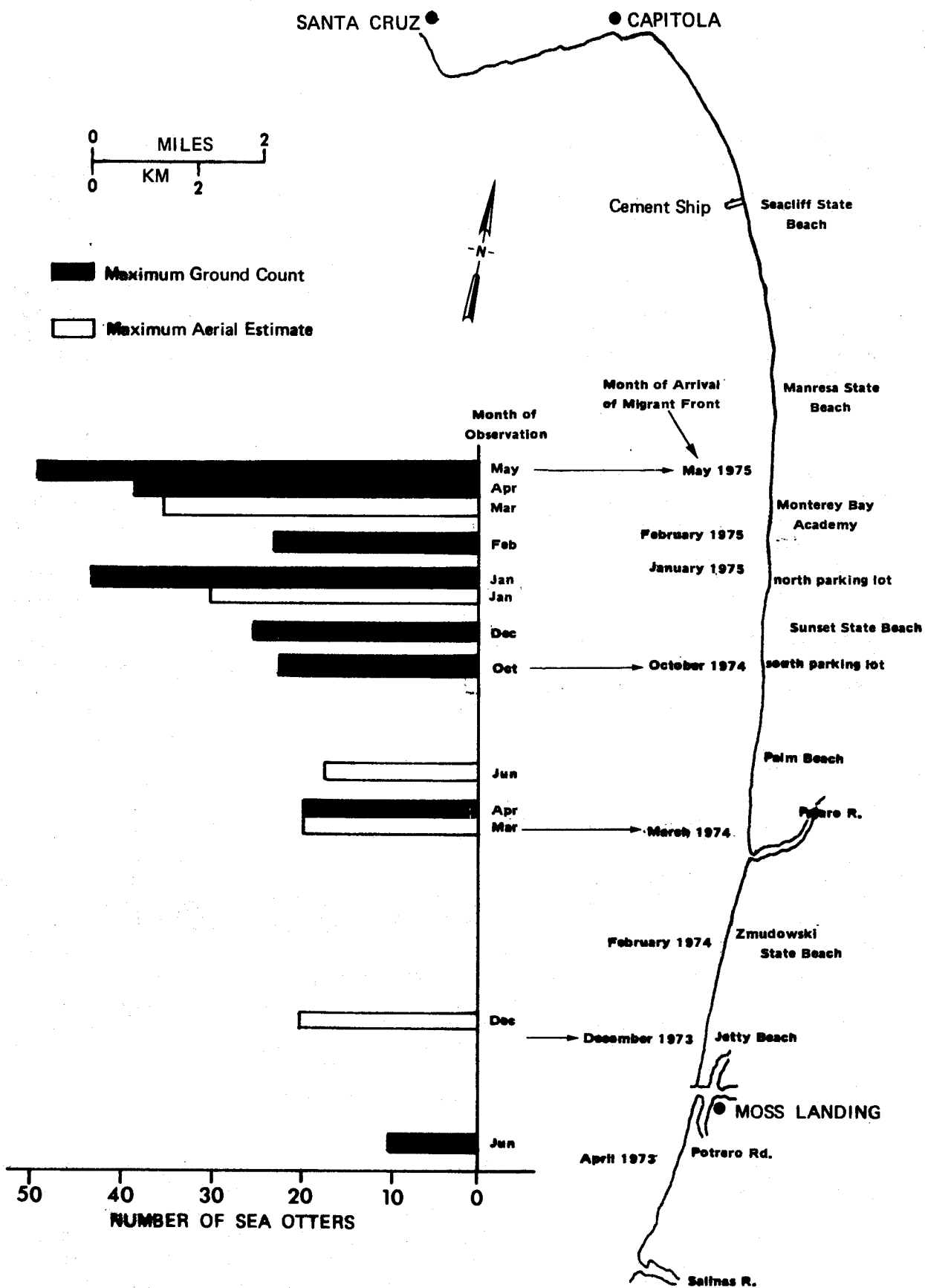


FIGURE 11. Distribution and number of sea otters from the Salinas River to Manresa State Beach April 1973 to May 1975.

counts have been instantaneous counts observing otters at four or five observation points on a beach run. The day after the 46 count by Johnson and Jameson an instantaneous count of 33 sea otters was made by the senior author in the same area. From this one comparison with a more thorough count it appears that more animals may have been foraging these beaches than our data have indicated. The low September aerial count for instance was made in midday and apparently the resting aggregate was missed by the aerial observers because 3 days later a ground count was made and animals were observed in their foraging area off Palm Beach. A more thorough aerial census was made of the offshore area in the January and March 1975 aerial censuses and offshore pelagic rafts of otters were located 1.5 to 2.0 miles directly off the area where ground observers had observed them foraging earlier that day.

Computation of the number of Pismo clams consumed by sea otters in Monterey Bay is dependent upon the assumption that as many otters were present between census periods as were counted or estimated during each census. Total counts or estimates were made in June 1973, during March, June, September October 1974, and in January and February of 1975 (Figure 11). Several spot checks were made at other times in 1974 from April through the rest of the year to determine the northernmost limit of distribution, and sea otters were sighted on each occasion except immediately after the storm period of 1975 described above. Assuming the minimum estimated or counted number was present on every day between censuses, around 20 animals remained along the beaches each day from April through September 1974, at least 25 animals were present from October through December 1974, an average of 30 animals were present in January 1975, and around 25 animals were present in February and March 1975. Assuming these minimum numbers were present along the beaches each day, a total of around 8,400 sea otter foraging days was expended from April 1974 through March 1975 in Monterey Bay. Applying a minimal consumption of 63 clams per day, a total of at least 520,000 large clams was eaten by sea otters in a year's time. Realistically, probably many more clams than this were killed by sea otters due to the wastefulness observed in several feedings and to the fact that smaller clams than 114 mm (4.5 inch) were consumed. For instance, if clams averaging only 102 mm (4.0 inch) in length containing 0.12 lbs. of meat per clam were consumed instead of 114 mm (4.5 inch) clams, about 100 clams per day would be required to accumulate 12 lbs. of meat; or if a sea otter could exist on only 10 lbs. of food per day, 83 clams 102 mm (4.0 inch) in length would be required each day. In this latter computation, nearly 700,000 Pismo clams may have been consumed over the last year in Monterey Bay.

SUMMARY

1. A statewide clammer census conducted in January 1975 revealed that except for one small area near Pismo Beach pier, Pismo clam stocks at the major clamming beaches in Orange and Los Angeles counties, the Pismo Beach and Morro Bay areas, and in northern Monterey Bay are in a healthy condition with good catches being recorded. Pismo clam stocks appear to be harvested on a sustainable annual yield and reproduction is above average in recent years. The highest catch-per-day

values were recorded near Newport Pier, Oceano, Morro Spit, and Sea-cliff State Beach in Monterey Bay.

2. Inside the sea otter's foraging range virtually no clams were taken. About 4 clams per 100 clammers were recorded at the four beach areas where sea otters had foraged for more than a year. These precluded beaches are Atascadero State Beach, Salinas River State Beach, Jetty Beach at Moss Landing and Zmudowski State Beach. At Palm Beach and Sunset State Beach, where sea otters were foraging during the census period, catches were down to about 22 clams per 100 clammers. Outside the sea otter's range in Monterey Bay, 302 clams per 100 clammers were recorded.
3. Trench transect and 15-minute dig data collected by Department biologists in 1953, 1966, 1968, 1970, and 1974 revealed that recruitment of young clams was good in 1953, poor in the 1966 and 1968 studies, and exceptionally good in the 1974 surveys. The dominant hatches contributing to the good recruitment measured in 1974 are the 1969, 1970, and 1971 year classes in Monterey Bay. The healthy stocks of legal and sublegal clams from 4 to 6 inches in length are from an accumulation of clams from many year classes with the 1962 and 1963 year classes contributing to a major portion of the legal catch. Sublegal clams in the 102 to 127 mm (4 to 5 inch) category are also depleted by sea otter foraging, but the dominant size group of 38 to 89 mm (1.5 to 3.5 inch) clams in the intertidal and shallow subtidal areas are not as greatly reduced.
4. An estimated 15,000 clammer days were expended in Monterey Bay from April 1974 through March 1975. About 45,000 legal clams were taken, an additional 4,800 clams left lying exposed on the sand by clammers and picnickers were picked up by gulls and dropped to break the shell, and another 5,000 illegal clams were estimated taken by clammers, totaling around 54,800 clams killed directly or indirectly by humans in this 12 month period. Adding several thousand clams possibly killed by clam fork damage and other human activities, around 60,000 Pismo clams may have been removed from Monterey Bay clam stocks due to man's activities during this one year study period.
5. Sea otters moved into the Potrero Road beach area in April of 1973 and foraged progressively northward removing most of the larger clams throughout the surf zone. Instead of spreading out over the entire food-rich surf zone, the sea otters moved along a "migrant front", progressively foraging clams to low levels before moving into the next dense population of clams. Pismo clams made up from 28 to 92% by numbers of food items along these beaches and considering the relatively small biomass of a mole crab Pismo clams probably contributed to over 95% of the diet by volume. Sea otters foraging along these beaches rested outside the surf zone up to 2 miles offshore, returning to the area previously foraged.
6. Numbers of sea otters ranged from 10 in June of 1973 to 46 in January 1975. Except for a two-day period after a heavy freshwater runoff of

muddy water in January 1975, sea otters were observed foraging during every ground and aerial census of these beaches. A rough conservative estimate of the number of clams consumed by sea otters in the April 1974 to March 1975 period was 520,000 clams. Considering that some sea otters continue to frequent areas previously heavily foraged, it can be expected that the small sublegal clams remaining in the intertidal zone will not reach legal size in sufficient numbers to develop another recreational fishery as long as sea otters are present.

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