REPRINT FROM
*Calif. Fish and Game* 75(4): 224–232 1989

# POPULATION DYNAMICS OF HARBOR SEALS IN THE GULF OF THE FARALLONES, CALIFORNIA [1]

SARAH G. ALLEN
Point Reyes Bird Observatory
4990 Shoreline Hwy, Stinson Beach, CA 94970

HARRIET R. HUBER [2]
Point Reyes Bird Observatory
4990 Shoreline Hwy, Stinson Beach, CA 94970

CHRISTINE A. RIBIC
Center for Quantitative Science
University of Washington, Seattle, WA 98195

AND

DAVID G. AINLEY
Point Reyes Bird Observatory
4990 Shoreline Hwy, Stinson Beach, CA 94970

**We surveyed harbor seals, *Phoca vitulina,* in the Gulf of the Farallones, California, at all known haul-out sites from March 1982 through February 1984, and studied them intensively at two haul-out sites, Double Point and the South Farallon Islands, from 1976 to 1986. Though present year round, seals were most abundant onshore during the breeding/molt season (March–July). The relative abundance of seals onshore at Double Point during the 1987 breeding season was double the number in 1976, and at the South Farallon Islands, numbers in 1986 were four times higher than in 1974. Individual females observed at Double Point during two 3-year sets had a 0.89 and 0.92 probability of parturition in successive years.**

## INTRODUCTION

Harbor seals, *Phoca vitulina,* have occurred in central California throughout historical times (Scammon 1968), but only in the past 20 years have state-wide surveys of their distribution and abundance been conducted (Carlisle and Aplin 1966 and 1971, Frey and Aplin 1970). Aerial surveys between 1983 and 1986 revealed that about 20% of the state population, excluding animals on the southern California Channel Islands, occurs at sites in the Gulf of the Farallones (Hanan, Calif. Dep. Fish and Game, La Jolla, Calif., pers. comm.). Few data, however, have heretofore been reported on population trends and reproductive rates for harbor seals in this region (Ainley, Huber, Henderson, and Lewis 1977, Allen, Ainley, Page, and Ribic 1985). Here we summarize observations of seals at haul-out sites in the Gulf of the Farallones between 1974 and 1987 and present data on reproductive success.

## STUDY AREA AND METHODS

The Gulf of the Farallones is bordered by the central California coast from Bodega Bay (lat 38° 20'N) southward to Point Diablo (lat 37° 39'N), and west to the Farallon Islands, 36 km offshore (lat 37° 41'N; Figure 1). Included in our study area are the coastal embayments Tomales Bay, Drakes Estero, and Bolinas

[1] Accepted for publication September 1989.

[2] Present address: National Marine Mammal Laboratory, NMFS/NWAFC/NOAA, 7600 Sand Point Way, N.E., Seattle, WA 98115.

Lagoon. Much of the coastline, except for that south of the Golden Gate, is largely undeveloped and all is under the jurisdiction of either the Point Reyes National Seashore, U.S. Fish and Wildlife Service, Gulf of the Farallones National Marine Sanctuary, or Golden Gate National Recreation Area.


FIGURE 1. Harbor seal haul-out sites in the Gulf of the Farallones.

In the study area seals haul-out on a diversity of habitats—tidal mud flats, offshore intertidal ledges, and sandy beaches. Coastal haul-out locations include Tomales Point, Point Reyes Headland, Double Point, Duxbury Reef, Tomales Bay, Drakes Estero, and Bolinas Lagoon. The South Farallon Islands (SFI), including Southeast Farallon Island and West End Island, are the only offshore sites, and seals haul-out there primarily on rocky intertidal ledges (Figure 1). Seals do not haul-out on coastal beaches that are heavily used by people south of Bolinas Lagoon.

We counted harbor seals at the Point Reyes coastal sites two times per month from March 1982 through February 1984. Multiple observers surveyed all sites on the same day within a 2-hr period; to obtain maximum numbers on shore, we counted seals when low to medium-low tides occurred between 1200 and 1600 h (e.g., Ainley *et al.* 1977, Allen *et al.* 1985, Fancher 1979, Stewart 1984).

At Double Point, we observed seals on 360 days from January 1976 to June 1987; most counts were made during the breeding season between 1200 and



1600 h at low to medium tide levels. On SFI, counts were made at low ti almost daily to derive a maximum weekly estimate beginning in 1974.

For analysis of seasonal use patterns, we divided the year into the period breeding and molt (March through July), and the non-breeding period (Augu through February). Breeding and molt overlap and thus we combined them in one period. We used a two sample t-test on the natural logarithm of the cou to test the null hypothesis that counts of seals ashore did not differ betwe periods within a year.

We distinguished between adults and pups based on size and coloratio Pups were easily identified during the breeding season at all locations becau of their small size and bright silver to black pelage at a time when adults a immatures were a faded, brown color. By the end of June, immature seals beg molting and we were no longer able to distinguish pups from immature sea We, therefore, only counted pups from March through June. Pup numbers we expressed as a percentage of the total number of seals counted. Maximu counts of pups for the region were based on same-day counts at all puppi sites.

We examined the change in relative abundance by regressing the natu logarithm of the mean number of adults and immatures against year for Dou Point and for the SFI using SPSSPC+ (Norusis 1986). Parallel slopes for the t sites were tested at alpha = 0.05 using the procedure in Weisberg (1980). T mean number of seals was calculated from the breeding period counts when t maximum number of seals was present.

We were able to identify 23 females at Double Point by shark scars a unusual spot patterns. Healed shark scars are prominent natural markings, a from photographic records and drawings, we were able to reidentify individu over time.

Following Siniff, DeMaster, and Hofman (1977), the conditional frequency parturition *(Fp)* of females was determined for successive samples of kno females in 3-year sets using the formula:

$$Fp = \frac{N_{i+1}}{N_i}$$

$N_1$ is the number of known females seen with a pup in year$_1$. Sixteen individ adult females identified from 1977 through 1979 represented set 1, and eight individuals from 1982 through 1984 represented set 2. We eliminated from tabulations two groups of known females: 1) females not seen all three ye (see Siniff *et al.* 1977); and 2) those that did not have pups in year 1. Fema eliminated in group one may have pupped elsewhere during the year abse and those in group two may not have been sexually mature in year 1 since s alone is an unreliable measure of age class (McLaren and Smith 1985). resulting sample sizes were 13 for set 1 and 11 for set 2. The probability parturition was estimated from a binomial birth model (Siniff *et al.* 1977) the equation

$$Xp = \frac{\sum P_i}{n},$$

ere P is years with pup for female$_i$ divided by total years female$_i$ was sent, n is the number of known females, and Xp is the probability of turition. Only known females present in three successive years were luded. If a female was determined to be pregnant because of the size and pe of her abdomen but was not seen attending a pup later, she was included he sample as having given birth.

## RESULTS

### Seasonal Use Patterns

Between 1982 and 1984 harbor seals were present throughout the year at astal locations but their relative abundance ashore varied seasonally with re seals hauled out during the breeding/molt period than during the nbreeding period (Table 1, 1982: $t = 5.4$, $df = 22$, $p < 0.001$; 1983: $t = 5.82$, $= 25$, $p < 0.001$). Maximum counts for the coastal region occurred from ıy through July with 2,502 seals in June 1982 and 2,449 in May 1983. Pups re recorded at all coastal locations and were first observed in late March and t observed in late June. Pup numbers peaked during the first week of May, h 566 in 1982 and 527 in 1983 (Table 2). Pups represented 24% of all seals unted (2,339) in 1982 and 22% of those counted (2,449) in 1983.

**le 1. The average number of seals at sites in the Gulf of the Farallones, by season in 1982–83 and 1983–84.[1]**

| Year | Coastal Sites[2] | South Farallon Islands |
|---|---|---|
| 2–83 | | |
| reeding/molt | | |
| $\bar{x}$ | 1841.3 | 54.8 |
| SE | 131.1 | 2.3 |
| range | 1214–2502 | 36–78 |
| n | 11 | 24 |
| lonbreeding | | |
| $\bar{x}$ | 928.3 | 42.4 |
| SE | 91.0 | 2.2 |
| range | 501–1559 | 20–63 |
| n | 13 | 29 |
| 3–84 | | |
| reeding/molt | | |
| $\bar{x}$ | 1740.4 | 53.9 |
| SE | 115.8 | 4.2 |
| range | 1242–2449 | 13–90 |
| n | 11 | 21 |
| lonbreeding | | |
| $\bar{x}$ | 997.3 | 51.6 |
| SE | 115.8 | 4.2 |
| range | 621–1591 | 33–76 |
| n | 16 | 25 |

s the mean number of seals, SE is the standard error of the sample, and n is the sample size.
multaneous counts conducted at all sites except South Farallon Islands.

In contrast to the Point Reyes coastal locations, seasonal variation was seen SFI in 1982 but not in 1983 (Table 1, 1982: $t = 4.72$, $df = 53$, $p < 0.001$; 1983: $= 0.5$, $df = 45$, $p = 0.6$). No pups were observed on SFI during the 1982 or 83 breeding season.

**Table 2. Maximum number of pups counted in May (1982 and 1983) in the Gulf of the Farallones for each location; percentage is of the total pup count.**

| | LOCATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tomales Bay | Tomales Point | Point Reyes | Drakes Estero | Double Point | Dux-bury Reef | Bolinas Lagoon | South Farallons | Total |
| 1982 | | | | | | | | | |
| Total | 58 | 135 | 19 | 170 | 263 | 1 | 17 | 0 | 566 |
| Percentage | 10.3 | 23.9 | 3.4 | 30.0 | 46.5 | 0.2 | 3.0 | | |
| 1983 | | | | | | | | | |
| Total | 45 | 122 | 0 | 122 | 262 | 3 | 17 | 0 | 527 |
| Percentage | 8.5 | 22.8 | 0 | 23.2 | 49.7 | 0.6 | 3.2 | | |

### *Double Point*

Monthly variation in numbers of seals at Double Point was typical of other coastal sites, with more seals hauled out in the breeding/molt season (Figure 2). Maximum counts occurred in April, May, and June; counts declined from August through November before increasing again in late winter and early spring.

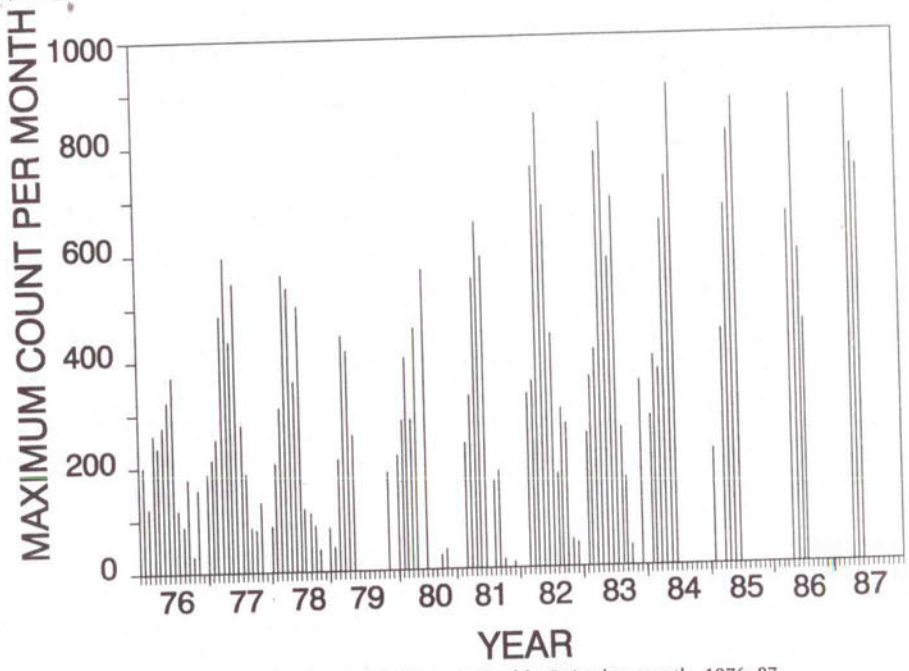
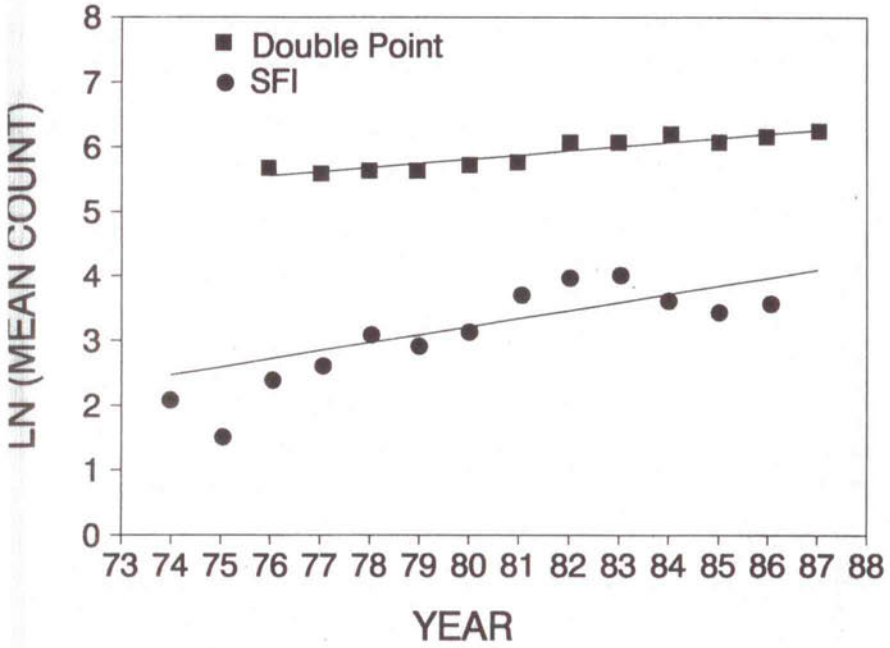



FIGURE 2. Maximum counts of seals onshore at Double Point by month, 1976–87.

Pups were initially seen in late March or early April; maximum pup counts occurred consistently during the first two weeks of May. Nearly half of all pups in the study area occurred at Double Point, 46.5% in 1982 and 49.7% in 1983, the only years when pups were counted at all sites (Table 2). Pups accounted for an average of 32.2% ($SE = 0.7$, $n = 12$) of all seals counted at Double Point during the breeding season between 1976 and 1987.

## Increase in Relative Abundance of Seals

The abundance of seals at both Double Point and SFI during the breeding molt period increased slowly from 1976 through 1987 (Figure 3). Over the ntire time period of study, the average number counted at Double Point oubled between 1976 (208) and 1987 (443) and quadrupled at SFI between 974 (8) and 1986 (37); however, both groups grew at the same rate (Double oint: slope = 0.076, $R^2$ = 0.88, SFI: slope = 0.17, $R^2$ = 0.71; parallel slopes: = 7.0, df1 = 1, df2 = 21, p > 0.05). Despite the overall increase during the reeding season at SFI, only 21 pups were seen there between 1974 and 1987, nd only 4 were observed in April or May.




GURE 3. Population growth rate of seals at Double Point between 1976 and 1987.

## Reproductive Rates

In the first three-year set of data on female pupping at Double Point, a total f 13 females (present all three years) were observed with pups during the first ear, 1977. Eleven were observed with pups in the second year, yielding a onditional frequency of parturition of 0.85. The proportion that gave birth all ree years for this set was 0.77. In the second set, 11 females (present all three ears) were seen with pups in 1982, and all were resighted with pups in 1983. his yielded a conditional frequency of parturition of 1.0; the proportion that ave birth all three years was 0.82. Both sets indicated that once having given irth, a female was very likely to give birth in a successive year. The probability f parturition in any year of the select group returning to Double Point was 0.89 or set 1 and 0.92 for set 2.

## DISCUSSION

The relative abundance of harbor seals varied seasonally within the Gulf of the Farallones between 1982–3 and 1983–4 with the exception of SFI in 1983. We suspect that the increase in abundance during the breeding/molt season at Point Reyes coastal locations is related to seals moving from other areas to Point Reyes to breed and to changes in daily haul-out patterns (Allen *et al.* 1985, Stewart 1984, Yochem, Stewart, DeLong, and DeMaster 1987). Seasonal movement was demonstrated by 4 of 17 radio-tagged, adult seals that moved out of the Point Reyes region from Drakes Estero during the fall in 1985 and returned the following breeding season (Miller 1988). Seals may emigrate to Point Reyes from southern San Mateo County haul-out sites from where Slater and Markowitz (1983) believed that adult females departed during the breeding season, a trend also observed at Año Nuevo Island (San Mateo Co.; Le Boeuf and Bonnell 1980). In Oregon, Brown and Mate (1983) speculated that harbor seals moved seasonally between coastal haul-out sites and estuarine ones in response to breeding and feeding preferences, and Roffe and Mate (1984) showed a correlation between harbor seal abundance and migration of salmonid fish in the Rogue River. Congregations of harbor seal nursery herds are also known in other regions (Knudtson 1977, Brown and Mate 1983, Slater and Markowitz 1983). Site fidelity of individual female harbor seals over multiple breeding seasons, though, has not been reported.

The ratio of pups to total animals at Double Point during the breeding season was higher (32.2%) than the 22–24% figures reported for Netarts and Tillamook Bays, Oregon (Brown and Mate 1983), and for sites in British Columbia (20%; Bigg 1969). Our estimates of parturition for females at Double Point may be biased because seals were not randomly selected; however, our figures for the fertility of harbor seals are similar to those of Boulva and McLaren (1979) who calculated a rate for known-age females of 0.79 at age 6, and 0.94 at age 7 and older. Though we were unable to determine the age of our seals, annual rates were similar over the two 3-year sets except for 1984 when the proportion of known females seen with pup declined to 0.61 from a prior average of 0.87 (SE = 0.01, n = 5). A strong climatic El Nino-Southern Oscillation event may have been a factor in this decline since it appeared to have affected the feeding habits and haul-out patterns of harbor seals in southern California (Yochem 1987, Stewart, Antonelis, DeLong, and Yochem 1988).

Data presented here for Double Point and SFI compared to earlier data (Carlisle and Aplin 1966, 1971) suggest an increase in harbor seal abundance in the Gulf of the Farallones over the past decade. Reproductive success may explain, in part, the increase in relative abundance seen at Double Point; however, the increase at SFI is probably a result of immigration because few pups have been seen there. SFI may be a resting area for migrating, nonbreeding animals; Payne and Schneider (1984) suggested that dispersing juvenile harbor seals accounted for increased abundance at a winter haul-out site in Massachusetts. Stewart *et al.* (1988) also observed a high rate of increase in the number of harbor seals on San Miguel Island, California, between 1973 and 1986 and suggested that immigration was partly responsible.

Changes in mortality rates and in sex and age composition may too have affected the abundance of seals onshore. Seals have been incidentally killed in set gill net fisheries in central California since the early 1980s (P. Wild, Calif. Dep. Fish and Game, Monterey, Calif., pers. commun.); however, the effect of these fisheries on seal population growth rate is uncertain. Changes in age structure could modify seasonal and annual variation in haul-out behavior. In harbor seals, *Phoca vitulina vitulina,* of Orkney, Scotland, Thompson (1987) described sexual and age related differences in molt completion dates and suggested these differences may influence peak abundance onshore for each age class.

The population increase may also be a response to lessened disturbance resulting from expanded public awareness, park/refuge status, and the Marine Mammal Protection Act of 1972 (see also Loughlin 1978), or to a shifting of seals in the region because of habitat loss in San Francisco Bay and at coastal sites in San Mateo County (Bartholomew 1949, Paulbitsky 1975, Slater and Markowitz 1983).

Our results provide information on long-term trends in the relative abundance of seals and indicate that the Gulf of the Farallones, a small region of the state, may support a large concentration of the state's reproductive population. To explain these trends in distribution and abundance or to derive estimates of absolute abundance and of survivorship require additional long-term study involving marked individuals of known age.

## ACKNOWLEDGMENTS

Financial support for this project was contributed by the Farallon National Wildlife Refuge, Marin County Department of Parks and Recreation, Marine Mammal Commission, National Marine Fisheries Service, Point Reyes Bird Observatory (PRBO), Point Reyes National Seashore, and Marine and Estuarine Division of the National Oceanic and Atmospheric Administration. Logistical support was provided by the Oceanic Society (Farallon Patrol) and U.S. Coast Guard (12th District). Assistants in the field were F. and R. Allen, C. Connors, C. Cutler, C. Depkin, J. Evens, L. Fry, C. Poulsen, S. Peaslee, A. Rovetta, D. Shuford, B. Stewart, S. Trivelpiece, J. Young, and many PRBO biologists including R. Boekelheide, H. Carter, P. Henderson, R. LeValley, J. Lewis, T. McElroy, S. Morrell, and C. Strong. D. Miller and D. Hanan, California Department of Fish and Game, provided information from aerial surveys. We especially appreciate the comments of R. Barrett, P. Boveng, D. DeMaster, G. Fellers, N. Smith, B. Stewart, and two anonymous reviewers. Finally, we are grateful to D. F. Miller, P. Gogan, R. E. Jones, and R. Risebrough for advice and encouragement. This is PRBO Contribution number 295.

## LITERATURE CITED

Ainley, D. G., H. R. Huber, R. P. Henderson, and T. J. Lewis. 1977. Studies on marine mammals at the Farallon Islands, California, 1970–1975. N.T.I.S. No. PB-274-046.

Allen, S. G., D. G. Ainley, G. W. Page and C. A. Ribic. 1985. The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. Fish. Bull., 82:493–500.

Bartholomew, G. A. 1949. A census of harbor seals in San Francisco Bay. J. Mamm., 30:34–35.

Bigg, M. A. 1969. The harbor seal in British Columbia. Fish. Res. Board Can. Bull., 172:1–33.

Boulva, J., and I. A. McLaren. 1979. Biology of the harbor seal, *Phoca vitulina,* in eastern Canada. Bull. Fish. Res. Bd., Can., 200:1–24.

Brown, R. F., and B. R. Mate. 1983. Abundance, movements, and feeding habits of harbor seals, *Phoca vitulina* at Netarts and Tillamook Bays, Oregon. U.S. Fish Bull. 81:291–301.

Carlisle, J. G., and J. A. Aplin. 1966. Sea lion census for 1965 including counts of other California pinnipeds. Calif Fish and Game, 52:119–120.

_____, and J. A. Aplin. 1971. Sea lion census for 1970 including counts of other California pinnipeds. Calif Fish and Game, 57:124–126.

Fancher L. 1979. The distribution, population dynamics, and behavior of the harbor seal, *Phoca vitulina richards* in south San Francisco Bay, California. Unpubl. M.S. Thesis, Calif. State Univ., Hayward, CA. 109pp.

Frey, H. W., and J. A. Aplin. 1970. Sea lion census for 1969, including counts of other pinnipeds. Calif. Fish and Game, 56:130–133.

Knudtson, P. M. 1977. Observations on the breeding behavior of the harbor seal in Humboldt Bay, California Calif. Fish and Game, 63:66–70.

Le Boeuf, B. J., and M. L. Bonnell. 1980. Pinnipeds of the California islands; abundance and distribution. Pp 475–493 in P. M. Power, ed. The California Islands: Proceedings of a multidisciplinary symposium. Haagan Printing, Santa Barbara.

Loughlin, T. R. 1978. Harbor seals in and adjacent to Humboldt Bay, California. Calif. Fish and Game, 64:127–132

McLaren, I. A., and T. G. Smith. 1985. Population ecology of seals: retrospective and prospective views. Mar Mamm. Sci. 1:54–83.

Miller, S. A. 1988. [S. G. Allen]. Movement and activity patterns of harbor seals at the Point Reyes Peninsula California. M.S. Thesis, Univ. of Calif., Berkeley, CA. 70pp.

Norušis, M. J. 1986. SPSS/PC+ for the IBM PC/XT/AT. SPSS Inc., Chicago.

Paulbitski, P. A. 1975. The seals of Strawberry Spit. Pacific Discovery, 28:12–15.

Payne, P. M., and D. C. Schneider. 1984. Yearly changes in abundance of harbor seals, *Phoca vitulina,* at a winte haul-out site in Massachusetts. U. S. Fish Bull., 82:440–442.

Roffe, T. J., and B. R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. Wildl. Manage., 48:1262–1274.

Scammon, C. M. 1968. The marine mammals of the northwestern coast of North America. Dover Publications New York. 319pp.

Siniff, D. B., D. P. DeMaster, and R. J. Hofman. 1977. An analysis of the dynamics of a Weddell seal populatior Ecol. Mono., 47:319–335.

Slater, L. M., and H. Markowitz. 1983. Spring population trends in *Phoca vitulina richardi* in two central Californi coastal areas. Calif. Fish and Game, 69: 217–226.

Stewart, B. S. 1984. Diurnal hauling patterns of harbor seals at San Miguel Island, California. J. Wildl. Manage 48:1459–1461.

_____, G. A. Antonelis, Jr., R. L. DeLong, and P. K. Yochem. 1988. Abundance of harbor seals on Sa Miguel Island, California, 1927 through 1986. Bull. Southern Acad. Sci., 87:39–43.

Thompson, P. M. 1987. The effect of seasonal changes in behavior on the distribution and abundance of commo seals, *Phoca vitulina,* in Orkney. Unpubl. Ph.D. Dissert., Univ. of Aberdeen, England. 167pp.

Weisberg, S. 1980. Applied linear regression. Wiley, New York. 283pp.

Yochem, P. K. 1987. Haul-out patterns and site fidelity of harbor seals at San Nicolas and San Miguel Islands California. M. S. Thesis, San Diego State Univ., San Diego. 89pp.

_____, B. S. Stewart, R. L. DeLong, and D. P. DeMaster. 1987. Diel haul-out patterns and site fidelity o harbor seals (*Phoca vitulina richardsi*) on San Miguel Island, California in Autumn. Mar. Mamm. Sci 3:323–332.

90 80474