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DIEL HAUL-OUT PATTERNS AND SITE FIDELITY OF HARBOR SEALS (*PHOCA VITULINA RICHARDSI*) ON SAN MIGUEL ISLAND, CALIFORNIA, IN AUTUMN

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ABSTRACT

We studied the haul-out patterns and movements of harbor seals (*Phoca vitulina richardsi*) on San Miguel Island, California, from 23 October through 6 December 1982 by attaching a radio transmitter to each of 18 seals and monitoring their presence ashore with continuously scanning receivers. Seals hauled out at all hours although, on average, the largest proportion of tagged seals was ashore between 1300 and 1500 h. Median durations of haul-out bouts of individual seals ranged from 4.7 to 21.8 h; 81% of all haul-out bouts were less than 12 h and 3% were longer than 24 h. Eighty-one percent of the seals that were resighted at least twice used only the sites where they were tagged; two seals used two sites and one seal used three. Most seals were hauled out on fewer than 51% of the days sampled. On average, about 41% of tagged seals hauled out each day whereas an average of about 19% was hauled out during peak afternoon hours. Using telemetry data to correct a count of 412 seals made during an aerial survey, we estimated absolute abundance at about 2,168 seals; a modified Peterson mark-recapture model produced an estimate of about 1,445 seals.

Key words: pinnipedia, harbor seals, haul-out patterns, Southern California Channel Islands, San Miguel Island, radiotelemetry.

Numbers of harbor seals (*Phoca vitulina richardsi*) ashore on the Southern California Channel Islands vary seasonally, with the fewest ashore in December and the most ashore in late May and June, when seals are molting (Stewart 1981, 1984; Stewart and Yochem 1984). Using time-lapse photography, Stewart (1981, 1984) found that the number of seals ashore on San Miguel Island, at all seasons, was lowest in the morning, increased to a peak in early afternoon, and decreased towards sunset. Although tide height did not influence the timing of peak haul-out at most sites, where haul-out space was available during all tides, it did influence the number of seals ashore during afternoon peak hours (Stewart 1981).

We report here the results of a radiotelemetry study of harbor seals on San Miguel Island in autumn 1982. The objectives were to examine the frequency and duration of haul-out bouts, and the movements among haul-out sites of individual harbor seals; with that information and census data, we estimated the absolute number of harbor seals that were using San Miguel Island.

Materials and Methods

We captured, using hoop nets, 18 seals at four sites on San Miguel Island (34°02'N, 120°22'W; Fig. 1) either by crawling to within several meters of

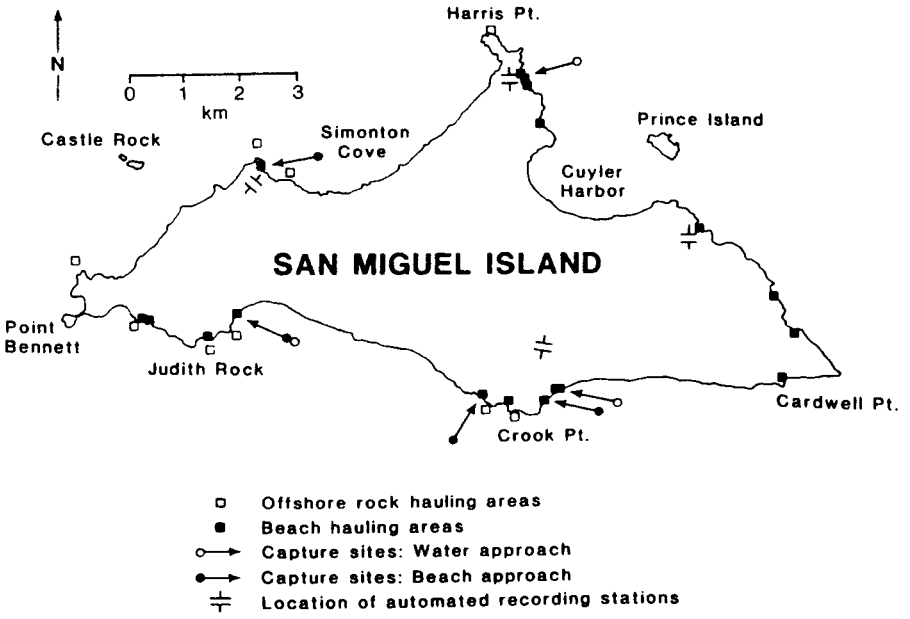

Figure 1. Harbor seal haul-out areas and capture sites on San Miguel Island.

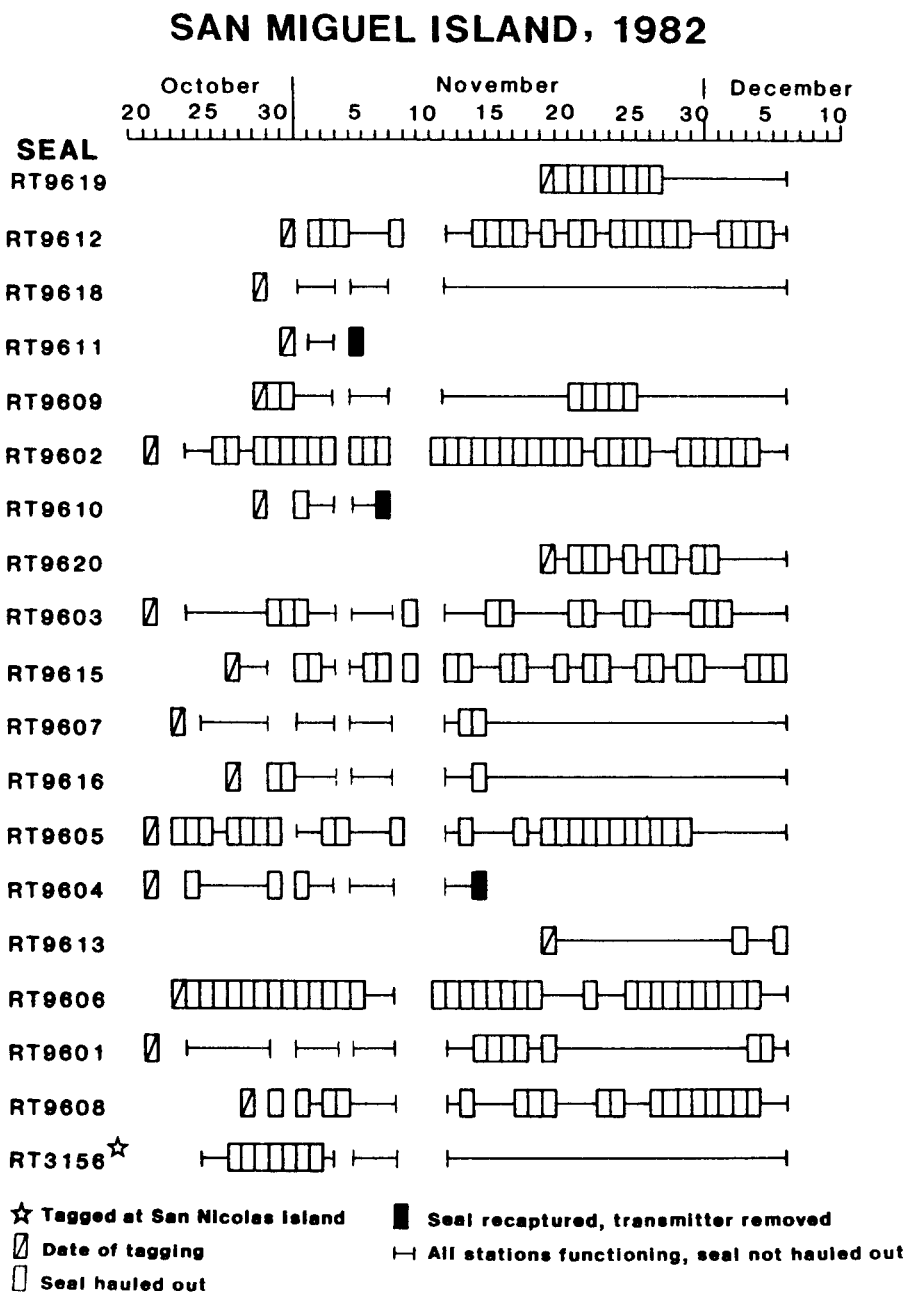

Figure 2. Daily presence of harbor seals on San Miguel Island in autumn, 1982.

Table 1. Location and elapsed time from capture of first resights of radio-tagged seals on San Miguel Island (OH = Otter Harbor, CK = Crook Point, TB = Tyler Bight, HS = Harris Point, HF = Hoffman Point).

Seal	Tagging site	Date tagged	Date of first resight	Location of first resight	Number of days after tagging before resighting
9601	CK	21 Oct	13 Nov	CK	22
9602	CK	21 Oct	26 Oct	CK	4
9603	CK	21 Oct	30 Oct	CK	8
9604	HS	21 Oct	24 Oct	HS	2
9605	HS	21 Oct	23 Oct	HS	1
9606	CK	22 Oct	23 Oct	CK	0
9607	TB	22 Oct	13 Nov	OH	21
9608	CK–TB	27 Oct	29 Oct	CK	1
9609	OH	29 Oct	29 Oct	HF	0
9610	OH	29 Oct	1 Nov	HF	2
9611	OH	31 Oct	5 Nov	HF	4
9612	OH	31 Oct	2 Nov	CK	1
9613	OH	19 Nov	3 Dec	OH	13
9615	OH	27 Oct	1 Nov	OH	4
9616	OH	27 Oct	30 Oct	OH	2
9618	CK	29 Oct	Not seen again		
9619	OH	19 Nov	20 Nov	OH	0
9620	OH	19 Nov	21 Nov	OH	1

them from concealed locations on the beach, or by swimming ashore from a motor vessel anchored 400 m to 500 m offshore from the haul-out site. We physically restrained each seal and then glued a VHF transmitter (6.5 cm long, 2 cm diameter, 50 g) to its dorsal pelage using a quick-setting epoxy. Each transmitter operated at a unique frequency between 164 and 165 MHz and radio signals were detected only when seals were hauled out. Transmission range was about 4 to 7 km and expected transmitter life was about four months.

We established automated recording stations at sites overlooking the major harbor seal haul-out areas at Hoffman Point, Harris Point, Otter Harbor and Crook Point (Fig. 1). Each station consisted of a programmable scanning receiver and a four element Yagi antenna connected to an Esterline Angus 20 channel event recorder. The entire system was powered by a 12-volt deep discharge marine battery. Except for a few days (*see* Figs. 2, 3) each haul-out site was monitored for the presence of radio-tagged seals automatically and continuously from 23 October 1982 through 6 December 1982. Each frequency in a receiver's memory was monitored for 32 sec each time that frequency was scanned. Because transmitter pulse rates varied from 40 to 80 pulses per min, scan intervals of 32 sec were sufficient to detect a seal if it was hauled out. Each frequency was

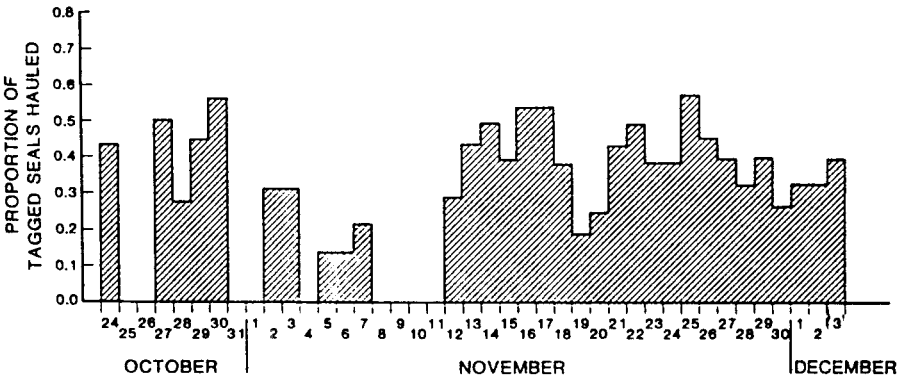

Figure 3. Proportion of radio-tagged seals hauled out at San Miguel Island by date (proportions are not presented for the dates 25, 26, 31 October, 1, 4, 8, 9, 10, 11 November because not all monitoring stations were operating on those dates).

scanned 6 to 15 times per h, depending on the number of frequencies being scanned. We placed a reference transmitter near each site to test for system malfunction.

We visited each site at least once every seven days to recharge batteries and service the event recorders. When we visited a haul-out site we searched for tagged seals for one to several hours to confirm that all transmitters were functioning.

On 11 November 1982 we surveyed, by air in a Cessna 337 Skymaster, all haul-out sites on San Miguel and Santa Rosa islands to document the number of seals ashore. We photographed seals that were hauled out at each site using a 35-mm camera (hand held) with a 75–210-mm telephoto lens and high speed color film. Counts of seals were made later from projected imagery. We determined the presence of radio-tagged seals at each site during those surveys using a portable scanning receiver attached to a four element Yagi antenna which was clamped to the aircraft's wing strut. On 1 December, we made an additional survey for radio-tagged seals at haul-out sites on Santa Rosa Island by circumnavigating the island in a 12-m motor vessel.

Results

One of 18 radio-tagged seals was not resighted, either visually or by telemetry, during the study. Sixteen seals were resighted at least twice and 13 of those hauled out only at the sites where they were captured. Two seals used two sites and one seal used three, although each seal hauled out most often at its tagging site. All seals that hauled out at more than one site were first resighted at locations other than where they were tagged.

Three seals hauled out within one day of tagging whereas most others were absent for one to four days (Table 1). Two seals, which each used only one site, were absent from the island for more than 20 d after being tagged (Table 1, Fig. 2).

Table 2. Proportion of radio-tagged harbor seals hauled out during one-hour intervals

One-hour interval	Mean proportion of seals hauled out	Standard error
0000–0100	.13	.02
0100–0200	.13	.01
0200–0300	.14	.02
0300–0400	.14	.01
0400–0500	.14	.01
0500–0600	.14	.01
0600–0700 (sunrise)	.14	.01
0700–0800	.14	.01
0800–0900	.15	.01
0900–1000	.16	.02
1000–1100	.16	.01
1100–1200	.17	.02
1200–1300	.18	.01
1300–1400	.19	.01
1400–1500	.19	.01
1500–1600	.18	.01
1600–1700	.16	.01
1700–1800 (sunset)	.15	.02
1800–1900	.13	.02
1900–2000	.11	.02
2000–2100	.12	.02
2100–2200	.11	.01
2200–2300	.11	.02
2300–0000	.11	.01

Most seals (14 of 17) were hauled out on fewer than 51% of the days sampled (Fig. 3) and, on average, a seal hauled out on 37% (range 4% to 75%, SE = .02%) of the days. An average of 41% (range 14% to 60%, SE = .03%) of seals was hauled out each day. The percentage hauled out each day during any one-hour period was much smaller, varying from 11% to 19% with the greatest percentage ashore between 1300 and 1500 h (Table 2).

On average, about 11% to 14% of the radio-tagged seals were hauled out during one-hour periods at night (1800 to 0600 h) while about 14% to 19% were hauled out each hour during the day (0600–1800 h; Table 2). Seven of 17 radio-tagged seals were hauled out most often at night while six were hauled out most often during the day; there were no obvious preferences among the other four seals and the times of captures (between 1030 and 1730) did not explain the differences in haul-out behavior (Yochem 1987). Nearly as many haul-out bouts began at night (46%) as during the day (54%). Thirty-four percent of all haul-out bouts began between 0800 and 1300 h (Table 3). The median duration of all haul-out bouts was 6 h (range = 1 to 30 h); most (81%) were less than 12 h long and few (3%) were longer than 24 h (Fig. 4). The

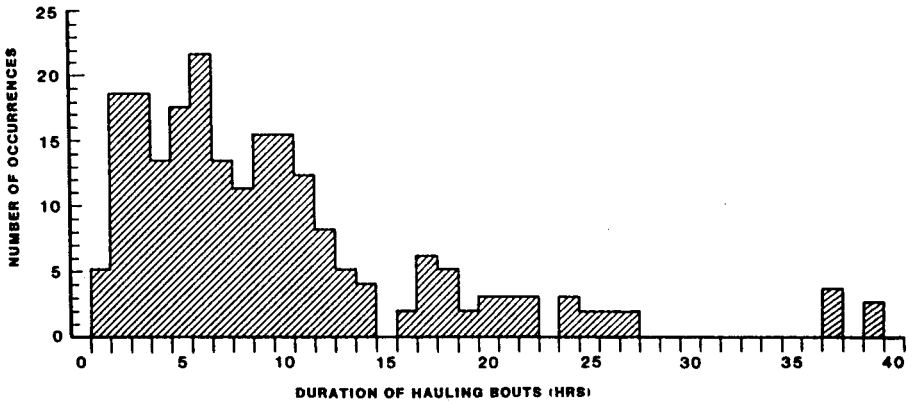

Figure 4. Frequency distribution of haul-out bout duration of harbor seals on San Miguel Island in autumn.

time at which a haul-out bout began had no apparent influence on its duration (Kruskal-Wallis one-way ANOVA, $P > .10$).

On 11 November between 1330 and 1400 h we counted 412 seals ashore on San Miguel Island. Using the telemetry data for seals hauled out during one-

Table 3. Haul-out bout onset time and duration.

Hour of onset of haul-out bout	Number of bouts	Median duration (hours)	Range (hours)
0000–0100	19	6	1–37
0100–0200	5	3	1–12
0200–0300	5	8	2–12
0300–0400	3	3	2–17
0400–0500	6	4	2–5
0500–0600	10	10	4–17
0600–0700	7	6	2–12
0700–0800	7	5	2–14
0800–0900	12	9.5	3–26
0900–1000	10	10	1–26
1000–1100	12	7	3–21
1100–1200	12	6	2–24
1200–1300	17	6	2–22
1300–1400	8	10	5–37
1400–1500	4	4	2–39
1500–1600	3	2	1–19
1600–1700	5	5	2–14
1700–1800	3	17	13–17
1800–1900	2	21	18–24
1900–2000	9	9	3–20
2000–2100	11	6	2–10
2100–2200	7	8	3–10
2200–2300	6	5	2–9
2300–0000	3	4	4–7

hour intervals (Table 2), we estimate that there were about 2,168 (95% confidence interval = 1,791 to 2,747) harbor seals using San Miguel Island then. Three of 14 radio-tagged seals were hauled out at the time of our survey; a modified Peterson mark-recapture model (Caughley 1977:142–143) yields a second estimate of 1,445 (SE = 643) seals.

Discussion

Although we found that most seals were faithful to one haul-out site on San Miguel Island, we cannot exclude the possibility that some, or all, may have been hauled out at sites on other Channel Islands or on the California mainland when they were absent from San Miguel Island. We did not observe any radio-tagged seals at Santa Rosa Island (about 5.3 km east of San Miguel Island) during our aerial or boat surveys. However, one juvenile male that was tagged at San Nicolas Island (33°15'N, 119°30'W) on 8 May 1982, and that regularly used only one site when it hauled out there through early June (Stewart and Yochem 1983), was observed hauled out on San Miguel Island from 3 November through 7 November. This seal was seen again on San Nicolas Island in spring 1983 (Yochem and Stewart 1985). These observations suggest that some inter-seasonal movement of seals among the Southern California Channel Islands does occur. Pacific harbor seals in other areas have been reported to use two or more haul-out sites up to 192 km apart (*e.g.*, Divinyi 1971, Brown 1981, Pitcher and McAllister 1981, Brown and Mate 1983, Beach *et al.* 1985, Herder 1986, Yochem 1987). Most of the long distance movements were inter-seasonal or inter-annual whereas shorter distance movements between sites were apparently intra-seasonal. Except for those few observations, patterns of dispersal and migration (if migrations do occur) of Pacific harbor seals are unknown.

Our data suggest that disturbance during tagging may prompt some seals to relocate to new sites (Table 1). Of the seals that hauled out at more than one site, nearly all appeared at the second site immediately after being tagged. However, 12 of 17 seals did not move to other sites immediately after being tagged and 11 of those 12 continued to use only the sites at which they were tagged. Pitcher and McAllister (1981) reported that most seals radio-tagged at Tugidak Island, Alaska, were loyal to specific haul-out sites in summer. Those authors suggested, however, that capture, handling, and attachment of radio transmitters may have affected haul-out patterns or site use, or both, of some seals and may have accounted for the relocations of some seals to areas away from the tagging sites. Additional studies of identifiable undisturbed seals (*i.e.*, controls) are needed to test hypotheses about the effects of human disturbance on harbor seal haul-out patterns.

Stewart (1981) found that few harbor seals were ashore on San Miguel Island in early morning and late evening, suggesting that few, if any, seals were ashore at night. Our findings indicate, however, that significant numbers of seals are ashore at night, at least in autumn. Furthermore, some seals apparently prefer to haul out at night while others prefer to haul out during the day (Yochem

1987). These findings have obvious ramifications for determining absolute abundance of seals from counts made during the day.

Sullivan (1979) suggested that harbor seals in northern California spent an average of 44% of their "daily activity budgets" hauled out but he did not specify whether this was a seasonal or annual average. We found that when a seal hauled out on San Miguel Island in autumn it spent an average of about 8.9 h, or 37% (range 19% to 65%, SE = .03%), of each 24-h period ashore. The difference between harbor seals in northern California and on San Miguel island, if real, may be related to season of data collection, habitat influences on behavior, or the age and sex composition of our sample.

Our data on the proportion of seals ashore during one-hour intervals agree with earlier findings at San Miguel Island that the greatest number of seals is ashore in early afternoon (Stewart 1984). Stewart (1981) derived correction factors to estimate daily peak haul-out numbers from counts made at non-peak times of day. However, such derived estimates measure only relative abundance as seals do not haul out every day (Fig. 2) and all seals that do haul out on a particular day are not ashore during peak haul-out hours (Table 2).

Whether the data which we present on proportions of seals ashore each hour (Table 2) can be used to estimate absolute abundance from census data depends on at least two assumptions. The first is that the age and sex composition of our sample of radio-tagged seals accurately represented the age and sex composition of the population. This may not have been true as most (13) were young males. Furthermore, our observations at San Miguel and San Nicolas islands (*e.g.*, Yochem 1987) suggest that the sex and age composition of seals ashore varies seasonally.

The second assumption is that the proportion (daily or hourly) of the population which is hauled out is consistent among seasons and years. Data from San Nicolas Island suggest, however, that these proportions vary seasonally, and perhaps annually, in response to changes in the environment (Yochem and Stewart 1985, Yochem 1987).

Therefore, estimates of absolute abundance of harbor seals at the Southern California Channel Islands using proportional correction factors should be made cautiously until those assumptions can be adequately tested. Furthermore, applying such correction factors to harbor seal populations in other areas may be inappropriate without making preliminary studies of haul-out behavior there. Geographic variations in habitat, in prey availability, distribution and abundance and in levels of human disturbance are likely to influence harbor seal haul-out patterns and time budgets.

Clearly, additional studies are needed to test these assumptions and to refine methods of estimation of absolute abundance of harbor seals at the Southern California Channel Islands and in other parts of the species' range.

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Literature Cited

Beach, R. J., A. C. Geiger, S. J. Jeffries, S. D. Treacy and B. L. Troutman. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980–1982. NWAFC Processed Report 85-04, NMFS, NWAFC, Seattle, WA. 316 pp.

Brown, R. F. 1981. Abundance, movements, and feeding habits of the harbor seal, *Phoca vitulina,* at Netarts Bay, Oregon. M.S. thesis, Oregon State University, Corvallis, OR. 69 pp.

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. Fishery Bulletin 81:291–301.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, NY. 234 pp.

Divinyi, C. A. 1971. Growth and movements of a known-age harbor seal. Journal of Mammalogy 52:824.

Herder, M. J. 1986. Seasonal movements and hauling site fidelity of harbor seals, *Phoca vitulina richardsi,* tagged at the Klamath River, California. M.A. thesis, Humboldt State University, Arcata, CA. 52 pp.

Pitcher, K. W., and D. C. McAllister. 1981. Movements and haulout behavior of radio-tagged harbor seals, *Phoca vitulina.* Canadian Field-Naturalist 95:292–297.

Stewart, B. S. 1981. Seasonal abundance, distribution, and ecology of the harbor seal (*Phoca vitulina richardsi*) on San Miguel Island, California. M.S. thesis, San Diego State University, San Diego, CA. 66 pp.

Stewart, B. S. 1984. Diurnal hauling patterns of harbor seals at San Miguel Island, California. Journal of Wildlife Management 48:1459–1461.

Stewart, B. S., and P. K. Yochem. 1983. Radiotelemetry studies of hauling patterns, movements, and site fidelity of harbor seals (*Phoca vitulina richardsi*) at San Nicolas and San Miguel islands, California, 1982. HSWRI Technical Report 83-152. HMRI, 1700 South Shores Road, San Diego, CA 92109. 54 pp.

Stewart, B. S., and P. K. Yochem. 1984. Seasonal abundance of pinnipeds at San Nicolas Island, California, 1980–1982. Bulletin of the Southern California Academy of Sciences 83:121–132.

Sullivan, R. M. 1979. Behavior and ecology of harbor seals, *Phoca vitulina,* along the open coast of northern California. M.S. thesis, Humboldt State University, Arcata, CA. 115 pp.

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 University, San Diego, CA. 89 pp.

Yochem, P. K., and B. S. Stewart. 1985. Radiotelemetry studies of hauling patterns, movements and site fidelity of harbor seals (*Phoca vitulina richardsi*) at San Nicolas Island, California, 1983. HMRI Technical Report 86-189. HMRI, 1700 South Shores Road, San Diego, CA 92109. 37 pp.

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