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Pregnancy and parturition rates of harbor seals in Monterey Bay, California

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PREGNANCY AND PARTURITION RATES OF HARBOR SEALS IN MONTEREY BAY, CALIFORNIA

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ABSTRACT

PREGNANCY AND PARTURITION RATES OF HARBOR SEALS IN MONTEREY BAY, CA

By Denise J. Greig

Reproductive rates of the harbor seal (Phoca vitulina) have not been documented previously in central California. The objectives were to test progesterone and estrogen as predictors of pregnancy in the Pacific harbor seal (*Phoca vitulina richardsi*) and to calculate pregnancy and parturition rates for seals in Monterey Bay, California. Seals were captured in Elkhorn Slough, California from September 1997 through March 2000. Seals were weighed, measured, and flipper tagged. Blood samples were drawn for hormone analysis and unique tags were attached to the pelage of the head to monitor adult females until the pupping season. Females with progesterone concentrations greater than 26nmol/L (7ng/ml) had a 95% probability of being pregnant. Estimated pregnancy rate based on progesterone concentration was 90% (35 out of 39) and parturition rate was 82% (32 out of 39). Mass of female seals increased during winter, decreased during summer, but was not a good indicator of pregnancy.

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Introduction

The Pacific harbor seal (*Phoca vitulina richardsi*) is a coastal pinniped, common throughout its range from Alaska to Mexico. Harbor seals forage in near shore waters but come ashore for rest and parturition. Females spend a greater proportion of time ashore during spring and summer when they give birth, nurse their pups, and molt (Hanan 1996). After molt, however, more time is spent at sea, presumably foraging and rebuilding fat stores for the next pupping season (Allen and others 1989). Females can live for 29 years, attain sexual maturity between 2 and 5 years of age, and give birth annually to a single pup (Bigg 1969).

Pacific harbor seals typically travel short distances on a daily basis to forage, but are capable of traveling hundreds of kilometers (Allen and others 1987). For example, a weaned pup tagged at Pebble Beach, CA was located 218 km from its capture site (Lander 1998), and an adult female tagged at Point Reyes, CA was located 480 km from her capture site (Miller 1976). Diurnal movements were interpreted as a response to prey availability by Hanan (1996), who monitored 71 seals in southern CA and found they vacated their haulout sites daily with occasional weeklong absences. He postulated that daily trips were local feeding trips, whereas longer trips were either to deeper water or to other haulout sites. In Elkhorn Slough, CA, harbor seals generally came ashore during the daytime and vacated the slough at night (Oxman 1995). By triangulating positions of radio-tagged seals equipped with time depth recorders, Eguchi (1998) determined that adult harbor seals captured in Elkhorn Slough foraged mostly at night in northern Monterey Bay. Thirteen seals radio-tagged in the San Juan Islands, WA, however, had no diurnal patterns (Suryan and Harvey 1998).

Seasonal movements have been associated with reproduction. Roffe (1984) reported that females regularly observed at the Rogue River, Oregon, vacated the area just before the pupping season, presumably traveling to alternate pupping sites. Conversely, numbers of harbor seals at Point Reyes doubled during pupping season and molt compared with winter (Allen and others 1987). One female radio-tagged at Point Reyes traveled north to the Klamath River, whereas a second traveled south to Pacific Grove during the winter. Others remained near Point Reyes year round.

Understanding seasonal movements is important because female harbor seals and their pups are extremely vulnerable to human interaction during pupping and lactation when they spend extended periods of time ashore and at the interface of land and water (St Aubin 1990). Here, seals can be exposed to chemical disturbances such as oil spills and runoff, as well as physical disturbances from people, dogs and boats. Susceptibility to disturbance at a given location will vary depending on age, sex, time of year, and the individual. Chronic, long-term exposure to chemical disturbances may increase the incidence of disease among the population or lower rates of survival or fertility (McLaren 1990). It is difficult to determine factors affecting long-term shifts in populations, or know if these changes are normal variation. It also is difficult to separate anthropogenic effects from natural disturbance such as an El Nino or shift in prey assemblages. For this reason it is necessary to have good baseline information about demographic parameters.

To understand sensitivity of harbor seals to natural and anthropogenic changes in the environment, knowledge of female reproductive status (i.e. pregnant, non-pregnant, lactating, ovulating) and timing of the reproductive cycle is needed. Pregnancy and parturition rates are useful parameters of population health because the number of animals pregnant and the number of those who carry their pups to full term reflect maternal health and reproductive success of the population.

The reproductive cycle of harbor seals is highly synchronized, therefore, pupping occurs at approximately the same time every year within a given geographic location (Temte and others 1991; Jemison 1997). Females nurse their pups for 3 to 6 weeks, and come into estrus and mate soon after the pup is weaned. The fertilized zygote slows in development at the blastocyst stage (32-64 cells), and remains dormant for 2 to 2.5 months until implantation when development resumes at a normal rate. This reproductive delay is called embryonic diapause or delayed implantation. During delayed implantation, the blastocyst floats freely in the uterus (Atkinson 1997). After implantation, active gestation continues for 8 to 8.5 months (Bigg 1969).

Timing of pupping varies with latitude along the coast from Washington to Mexico, occurring earlier in the south (mid-March) and later in the north (early June, Temte and others 1991). Temte (1994) modeled the latitudinal variation in time of pupping among captive and wild seals and concluded that reproductive synchronization occurs just before blastocyst implantation and is triggered by photoperiod. By manipulating light exposure during delayed implantation, Temte (1994) delayed the time of pupping in 6 captive females.

Using the date of birth of harbor seals from Mexico to Washington, Temte (1994) calculated that the critical photoperiod that triggered implantation occurred 283 days (range 274 to 291days) before parturition with implantation occurring 255 to 270 days before birth. Because the reproductive cycle is synchronized via photoperiod at the time of implantation, females will begin active gestation at approximately the same time (within a few weeks of each other) at a given geographical location. If the time of pupping is known in a given location, then reproductive status can be inferred using time of year, but pregnancy rate and individual reproductive status (pregnant or non-pregnant) remain unknown.

Individual reproductive status traditionally was determined by killing animals and examining their reproductive tracts (Harrison 1960; Bigg 1969). Monitoring hormones in blood, urine, feces, or saliva, however, can provide an alternative, relatively non-invasive, method of obtaining reproductive status of individuals in wild populations. In particular, progesterone and estrogen have been used to detect ovulation and pregnancy in mammals. Ovulation usually is preceded by an increase in estrogen, and followed by an increase in progesterone. Progesterone production during this time is maintained by the corpus luteum that forms from the follicle of ovulation. If fertilization occurs, progesterone remains elevated and continues to increase throughout pregnancy, probably maintained by the corpus luteum and the placenta (Reijnders 1990). Estrogen also is produced during pregnancy with levels increasing as pregnancy progresses. Even if fertilization does not occur, progesterone concentrations remain elevated through a luteal phase before decreasing. Concentrations of both hormones then remain low in non-pregnant animals until estrogens increase before the next ovulation.

The length of the luteal phase varies with species, and in phocids, it may extend from the time of estrus until implantation. In captive harbor seals, where serial samples are more easily obtained, circulating concentrations of progesterone and estrogen increased at ovulation and were maintained at elevated levels throughout delayed implantation (Raeside and Ronald 1981). In females that ovulated, but did not become pregnant, these hormones began to decline around the time when the pregnant females implanted. This elevated progesterone concentration in a non-pregnant animal is referred to as pseudopregnancy (Atkinson 1997). In pregnant females, progesterone and estrogen increased steadily from implantation through active gestation (Raeside and Ronald 1981; Reijnders 1990).

Because the progesterone may be elevated from ovulation or pseudopregnancy, the use of progesterone concentration as a predictor of pregnancy is highly dependent on the reproductive synchrony of harbor seals. Wild female harbor seals in British Columbia only ovulated during the reproductive period, but males were in breeding condition March through November (Bigg 1969). In Scotland, mating behavior among subadults occurred before the pupping period (Venables and Venables 1957), however, Bishop (1967) suspected that subadult males were just practicing mating behaviors during this period. Nicholson (2000) observed subadult male harbor seals practicing copulatory behaviors with each other in Monterey Bay, CA. Harrison (1960) reported that three females collected in England ovulated two months earlier than other females in the area. These females were young and showed no evidence of previous pregnancy, leading him to conclude that "out of season" mating behavior usually occurs among younger animals and that adult females were synchronous in their timing of reproductive events.

Because of the increase in progesterone and estrogen in pregnant harbor seals during gestation and the reproductive synchrony of the harbor seal, seasonal hormone levels can be used to detect pregnancy in wild populations of harbor seals. In northern Europe, progesterone levels, standard length, and month of capture, were used to correctly predict pregnancy in the harbor seal (*Phoca vitulina vitulina*) 95.8% of the time and non-pregnancy 100% of the time (Gardiner and others 1996; Gardiner and others 1999).

Individual reproductive status has been linked to animal health and body condition. Mass of newborn harbor seals was correlated with maternal mass, body condition, and age (Bowen and others 1994; Ellis and others 2000). Ellis and others (2000) found that maternal age explained 54% of the variance in birth mass and maternal mass explained 20% of that variance. Reproductive parity, however, was more important than age in determining mass at birth, i.e., first time mothers gave birth to pups with less mass.

Reproductive status also has been linked with condition at implantation. Failure of primiparous Antarctic fur seals (*Arctocephalus gazella*) to pup in the following season may have reflected their inability to regain body condition before implantation (Lunn and others 1994). Boyd and others (1999) suggested that pinniped females can terminate pregnancy before implantation if they lack the resources to sustain a pregnancy. Condition during pregnancy, however, is less well documented. Harbor seals of both sexes captured in Alaska had thicker blubber layers during winter and less fat during periods of pupping and molt (Pitcher 1986), and females captured during late pregnancy averaged 1 cm greater blubber thickness than females captured during lactation (Bishop 1967).

The objectives were 1) to test progesterone and estrogen as predictors of pregnancy in Pacific harbor seals throughout the gestation period, 2) to calculate pregnancy rates and parturition rates for captured seals, and 3) to determine whether morphological measurements such as body mass could predict pregnancy. Body condition (mass/length) was tested as a predictor of pregnancy, and body condition adjusted for fetal and placental mass was used to examine female condition during pregnancy.

An elevated ratio of progesterone to estrogen was hypothesized to predict pregnancy during active gestation. No differences were expected between pregnancy and parturition rates, that is, seals which implanted were expected to carry their fetus to term. It was further hypothesized that pregnancy could be predicted using morphological measurements and body condition. Lastly, pregnant females were predicted to have greater body condition than non-pregnant females.

Methods

Elkhorn Slough (121.79° W, 36.80° N; Fig. 1) is a tidal estuary located in Monterey Bay, California. Harbor seals have used the slough as a resting site since the mid seventies (Harvey and others 1995), but the first harbor seal births were not recorded until 1991 (Osborn 1992). Pupping begins in the slough during early April and greatest numbers of births occur in early May. Using data from Temte (1994), females should implant in August and active gestation should occur from August/September through April.

Harbor seals (n=236) were captured from September 1997 through March 2000, 125 were female, of which, 89 were classified as adult (Table 1). Animals were captured using a seine net (Jeffries and others 1993) and brought to the beach where they were weighed and measured. Mass was determined within 0.25 kg using an electronic scale. Standard and curvilinear lengths and hip, midtrunk, and axillary girths were measured to the nearest cm. Blue cattle ear tags (Allflex, 101 Livestock, Salinas, California) with unique numbers were placed in the interdigital webbing of each rear flipper. Blood samples for hormone analysis were collected from the extradural vein using a spinal needle (3 ½ inch, 18 gauge, Becton Dickinson, Franklin Lakes, NJ) into an evacuated, heparinized tube. Blood was centrifuged within 5 hr of collection and the plasma was frozen.

Nine of the females were captured more than once: 5 of them were adults and had duplicate blood samples collected. An adult female harbor seal (HS 1384), that had been previously captured and tagged in Elkhorn slough on 15 June 1995 (flipper tag #345, Eguchi 1998), was admitted to The Marine Mammal Center, Sausalito, California on 31 May 2000 with trauma to the face and flipper. During rehabilitation, blood samples were obtained twice a month from October 2000 through December 2000.

To monitor movements, confirm pregnancy at parturition, and obtain birth dates of pups during the 1998/1999 season, potentially pregnant females were outfitted with orange plastic head tags with unique numbers (Sea Mammal Research Unit, St Andrews, Scotland). Pelage was cleaned with water and acetone and dried with compressed air. Tags were glued to the pelage with an industrial-grade cyanocrylite adhesive (Loctite 422, Rocky Hill, CT, Jeffries and others 1993) and placed on the top of the head to maximize visibility. Five head tags were attached to females in the fall (Sep/Oct 1998) and 8 in the spring (Feb/Mar 1999). Because harbor seals generally molt after lactation (Bishop 1967), it was expected that tags would remain on the animals through pregnancy, parturition, and lactation.

To increase chances of locating females with their pups during the 1999/2000 season, a VHF radio transmitter (Advanced Telemetry Systems (ATS), Isanti, MN) with a unique frequency and visual coding was glued to the head of adult females. Ten radio tags and 4 head tags were deployed in fall (Oct-Dec 1999) and 7 radio tags in spring (Feb-Mar 2000). Individual females were identified by their 2 digit head tag number or their 3 digit radio tag frequency (Table 2).

In 1999 and 2000, numbers of harbor seals in Elkhorn Slough were counted every 1 to 4 days from the end of March to the beginning of June. A boat with an outboard motor was used to survey each site in the slough (Fig. 1), and numbers ashore were counted using 7x50 binoculars and a 45x spotting scope. During counts, females with head or radio tags were located and birth dates estimated for their pups.

In addition to surveys within Elkhorn Slough, tagged animals were located along the coast from land and air. When mother-pup pairs were located from shore and visually identified, a birth date was estimated for the pup. A VHF receiver (ATS) and hand-held antenna (Telonics, Mesa, AZ) were used to search for animals from land. Most searches were conducted from Moss Landing south to Point Lobos (121.95° W, 36.52° N, ~37 km from Elkhorn Slough) or from Moss Landing north to Año Nuevo (122.34° W, 37.12° N, ~60 km from Elkhorn Slough). Flights were conducted by Bob VanWagenen (Ecoscan Resource Data, Watsonville, California), and surveys were flown in a Cessna 180 high-winged aircraft. A 4-element yagi antenna was attached to each wing strut and connected via coaxial cables to a receiver (ATS) and switch box (Telonics) inside the aircraft (Lander 1998). Four surveys were flown between 11 April and 12 May covering an area from Morro Bay (120.88° W, 35.37° N) to Humboldt Bay (124.24° W, 40.76° N).

From November 1999 through May 2000, a DCC II datalogger (Model D5041; ATS), VHF receiver, and antenna mounted in Elkhorn Slough continuously recorded the presence of animals in the slough. The data logger recorded the number of pulses detected for each frequency during 30 second intervals. Because there were varying levels of interference for different frequencies, an animal was considered present and hauled-out in the slough if two or more consecutive records for its frequency had the correct number of pulses (e.g. 29 to 31 for tags with 60 pulses/min; 22 or 23 for tags with 45 pulses/min).

To assess activity patterns in the slough, data were analyzed for 8 radio-tagged seals that regularly used the slough. When a seal was detected twice within 15 minutes and the pulse rate was 29 to 31 for one of the records, the animal was considered to be ashore for some part of that hour. The number of radio-tagged seals ashore was determined for each hour and the hourly counts averaged for each month. Activity patterns were analyzed from 7 December 1999 to 29 February 2000. Because the coaxial cable connecting the antenna to the datalogger was partially dislodged and the connection unknowingly compromised sometime in March or April, hourly resolution was no longer possible. Data collected by the DCC during later months only were used to detect a seal's presence or absence in the slough on a given day.

Progesterone analyses were conducted in July of 1999 and 2000. Progesterone concentration in duplicate 0.1-ml samples of plasma was measured directly, without extraction, using a radioimmunoassay (RIA) kit from Diagnostic Products Corporation (DPC, Los Angeles, California). Designed for detecting progesterone in humans, the kit was validated for harbor seal plasma using the standards provided and a pool of plasma from male harbor seals captured in Elkhorn Slough. Linearity was tested with increasing volumes of a pooled sample: volumes of 50, 100, 200, and 300 μl yielded concentrations of 2.1, 4.8, 7.5, and 8.8 ng/ml ($y=0.026x+1.5903$, $r^2=0.9269$). Parallelism was tested by running 50 μl of a low concentration pool sample with 50 μl of each of the standards. The lines were parallel between 2 and 40ng/ml.

Each July, an assay was conducted with samples collected during the previous gestation period. Samples with concentrations greater than the standard curve were assayed again at lower dilutions. Mean non-specific binding was 1.08 % ± 0.16 SE (n=4), and mean sensitivity was 0.009 ng/ml ± 0.003 ng/ml SE (n=4). Interassay coefficient of variation (CV) from a sample of pooled plasma run in each of the assays was 8%. Intraassay CVs for duplicate samples averaged 4% and all were <10%. Results from the different assays and years were considered comparable.

Analyses of estrogen were conducted in July 1999 on samples from the 1998/1999 season. An RIA, modified for marine mammals by Dr. Shannon Atkinson (Alaska SeaLife Center, Seward, AK), was used to detect estrone in harbor seal plasma. Duplicate 0.1-ml plasma samples were extracted in diethyl ether (1:10 volume: volume) and the extract assayed using 1,2,6,7-[^{3}H] estrone tracer and an estrone antisera raised in sheep. Mean non-specific binding was 4.2% ± 1.56 SE (n=2), and mean sensitivity was 0.156 pg/ml ± 0.17 pg/ml SE (n=2). Linearity was tested with increasing volumes of a pool sample: volumes of 100, 400, and 600 µl yielded concentrations of 5.7, 17.1 and 33 pg/ml ($y=0.0535x+0.9897$, $r^2=0.9551$).

Analysis of Variance (ANOVA) was used to test for differences in mean mass or mean standard length of females greater than 60 kg among each of the three years (1997/1998, 1998/1999, 1999/2000). Because there were no differences among the three years in mass (n=39, p=0.312, df=38) or standard length (n=39, p=0.763, df=38), data from the three years were pooled.

A t-test was used to test whether mean concentrations of progesterone from 12 known pregnant animals (observed with a nursing pup) were different from 12 non-pregnant animals (either captured between parturition and ovulation, or monitored throughout gestation and never observed pregnant or nursing a pup). Progesterone concentrations from the 24 animals with known pregnancy status were modeled in a binary logistic regression to generate an equation for assigning pregnancy status to the rest of the females based on their progesterone concentrations.

Pregnancy rate was calculated as the number of pregnant female harbor seals divided by the total number of adult females captured during the gestation period (September - March). Thirty-nine females of more than 60 kg were used for this calculation because, based on progesterone concentration, the lightest pregnant female was 60.5 kg (Fig. 2) and the inclusion of lighter, probably younger, females would have biased the pregnancy rate. One female was twice the mass (142.5 kg) of some of the other females, and her progesterone concentration (455 nmol/L) was almost double that of the next greatest. She was considered an outlier and excluded from all figures.

A binary logistic regression model using data from all 46 adult females captured between September and March was used to determine if pregnancy (as assigned by progesterone concentration) could be predicted by mass and time of capture; time of capture was separated into early (September-December) or late (February-March) gestation. No females were captured during January.

An index of condition was calculated by plotting mass over length for all female seals and fitting a curve to the data (Fig. 3). Mass predicted by the curve was subtracted from the animal's actual mass to obtain a condition value. A binary logistic regression using data from all 46 adult females was used to test whether pregnant animals could be identified by this mass to length ratio.

To test for differences in condition between females greater than 60 kg captured during early gestation and those during late gestation, predictions of mass for pregnant females were reduced to compensate for the increases in fetal and placental masses through gestation (Guinet and others 1998). Because prenatal growth in harbor seals occurs linearly for 7.8 months (McLaren 1993), fetal mass was calculated by regressing the average mass at birth for April (10kg) back to an assumed mass of zero in September. Active prenatal growth should begin about 223 days before pupping (Bigg 1969; Boulva and others 1979; McLaren 1993), thus counting back from mid-April, active fetal growth was expected to begin mid-September. Placental mass was calculated as 10% of the fetal mass (Guinet and others 1998). These values were subtracted from the original mass of the pregnant females based on their month of capture. Finally, the mass predicted by the curve (Fig. 3) was subtracted from the adjusted mass to obtain a condition value. A t-test was used to test for differences in mean condition of pregnant animals between early and late gestation and between pregnant and non-pregnant animals during late gestation. Because all females captured during early gestation were pregnant (based on progesterone concentration), pregnant and non-pregnant females could not be compared for this time.

Mass, mass/length, and adjusted condition were plotted over time to examine changes in female morphology during different phases of the reproductive cycle.

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS, version 10.0 for Windows).

Results

In Elkhorn Slough, pupping began in early April with greatest pup counts in the middle of May (Fig. 4). All tagged females located with their pups gave birth between 9 April and 28 April.

During the 1998/1999 season, four seals (Nos. 66, 67, 72, 73) were located with pups in Elkhorn Slough. Three seals (Nos. 65, 70, 71) vacated the slough before pupping and were not relocated. Three others (Nos. 63, 68, 69) remained in the slough, but were never seen with a pup, and the other 2 seals (Nos. 61, 62) were not located regularly.

Only one head-tagged seal (#64) was located outside of the slough. She was observed to the south at Pebble Beach Golf Course, Pebble Beach (121.94° W, 36.56° N). Number 64 may have had a pup to the south, but was not observed nursing because she was located late in the pupping season. After pupping and the molt, four tags (No. 64, 67, 68, 72) washed ashore and were found on beaches between Monterey and Santa Cruz, California: 3 were returned in late June and one in early July.

During the 1999/2000 season, 5 females gave birth and nursed their pups in the slough (Nos. 503, 510, 717, 735, 884), and 3 were located to the south with pups (#360 at Fanshell Beach and #595 and #615 off Cypress Golf Course, Fig. 5). Five were absent from the slough during pupping and lactation (Nos. 041, 563, 754, 855, 40). From the length of their absences and their physical appearance before and after they returned to the slough, I suspected that they gave birth at an alternate location; #855 was heard from the air and from land (but not visually identified) at Lopez Point, 100 km south of

Elkhorn slough, and #041 was observed in Mowry Slough in San Francisco Bay, 200 km to the north (SFSU Harbor Seal Project, pers. comm.) a few days before she returned to the slough.

One head tag washed ashore near Santa Cruz and was returned in December 1999 (#18). Three other animals probably lost their tags; observed tags were barely attached to the pelage in the spring (Nos. 20, 772, 795), thus it was not known if they remained in the slough throughout pupping. Two seals were observed in the slough, but without pups (# 460, and #772 until 25 April 2000) and a final 3 were not located regularly (Nos. 430, 822, 31).

The 4 tagged females that gave birth in Elkhorn slough in 1999 were identified (via their flipper tags) in the slough with pups in 2000. Number 63, who was present in the slough without a pup in 1999, also was observed in the slough with a pup in 2000. Thirteen additional animals flipper tagged in Elkhorn Slough between 1995 and 1999 (this study, Eguchi 1998) were sighted in spring 2000 with pups: 6 were observed at Pebble Beach, and 7 in the slough.

Use of the slough by radio-tagged seals varied among individuals and among months. Percentage of days spent in the slough varied for each individual, but 7 of 8 seals spent fewer days in the slough in February than in December or January (Table 3). Seals rested in the slough at all hours, but the greatest percentages of radio-tagged seals were ashore during the middle of the day. This mid-day peak was more prominent in December and January than in February (Table 4).

Four females, that gave birth in the slough and were monitored from tagging through weaning (Nos. 884, 735, 510, 503), were regularly present in the slough with absences ranging from 1 to 29 days. A few days before parturition these females were present in the slough everyday. Consecutive days present in the slough after giving birth averaged 24 days (range 19 to 30 days). Five animals present in the slough before giving birth (855, 754, 563, 041, #40) were absent an average of 40 days (range 37 to 52 days) during pupping and returned to the slough. Lactation and weaning, therefore, lasted somewhere between 24 and 40 days (3.5 to 6.0 weeks) although probably closer to 3-4 weeks as females who traveled elsewhere for pupping had to travel there and back.

Mean progesterone concentrations were significantly different between 12 pregnant and 12 non-pregnant adult female harbor seals ($t=5.171$, $df=22$, $p=0.000$). The probability of pregnancy was calculated using the following equation:

$$\hat{Y} = \frac{e^{(P*1.424-34.284)}}{(1+e^{(P*1.424-34.284)})}$$

where $\hat{Y}$= the probability of pregnancy and P= progesterone concentration in nmol/L.

Using this model, female harbor seals with progesterone concentrations >26 nmol/L (8.2 ng/ml) had a 95% probability of being pregnant, whereas female harbor seals with progesterone concentrations <22 nmol/L (6.9 ng/ml) had a 95% probability of not being pregnant. Female seals were then classified as pregnant or non-pregnant based on their progesterone concentration: 35 out of 39 (90%) of adult females caught between September and March were pregnant (Fig. 6). Mean progesterone concentration for pregnant females was 66 nmol/L (SE=1.2, n=19) during early gestation and 140 nmol/L

(SE=7.3, n=15) during late gestation (excluding the female with 455nmol/L). Estrone concentrations were correlated with progesterone concentrations, but estrone concentrations were not useful indicators of pregnancy by themselves (Fig. 7).

Three animals classified as pregnant based on progesterone concentration (Nos. 63, 460, 772) were observed without pups in the spring. Whether these three animals were pregnant or pseudopregnant at the time of capture is not known. Including these three in the calculation, parturition rates were 82% (32 out of 39) for females greater than 60kg, captured between September and March.

Mass and time of capture (early or late gestation time) used in a logistic regression model correctly identified pregnancy status 93.5% of the time (Table 5). The model classified pregnancy using the following equation:

$$S = -0.146m - 3.119t + 10.989$$

where m=mass (kg) and t=time of capture (September - December=1 and February - March=0).

A negative S value indicated pregnancy. Using this equation harbor seals greater than 53.9kg during early gestation or 75.3kg during late gestation could have been pregnant. The probability of pregnancy was calculated using the following equation:

$$\hat{Y} = \frac{e^{(-0.146m-3.119t+10.989)}}{(1+e^{(-0.146m-3.119t+10.989)})}$$

Using this model, during early gestation female harbor seals with mass >74 kg had a 95% probability of being pregnant and females with a mass <33 kg had a 95% probability of not being pregnant. During late gestation, female seals with mass >74kg had a 95% probability of being pregnant and female seals with mass <55kg had a 95% probability of not being pregnant.

Condition (unadjusted mass:length ratio) was not useful for predicting pregnancy. It classified all 46 adult females as pregnant.

Among pregnant females, mean adjusted condition was greater for animals captured during late gestation than early gestation ($t=-2.894$, $df=33$, $p=0.007$). Among females captured during late gestation, there was no difference in mean adjusted condition between pregnant and non-pregnant seals ($t=0.371$, $df=17$, $p=0.722$).

Females with the least mass were captured in the summer (May - August). Female mass increased from September through March (Fig. 8). Condition followed the same trend even after mass was adjusted for the fetal and placental mass (Fig. 9). In the spring, female body condition was greater than the average whereas, from May through October, females exhibited poorer body condition (Fig. 9). This trend was not observed in males whose mass remained relatively constant throughout the year (Fig. 10).

Discussion

Activity of adult female harbor seals in Elkhorn Slough during December through February was consistent with individuals studied at Point Reyes (Allen and others 1987); female harbor seals at Point Reyes traveled to distant sites and were gone for extended periods of time (Allen and others 1987). Harbor seal number 041, eventually located in San Francisco Bay, followed this pattern as she was absent from the slough for several months (Fig. 11). Eight of 10 females captured during the fall were present regularly in the slough during the study period, with most absences lasting less than 7 days. These animals were probably at sea foraging when absent from the slough, and behaved similarly to harbor seals considered resident at Point Reyes (Allen and others 1987).

A diurnal activity pattern was evident, but not pronounced, among the radio-tagged seals, with more seals present at mid-day than midnight (Table 3). In Orkney, Scotland, harbor seals had a marked diurnal haul-out pattern during the summer, but no diurnal pattern during the winter (Thompson and others 1989). Thompson and others (1989) observed that males came ashore regularly during the molt, but females spent greater time ashore during pupping and lactation and spent greater time at sea during the molt. Year-round data would be required to determine whether a similar pattern exists in the slough.

Female attendance at pupping sites in the slough increased just before birth as females returned to the same location daily (Fig. 11), consistent with behavior reported for pregnant harbor seals in Scotland (Thompson and others 1989; 1994). Because of their increased presence ashore, pregnant, radio-tagged females should have been easy to locate at their pupping locations. Because some of the seals could not be located, it is possible that they either ranged further than expected or lost their radio tags.

Four of the radio-tagged seals vacated Elkhorn Slough during the pupping season and were not visually relocated until they returned to the slough 4 to 6 weeks later with the thin appearance of a seal that had lactated. One of the 4 was located during aerial surveys south of Big Sur (100 km from Elkhorn Slough) and another observed in south San Francisco Bay (200 km from Elkhorn Slough). The other two may have traveled even further north or south for pupping. All 4 returned to the slough before signs of ovulation were observed in the hormone data, implying that they probably would have come into estrus and mated in the slough. Estrus in harbor seals begins a few days after they wean their pup (Bigg and Fisher 1974), and elevated progesterone concentrations after lactation indicated that some females from the slough may have ovulated by 1 June (Fig. 6).

Giving birth and mating at separate geographic locations may increase gene flow among the harbor seal population and explain part of the high genetic variability among harbor seals. There is greater genetic difference between harbor seals from Monterey Bay and the Washington coast than between harbor seals from Monterey Bay and the Oregon coast (Lamont and others 1996), but studies of gene flow within California have not been conducted.

There are problems associated with characterizing individual reproductive status based on hormone levels in blood plasma. Analysis of circulating concentrations of progesterone and estrone are an easily obtained measure of hormonal status, but results can be misleading because they may not accurately reflect the physiological activity of these hormones in the body. Hormone activity can be affected by the rate of hormone secretion, plasma binding capacity, the rate of conversion to metabolites, or the density of cellular receptors (St Aubin 2001). Using a single hormone sample from an individual to characterize reproductive status also has the potential for error because progesterone is released into the body in pulses and pulse length and amplitude vary among species. For the purposes of this study it was assumed that the number of seals captured would provide a range of possible values that would cover the highs and lows in circulating progesterone concentration.

Because pseudopregnancy did not extend through implantation in captive harbor seals (Reijnders 1990), I classified animals with elevated progesterone levels during the time of active gestation as pregnant. A non-pregnant female harbor seal (HS1384) in captivity from June through the end of the year, however, had an elevated progesterone concentration in October before levels decreased in November indicating that pseudopregnancy among non-pregnant females may be possible during the first few months when pregnant females are gestating. There is no method of quantifying the extent of this potential error on the calculation of pregnancy rate, but progesterone should not be used to detect pregnancy for future studies during the first two to three months of active gestation.

Two animals captured in fall (Nos. 63, 772), that were pregnant based on progesterone concentration, did not appear pregnant in the spring and were never located with pups. It is possible that these two females were pregnant, but resorbed their fetuses after they were captured, or that they were pseudopregnant. A similar phenomenon was described for a captive gray seal (*Halichoerus grypus*) where progesterone was monitored throughout the year (Seely 1990). Progesterone concentration of this gray seal was elevated during the first three months of gestation, but then returned to low levels at the same time an x-ray confirmed she was not pregnant. It is not known whether she was pregnant or pseudopregnant during those early months. A third animal, captured in the slough in the spring (#460), and classified as pregnant based on her progesterone level, did not appear pregnant. She remained in the slough during the pupping season and was never seen with a pup. It is possible that her elevated progesterone was an indicator of early ovulation. She also had a shark wound on her side and may have aborted her fetus because of trauma.

Reproductive failure has been reported in the harbor seal based on the examination of reproductive tracts. One female harbor seal collected during active gestation had resorbed her embryo, but still had fetal membranes in her uterus (Bigg 1969). Three other seals collected during late gestation had large corpora albicantia that implied a pregnancy had been maintained after implantation, but there were no signs of pregnancy in the uteri. These females might have exhibited elevated progesterone levels until the fetus died or was expelled.

In gray seals there were no changes in pregnancy rates during gestation (Boyd 1985), but given the possibility of reproductive failure, pregnancy rate might be greater among harbor seals during early gestation than later in the gestation period. Pregnancy rate during late gestation should approach parturition rate, but it would be necessary to validate pregnancy results at the time of capture to test this hypothesis. Ultrasound is one technique which might be useful for interpreting progesterone results at the time of capture.

Pregnancy rate can vary with maternal age. Bigg (1969) reported reproductive failure in 7 of 35 females aged 2 to 7 years and 1 of 31 females aged 8 to 28 years. Boyd (1985) found pregnancy rate was less among gray seals in younger age classes (age classes 2+, 3+ and 4+) where many females were pregnant for the first time. According to age-specific morphology data collected by Bishop (1967), mass and standard length of female harbor seals collected in Alaska increased linearly until the age of 5 years before becoming asymptotic. Age was not determined for animals captured in Elkhorn Slough, but, the average mass and length of females in this study was consistent with animals aged 5 years or older. Some of the smaller females, however, may have been younger and pregnant for the first time. For example, one female (# 63) with elevated progesterone concentration and no pup, was one of the smaller females and may have been young and ovulating for the first time. She was observed in the slough with a pup the following year.

Pregnancy rates have been reported for harbor seals around the world. In the Kattegat-Skagerrak, pregnancy rate was 92% (68 of 74 females), however between the ages of 5 and 25, pregnancy rate was 98% (60 out of 61, Harkonen and Heide-Jorgensen 1990). In Norway, pregnancy rate was 90% (21 out of 23) for females 8 years and greater, whereas rates were 47% (8 out of 17) for females 4 to 7 years of age (Bjorge 1992). In eastern Canada, pregnancy rate was 95% (35 out of 37) for female harbor seals

7 years and greater (Boulva and others 1979), and in British Columbia, pregnancy rate was 80% (28 out of 35) for females 2 to 7 years old and 97% (30 out of 31) for females 8 to 28 years old (Bigg 1969). Bigg (1969) then used randomly sampled adult females from his dataset to calculate an average adult fecundity of 88%.

There was no difference between the 90% (35 out of 39) pregnancy rate in this study and the overall rates for all other studies (2x2 contingency test, $p>0.05$, $v=1$, $x^2=3.841$). Using a chi square 2x2 contingency test with the current sample size (Zar 1996), a difference in pregnancy rate over time would not be detected unless pregnancy rate decreased to 79% (31 out of 39) or increased to 97% (38 out of 39). Increasing the sample size would increase the power to detect a statistical difference in pregnancy rates between geographic locations and between years.

Maternal age, mass, experience, and condition have been correlated with pup mass and weaning success in phocids and otariids (Bowen and others 1994; Lunn and others 1994; Ellis and others 2000). Differences between pregnant and non-pregnant females during the course of gestation, however, have rarely been examined. Possible reasons for this gap in knowledge may be the inability to detect pregnancy, difficulties capturing animals during the winter when they spend less time ashore, lack of non-pregnant animals among a species with a 90% pregnancy rate, and logistics of conducting field work in cold temperatures with reduced daylight.

Regardless of reproductive status, females captured in the slough during gestation had a greater mass than those captured during lactation, estrus, and delayed implantation. The condition data followed the same trend and was not a good predictor of pregnancy during gestation. Regardless of whether they are carrying a fetus, females may cycle through a winter period of greater mass and a summer period of lesser mass. Boyd (1984) found a correlation between body condition of gray seals and implantation time: females that increased in body condition earlier in the year, implanted earlier. Boyd and others (1999) proposed that metabolic rate and the timing of the reproductive cycle were regulated by the same mechanism. All females may start gaining mass at the time of implantation regardless of reproductive status. Renouf and others (1993) proposed that metabolic rate varied seasonally in the harp seal (*Phoca groenlandica*), with animals gaining mass during winter even as they consumed less prey. Trumble and Castellini (pers. comm.) also found that mass in captive harbor seals did not vary directly with food intake.

The use of morphology to predict pregnancy was not reliable. The model basically set a cut-off mass for pregnancy which was able to predict the pregnant animals, but was not able to distinguish non-pregnant animals because these seals also increased in mass in the spring. Initially, mass and time of capture appeared to be a reasonable predictor of pregnancy (the model was correct 93.5% of the time), but results were biased by the low number of non-pregnant seals in the study. If numbers of non-pregnant animals were increased, predictive ability would have decreased.

Despite the pregnant appearance of females about a month before parturition, the mass:length condition index was not a good predictor of pregnancy. Although the index predicted which animals were pregnant, it was not able to distinguish non-pregnant animals because during the period of late pregnancy (February and March), non-pregnant females had body mass and condition comparable with pregnant females.

In conclusion, progesterone concentration was a reliable predictor of pregnancy during the last three months of pregnancy (February through April). Based on serial results from HS1384, progesterone concentration may not be a good predictor of pregnancy in early gestation (Aug through Oct). Progesterone concentration may be useful during these early months, however, for assessing whether a seal has ovulated because no immature seals had elevated progesterone concentrations during gestation (Fig. 2). Pregnancy rates can only be compared with parturition rates if animals are monitored from time of capture until parturition and if pregnancy is confirmed at the time of capture, preferably by a combination of progesterone and some other means of pregnancy evaluation such as ultrasound. The pregnancy rate in this study (90%) was consistent with pregnancy rates reported for harbor seals in British Columbia (88%, Bigg 1969), and progesterone concentrations provided useful information about individual reproductive status.

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Table 1. Capture date and site (D=Dairies, Di=Dikes, V=Vierras, SB=Seal Bend), flipper tag numbers (left and right hind flipper), sex, age class (P=pup, W=weaner, Y=yearling, S=subadult, A=adult), mass (kg), standard length (cm), and axillary girth (cm) of 236 harbor seals captured in Elkhorn Slough, CA from September 1997 through March 2001.

		Flipper tag number						
Date	Site	Left	Right	sex	Age	Mass	Girth	Length
9/4/97	D	445	445	F	A	44.1	101	117
9/4/97	D	446	446	F	P	14.5	58	82
9/4/97	D	444	444	F	P	20.5	66	90
9/4/97	D	12281	449	F	P	28.2	82	101
9/4/97	D	443	443	F	P	29.1		105
10/8/97	V		447	M	A	107.4	119	147
10/28/97	Di	450	450	M	A	48.2	90	123
10/28/97	Di	454	448	F	A	78.8	107	149
11/14/97	D	455	455	F	A	61.2	106	121
11/14/97	D	353	353	F	A	62.0	101	122
11/14/97	D	452	452	F	A	93.4	120	150
11/14/97	D	451	451	F	A	97.4	122	151
11/14/97	D	456	456	M	A	116.8	117	150
3/27/98	SB	467	467	F	A	53.0	100	120
3/27/98	SB	491	491	F	A	86.2	105	132
3/27/98	SB	475	475	F	A	87.6	105	140
3/27/98	SB	477	477	F	A	90.2	112	145
3/27/98	SB	476	476	F	A	95.5	113	139
3/27/98	SB	474	474	M	Y	23.2	77	97
3/27/98	SB	473	473	M	Y	26.0	79	101
4/7/98	D		P1	M	P	8.6	51	74
4/7/98	D		P2	M	P	9.0	47	63
4/17/98	D		457	M	A	41.8	92	124
4/17/98	D	490		M	A	53.2	98	132
4/17/98	D		478	F	A	59.4	95	127
4/17/98	D		483	F	A	59.6	99	134
4/17/98	D		484	F	A	61.4	105	129
4/17/98	D		348	F	A	64.6	108	135
4/17/98	D		486	M	A	68.4	98	127
4/17/98	D		485	F	A	73.4	93	142

		Flipper tag number						
Date	Site	Left	Right	sex	Age	Mass	Girth	Length
4/17/98	D		480	F	A	74.2	114	134
4/17/98	D		241	F	A	107.2	122	156
4/17/98	D	481	481	M	P	8.2	62	82
4/17/98	D	479	479	M	P	11.2	60	78
4/17/98	Di	482	482	M	P	14.8	63	83
4/28/98	Di	500	500	F	A	44.4	92	135
4/28/98	Di	495	495	F	A	46.4	89	121
4/28/98	Di	493	493	F	A	50.4	89	114
4/28/98	Di	497	497	F	A	53.2	97	133
4/28/98	Di	498	498	F	A	53.4	92	129
4/28/98	Di	492	492	F	A	74.8	103	119
4/28/98	Di	494	315	M	A	104.2	113	153
4/28/98	Di		348	F	A			
4/28/98	Di	502	502	M	P	8.0	47	70
4/28/98	Di		479	M	P	9.4	52	77
4/28/98	Di	503	503	F	Y	29.4	76	114
4/28/98	Di	499	499	M	Y	30.2	70	105
4/28/98	Di	501	501	F	Y	34.4	79	118
4/28/98	Di	491		F	Y	43.2	89	104
5/5/98	D	509	10294	F	S	39.8	91	117
5/5/98	V	504	504	F	A	51.2	91	129
5/5/98	D	512		F	A	61.8	96	140
5/5/98	D	516		F	A	67.8	96	148
5/5/98	D	511		F	A	68.0	99	144
5/5/98	D		515	F	A	70.0	104	140
5/5/98	D		513	F	P	22.2	75	85
5/5/98	V	506	506	M		33.0	80	116
5/5/98	V	507	507	F		37.0	81	118
5/5/98	V	508	508	F	Y	27.4	75	102
5/5/98	V	505	505	M	Y	32.4	80	105
5/12/98	Di		12223	F	A	37.8	75	113
5/12/98	V	520	520	M	A	55.0	96	134
5/12/98	Di		7	M	A	89.0		140
5/12/98	Di		4	M	A	97.4		145
5/12/98	Di	521	521	M	A	109.4		153
5/12/98	Di	8		F	P	22.8	71	88

Date	Site	Flipper tag number Left	Right	sex	Age	Mass	Girth	Length
5/12/98	Di	481	481	F	P	24.6	76	89
5/12/98	Di	5		M	P	30.2	78	91
5/12/98	Di	474	474	M	Y	28.6	75	92
5/21/98	Di	543	542	F	A	47.2	102	125
5/21/98	Di	553	552	F	A	60.8	98	126
5/21/98	Di	558	559	F	A	66.8	95	142
5/21/98	Di	541	540	M	A	71.6	94	118
5/21/98	Di	24	23	F	A	72.8	105	142
5/21/98	Di	550		F	A	74.2	103	143
5/21/98	Di	20	9	M	A	83.2		137
5/21/98	Di	22	21	F	P	15.6	67	77
5/21/98	Di	549	539	F	P	19.4	72	85
5/21/98	Di	537	25	F	P	23.2	77	94
6/10/98	Di	591	590	F	A	45.0	93	115
6/10/98	Di	584	585	F	A	54.4	98	130
6/10/98	Di	516	586	F	A	56.8	95	132
6/10/98	Di	587	588	F	A	59.0	93	143
8/8/98	Di	593	592	F	A	69.6	49	148
9/17/98	Di	597	598	F	A	40.0	81	116
9/17/98	Di	600	601	F	A	45.6	84	128
9/17/98	Di	596	365	M	A	93.6	106	153
10/15/98	Di	562	563	M	A	98.6	105	160
10/29/98	Di	711	713	F	A	65.8	92	135
10/29/98	Di	595	594	M	A	65.8	101	135
10/29/98	Di	703	704	M	A	68.7	107	145
10/29/98	Di	702	701	F	A	76.4	97	156
10/29/98	Di	568	569	F	A	82.0	94	145
11/19/98	Di	409	409	M	A	48.2	82	123
11/19/98	Di	564	565	M	A	101.8	114	158
12/10/98	V	706	705	M	A	51.4	96	115
12/10/98	V	604	605	M	A	59.2	90	132
12/10/98	V	303	303	M	A	81.6	116	139
12/10/98	V	567	566	M	A	86.2	112	141
12/10/98	V	589	599	M	A	95.8	120	156
12/10/98	V	603	602	M	A	110.8	112	151
1/11/99	V	407	727	M	A	55.8	99	127

Date	Site	Flipper tag number Left	Right	sex	Age	Mass	Girth	Length
1/11/99	V	709	725	M	A	77.4	116	137
1/11/99	V	710	358	M	A	85.6	115	135
1/11/99	V	717	565	M	A	97.6	107	150
1/11/99	V	716	726	M	A	146.2	119	163
2/22/99	D	730	731	F	A	61.4	98	128
2/22/99	D	720	719	F	A	80.4	98	134
2/22/99	D	715	718	F	A	80.6	107	129
2/22/99	D	737	736	F	A	100.6	108	140
2/22/99	D	723	724	F	A	107.2	100	142
2/22/99	D	722	721	F	A	116.4	120	133
2/22/99	D	735	734	M	S	41.4	89	107
2/22/99	D	733	732	M	S	41.8	92	111
3/12/99	D	707	708	F	A	91.0	100	141
3/12/99	Di	740	741	F	A	100.4	108	142
3/12/99	D	739	738	F	Y	28.4	85	101
3/12/99	D	728	729	?	Y	36.4	85	114
3/29/99	Di	743	744	M	A	90.8		149
3/29/99	Di	742	418	M	A	120.6		159
4/12/99	Di	748	749	M	P	10.0	51	73
4/12/99	Di	746	747	M	P	11.6	52	86
4/19/99	D	758	756	F	A	59.8	100	131
4/19/99	Di	761	762	F	A	69.0	98	129
4/19/99	D	755	757	F	A	77.2	125	140
4/19/99	Di	775	774	M	A	145.0		159
4/19/99	D	753	751	F	P	8.8	52	67
4/19/99	D	752	754	F	P	9.2	47	76
4/19/99	Di	759	760	F	P	21.2	67	71
4/26/99	Di	745	750	M	A	64.2	94	135
5/3/99	Di	778	777	M	A	69.6	96	125
5/3/99	Di	764	763	M	A	73.4	101	138
5/3/99	Di	776	773	M	A	93.6	98	143
5/3/99	Di	770	769	M	A	99.6	106	144
5/3/99	Di	768	767	M	A	137.0	130	166
5/3/99	Di	772	771	F	S	46.6	92	108
5/3/99	Di	766	765	M	Y	37.6	83	105
5/12/99	Di	778	777	M	A	55.8	93	120

		Flipper tag number						
Date	Site	Left	Right	sex	Age	Mass	Girth	Length
5/12/99	Di	798	797	F	P	21.4	69	82
5/12/99	Di	788	787	M	P	22.2	70	85
5/12/99	Di	784	783	F	P	23.6	73	81
5/12/99	Di	786	785	M	P	25.6	71	87
5/17/99	Di	800	799	F	A	66.8	85	135
5/17/99	Di	793	794	M	A	86.2	93	142
5/17/99	Di	781	782	M	A	92.4	98	147
5/17/99	Di	371	795	M	A	104.4	107	153
5/17/99	Di	791	792	M	A	105.6	116	149
5/24/99	Di	817	818	M	A	63.0	89	129
5/24/99	Di	788	787	M	P	22.8		
6/2/99	Di	825	823	F	A	48.9	89	137
6/2/99	Di	477	477	F	A	53.5	91	148
6/2/99	Di	833	842	F	A	59.4	97	140
6/2/99	Di	826	834	F	A	60.6	105	134
6/2/99	Di	841	840	F	A	64.6	99	146
6/2/99	Di	832	831	M	A	72.1	102	136
6/2/99	Di	843	844	M	A	76.0	108	149
6/2/99	Di	846	845	F	A	79.7	111	153
6/2/99	Di	815	816	M	A	82.4	103	158
6/2/99	Di	370	370	M	A	83.2	109	138
6/2/99	Di	550	827	F	A	89.2	110	150
6/2/99	Di	824	835	M	A	90.6	105	166
6/2/99	Di	814	828	M	A	109.9	117	158
6/2/99	Di		724	F	A			
6/2/99	Di	807	808	M	P	20.0	67	77
6/2/99	Di	784	783	F	P	24.6	79	81
6/2/99	Di	443	838	F	S	36.0	77	106
8/20/99	Di	849	850	M	A	86.2		
8/20/99	Di	852	851	F	S	42.2		
9/20/99	Di	870	839	F	A	43.2	84	119
9/20/99	Di	880	881	F	A	45.0	93	113
9/20/99	Di	490	866	M	A	61.6	98	131
9/20/99	Di	886	520	M	A	67.6	105	147
9/20/99	Di	865	860	M	A	71.8	111	142
9/20/99	Di	905	906	M	A	76.4	109	142

		Flipper tag number						
Date	Site	Left	Right	sex	Age	Mass	Girth	Length
9/20/99	Di	884	873	M	A	76.6	104	139
9/20/99	Di		861	M	A	100.2	112	159
9/20/99	Di	824		M	A	106.8	120	159
9/20/99	Di	791	792	M	A			
10/4/99	Di	867	869	F	W	24.0	71	88
10/4/99	Di	857	862	F	W	27.5	75	101
10/26/99	Di	887	888	F	A	51.0	95	114
10/26/99	Di	908	907	F	A	60.5	98	133
10/26/99	Di	890	475	F	A	71.0	106	125
10/26/99	Di	891	892	F	A	72.5	103	127
10/26/99	Di	879	882	F	A	80.0	106	135
10/26/99	Di	909	910	F	A	90.0	107	152
10/26/99	Di	878	877	F	P/Y	24.0	74	95
10/26/99	Di	911	912	F	S	34.0	82	110
10/26/99	Di	923	922	F	S	41.0	89	110
10/26/99	Di	874	876	M	S	45.5	91	114
10/26/99	Di	883	885	M	S	48.0	89	121
11/9/99	Di	913	889	F	A	75.5	102	137
11/15/99	Di	916	917	F	A	46.0	87	117
11/15/99	V	898	897	F	A	75.5	99	140
11/15/99	V	896	895	F	A	76.0	101	139
11/15/99	V	893	894	M	A	103.0	104	156
11/22/99	D	926	927	F	A	98.0	114	146
11/22/99	D	935	934	M	W	24.5	73	104
12/7/99	Di	918	919	F	A	77.5	110	141
12/7/99	Di	914	915	M	A	91.0	111	147
12/7/99	Di	550	827	F	A	109.0	121	149
12/7/99	Di	920	921	F	A	113.5	130	149
12/7/99	Di	766	900	M	S	73.0	92	108
2/14/00	SB	937	936	F	A	74.0	105	122
2/14/00	SB	945	944	F	A	82.0	105	130
2/14/00	SB	928	929	F	A	142.5	130	150
2/14/00	SB	949	948	M	S	71.0	102	132
2/14/00	SB	950	899	M	Y	29.5	84	92
2/14/00	SB	942	943	M	Y	37.5	86	108
2/14/00	SB	650	649	M	Y	41.0	92	108

Date	Site	Flipper tag number Left	Right	sex	Age	Mass	Girth	Length
2/24/00	D	924	925	M	S	53.5	97	126
3/1/00	Di	931	930	M	A	85.0	111	144
3/1/00	D	593	592	F	A	108.5	119	156
3/7/00	Di	628	635	M	A	59.5	98	135
3/7/00	Di	636	637	M	A	66.0	107	132
3/7/00	SB	631	630	F	A	67.0	110	124
3/7/00	Di	937?	938	M	A	88.0	107	150
3/7/00	Di	632	633	M	A	93.0	119	137
3/7/00	Di	940	945	M	A	110.5	114	160
3/7/00	Di	641	642	M	A	120.5	122	152
3/7/00	Di	946	629	M	S	53.0	98	130
3/7/00	Di	878	877	F	Y	17.0	81	92
3/7/00	Di	634	639	F	Y	32.0	77	103
3/7/00	Di	627	626	M	Y	36.5	79	105
3/10/00	D	638	640	M	A	55.5	98	129
3/10/00	Di	653	654	M	A	93.5	109	152
3/10/00	D	646	645	F	A	103.0	123	140
3/10/00	Di	259&652	259	M	A	114.5	110	164
3/10/00	D	941	273	F	A	115.0	120	153
3/10/00	Di	659	660	M	A	115.0	123	138
3/10/00	Di	643	644	F	Y	20.5	70	93
3/10/00	Di	648	647	M	Y	30.5	83	107
3/13/00	D	655	651	F	A	79.0	112	132
3/15/00	D	672	673	F	Y	33.5	73	102
3/15/00	D	665	664	M	Y	34.0	84	107

Table 2. Date of capture, flipper tag numbers (left and right hind flipper), head or radio tag visual ID, radio tag frequency, age class (P=pup, W=weaner, Y=yearling, S=subadult, A=adult), progesterone concentration (nmol/L), estrone concentration (pmol/L), and estimated birth date of their pup for 125 female harbor seals captured in Elkhorn Slough, CA.

Date	Left	Right	Visual ID	Frequency	Age	Prog	Estro	Bdate
9/4/97	445	445			A			
9/4/97	446	446			P			
9/4/97	444	444			P			
9/4/97	12281	449			P			
9/4/97	443	443			P			
10/28/97	454	448			A	82		
11/14/97	455	455			A	55		
11/14/97	353	353			A	75		
11/14/97	452	452			A	62		
11/14/97	451	451			A	81		
3/27/98	467	467			A	6	71	
3/27/98	491	491			A	107	356	
3/27/98	475	475			A	0		
3/27/98	477	477			A	99	359	
3/27/98	476	476			A	6	106	
4/17/98		478			A			
4/17/98		483			A			
4/17/98		484			A			
4/17/98		348			A	1	36	
4/17/98		485			A	3	69	
4/17/98		480			A	3	108	
4/17/98		241			A	147	560	
4/28/98	500	500			A	4	68	
4/28/98	495	495			A	2	6	
4/28/98	493	493			A	3	91	
4/28/98	497	497			A	3	112	
4/28/98	498	498			A	4	85	
4/28/98	492	492			A	130	218	
4/28/98		348			A			
4/28/98	503	503			Y	3	101	
4/28/98	501	501			Y			
4/28/98	491				Y			
5/5/98	509	10294			S	2	75	

Date	Left	Right	Visual ID	Frequency	Age	Prog	Estro	Bdate
5/5/98	504	504			A	1	45	
5/5/98	512				A	42	57	
5/5/98	516				A	49	107	
5/5/98	511				A	2	91	
5/5/98		515			A	3	74	
5/5/98		513			P			
5/5/98	507	507				3	37	
5/5/98	508	508			Y			
5/12/98		12223			A			
5/12/98	8				P			
5/12/98	481	481			P			
5/21/98	543	542			A			
5/21/98	553	552			A			
5/21/98	558	559			A			
5/21/98	24	23			A			
5/21/98	550				A			
5/21/98	22	21			P			
5/21/98	549	539			P			
5/21/98	537	25			P			
6/10/98	591	590			A	32	43	
6/10/98	584	585			A	1	24	
6/10/98	516	586			A	15	47	
6/10/98	587	588			A	61	32	
8/8/98	593	592			A	124		
9/17/98	597	598	61		A	9	5	
9/17/98	600	601	62		A	11	45	
10/29/98	711	713	63		A	60	57	
10/29/98	702	701	65		A	78	120	
10/29/98	568	569	64		A	46	87	
2/22/99	730	731	69		A	13	73	
2/22/99	720	719	71		A	89	247	
2/22/99	715	718	67		A	175	375	4/28/99
2/22/99	737	736	68		A	3	92	
2/22/99	723	724	70		A	58	156	
2/22/99	722	721	66		A	83	214	4/24/99
3/12/99	707	708	72		A	64	83	4/14/99
3/12/99	740	741	73		A	139	602	4/19/99
3/12/99	739	738			Y			
4/19/99	758	756			A	8	58	

Date	Left	Right	Visual ID	Frequency	Age	Prog	Estro	Bdate
4/19/99	761	762			A	4	66	
4/19/99	755	757			A	1	24	
4/19/99	753	751			P			
4/19/99	752	754			P			
4/19/99	759	760			P	0		
5/3/99	772	771			S	2	39	
5/12/99	798	797			P			
5/12/99	784	783			P			
5/17/99	800	799			A	3	31	
6/2/99	825	823			A	33	40	
6/2/99	477	477			A	5	36	
6/2/99	833	842			A	39	19	
6/2/99	826	834			A	36	81	
6/2/99	841	840			A	27	55	
6/2/99	846	845			A	29		
6/2/99	550	827			A	57		
6/2/99		724			A	26	61	
6/2/99	784	783			P			
6/2/99	443	838			S			
8/20/99	852	851			S			
9/20/99	870	839			A	10		
9/20/99	880	881			A	11		
10/4/99	867	869			W			
10/4/99	857	862			W			
10/26/99	887	888	18		A	12		
10/26/99	908	907	20		A	108		
10/26/99	890	475	o	164.735	A	36		4/18/00
10/26/99	891	892	3	164.595	A	58		4/23/00
10/26/99	879	882	1	164.822	A	98		
10/26/99	909	910	+	164.795	A	42		
10/26/99	878	877			P/Y			
10/26/99	911	912			S	8		
10/26/99	923	922			S	11		
11/9/99	913	889	4	164.615	A	46		4/24/00
11/15/99	916	917	31		A	2		
11/15/99	898	897	5	164.772	A	55		
11/15/99	896	895	7	164.717	A	36		4/22/00
11/22/99	926	927	2	164.041	A	71		
12/7/99	918	919	40		A	111		

Date	Left	Right	Visual ID	Frequency	Age	Prog	Estro	Bdate
12/7/99	550	827	9	164.755	A	58		
12/7/99	920	921	8	164.854	A	68		
2/14/00	937	936	11	164.503	A	237		4/19/00
2/14/00	945	944	dot	164.460	A	65		
2/14/00	928	929	78	164.430	A	455		
3/1/00	593	592	6	164.883	A	105		4/14/00
3/7/00	631	630			A	1		
3/7/00	878	877			Y			
3/7/00	634	639			Y			
3/10/00	646	645	29	164.563	A	169		
3/10/00	941	273	X	164.510	A	176		4/19/00
3/10/00	643	644			Y			
3/13/00	655	651	triangle	164.360	A	240		4/9/00
3/15/00	672	673			Y			

Table 3. Percentage of days 8 radio-tagged seals were ashore in Elkhorn Slough in December 1999, and January and February 2000.

Seal	Dec	Jan	Feb
595	96	77	48
615	61	55	38
717	52	55	48
735	100	100	97
754	83	84	76
772	57	55	83
795	78	71	45
855	96	90	79
x	78	73	64
SE	11.10	10.48	9.17

Table 4. Average percentage of radio-tagged females (n=8) ashore in Elkhorn Slough from Dec 9, 1999 to February 29, 2000 by month and time of day. Mean numbers of radio-tagged females hauled out in the slough per day were 6.2 (se=0.05) in Dec, 5.8 (se=0.06) in Jan, and 5.1 (se=0.05) in Feb. 0:00 covers the hour from 0:00 to 0:59.

Time	Dec	Jan	Feb
0:00	11	13	15
1:00	12	15	14
2:00	14	13	13
3:00	16	16	13
4:00	16	16	14
5:00	20	14	19
6:00	28	14	15
7:00	29	20	16
8:00	31	29	16
9:00	37	33	15
10:00	41	38	17
11:00	42	40	18
12:00	45	45	20
13:00	40	44	21
14:00	35	41	21
15:00	32	42	22
16:00	26	36	21
17:00	22	31	18
18:00	20	26	15
19:00	18	22	12
20:00	15	16	11
21:00	13	15	15
22:00	10	16	16
23:00	11	13	18

Table 5. Results of the binary logistic regression model testing mass and time of capture as predictors of pregnancy. P = pregnant and N= non-pregnant. Mass is in kg and Time is a catgegorical variable divided into early (captured from September-December) and late (captured February-March) in the gestation period.

	Predicted			
Observed	Pregnancy status			Percentage Correct
	P	N	Total	
P	34	1	35	97.1
N	2	9	11	81.8
Total	36	10	46	93.5

	Variables in equation	Model if term removed	
	β	Model Log likelihood	Significance of change
Mass	-0.146	-25.292	0.000
Time	-3.119	-16.409	0.009
Constant	10.989	54.839	

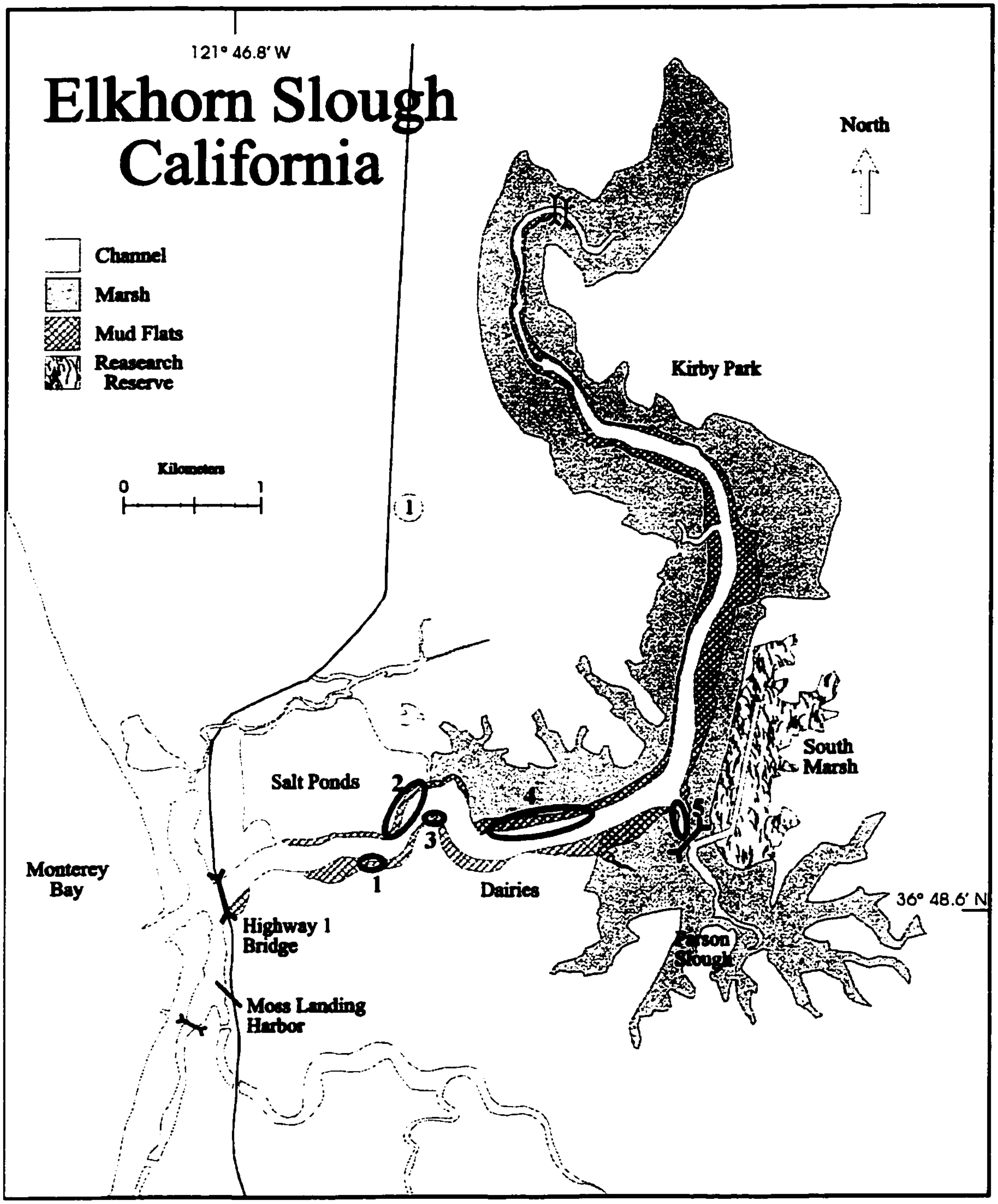

Figure 1. Areas within Elkhorn Slough, California, where harbor seals were captured or located with their pups. 1=Vierras, 2=Dikes, 3=Seal Bend, 4=Dairies, 5=Railroads

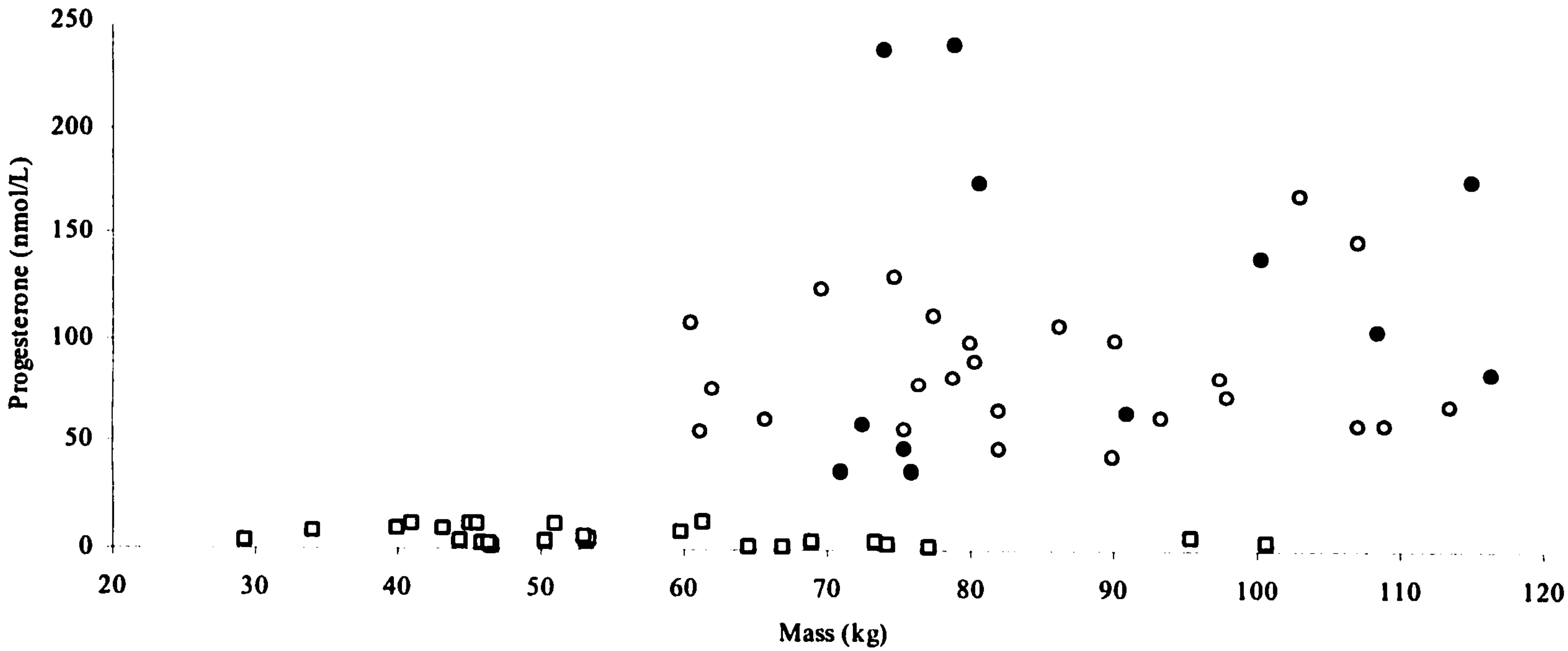

Figure. 2. Progesterone concentration (nmol/L) of female harbor seals (n=64) captured during gestation (September-April) plotted against their body mass (kg). Closed circles are known pregnant, open circles are pregnant based on progesterone concentration, and squares are non-pregnant.

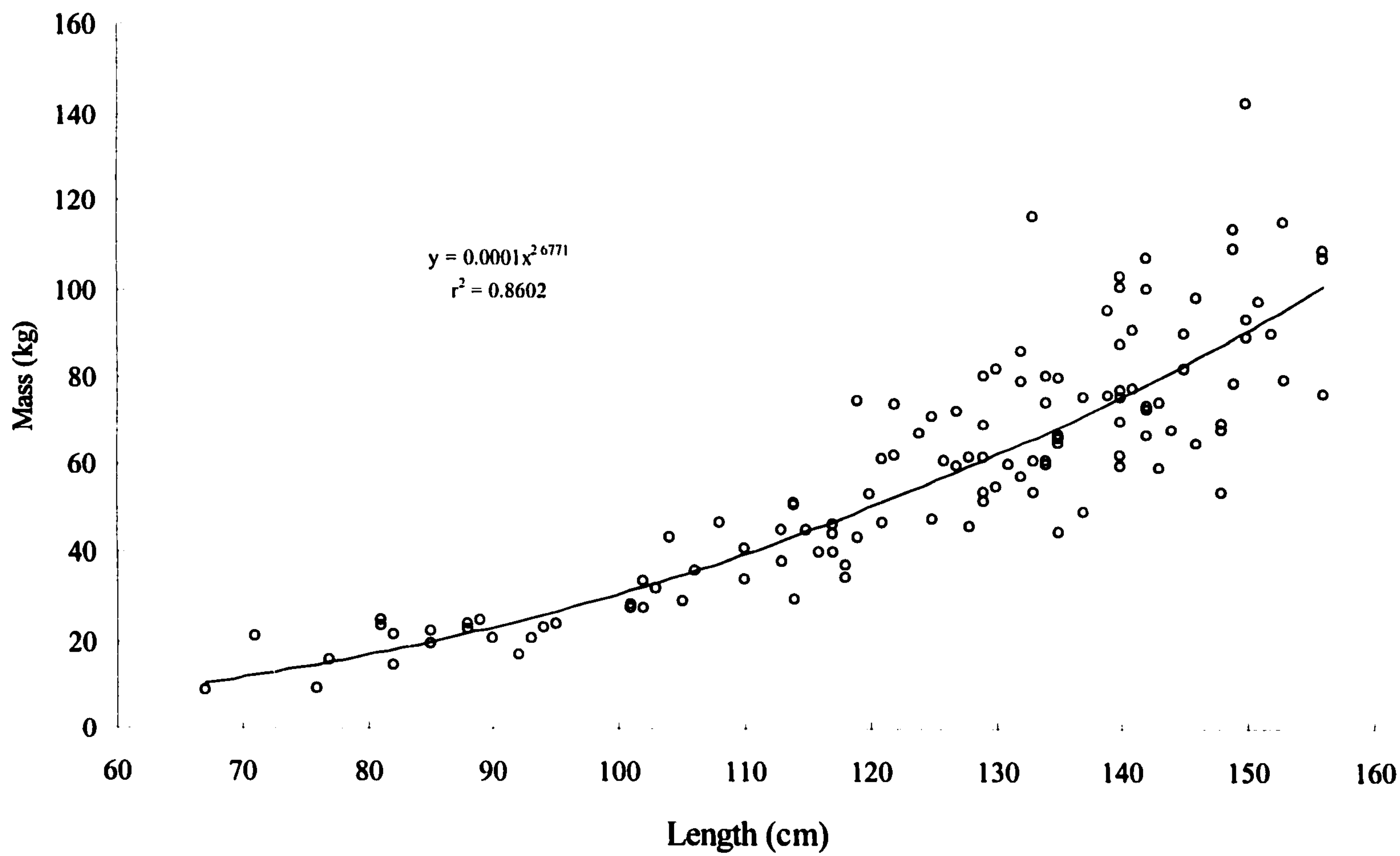

Figure 3. Relationship between mass (kg) and length (cm) for 123 female harbor seals captured in Elkhorn Slough from September 1997 through March 2000.

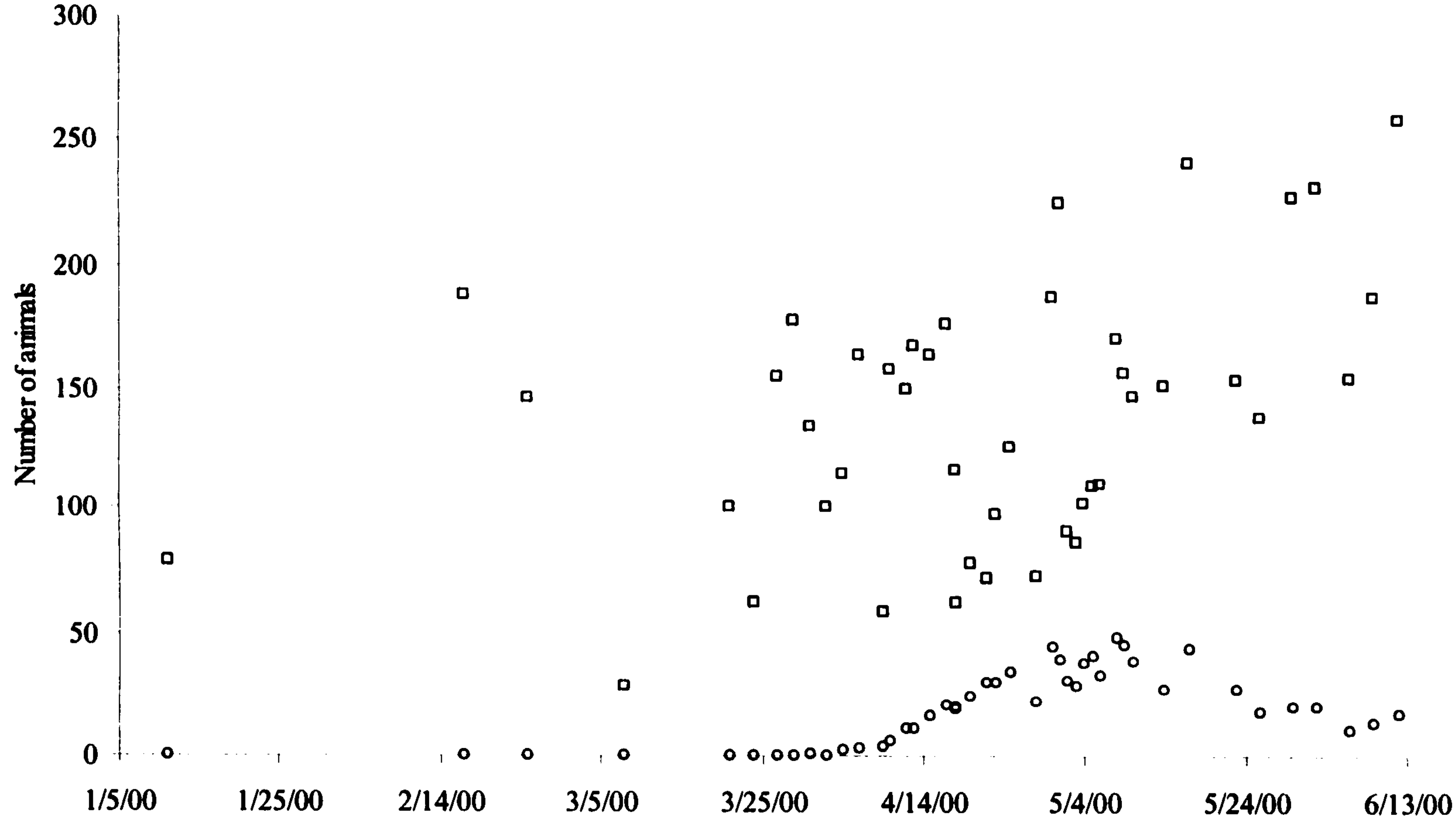

Figure 4. Counts of seals ashore in Elkhorn Slough during spring of 2000. Squares = total number of seals, and circles = pups.

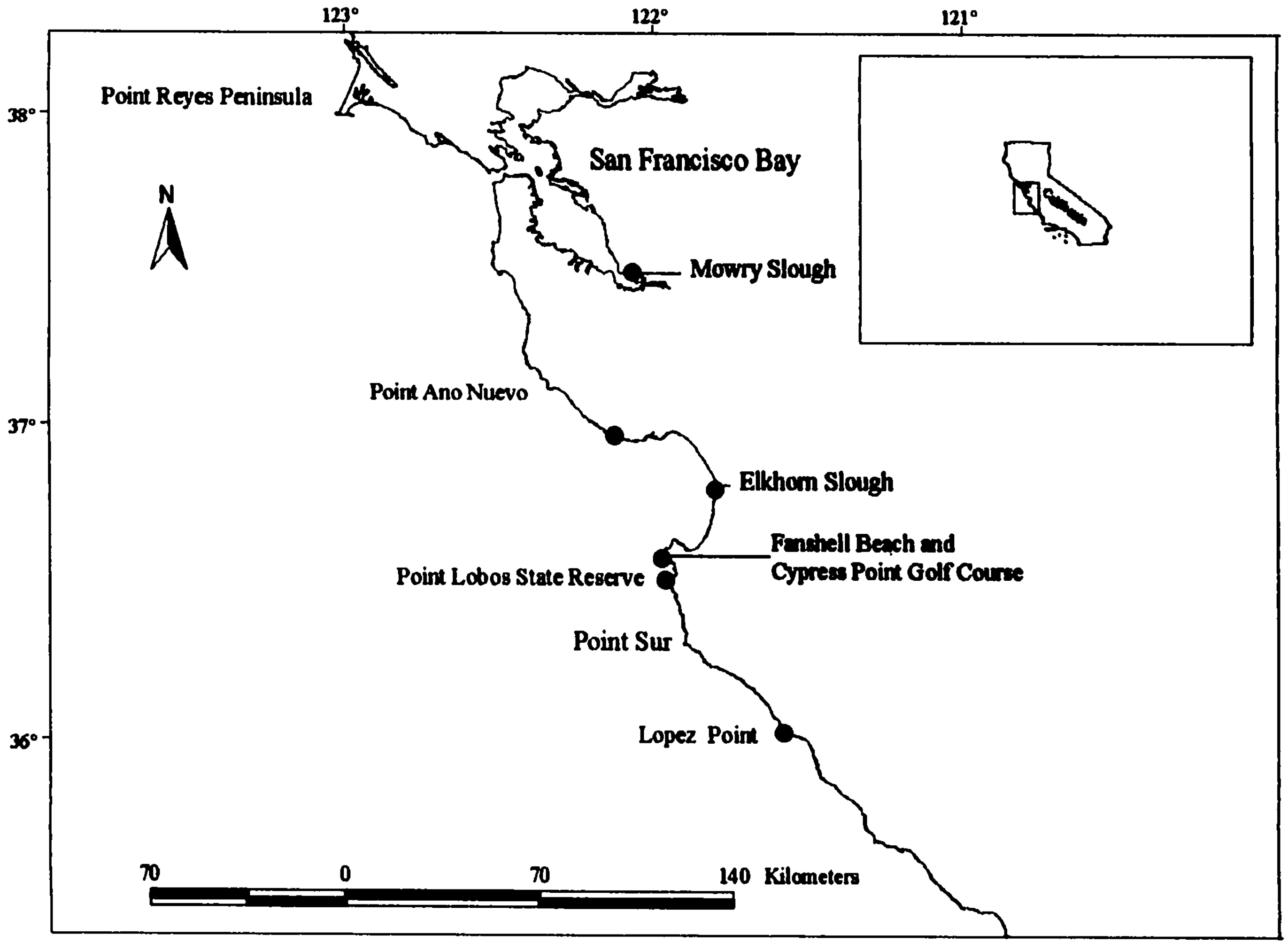

Figure 5. Circles indicate locations of radio-tagged harbor seals that were tagged in Elkhorn Slough during 1999 and 2000.

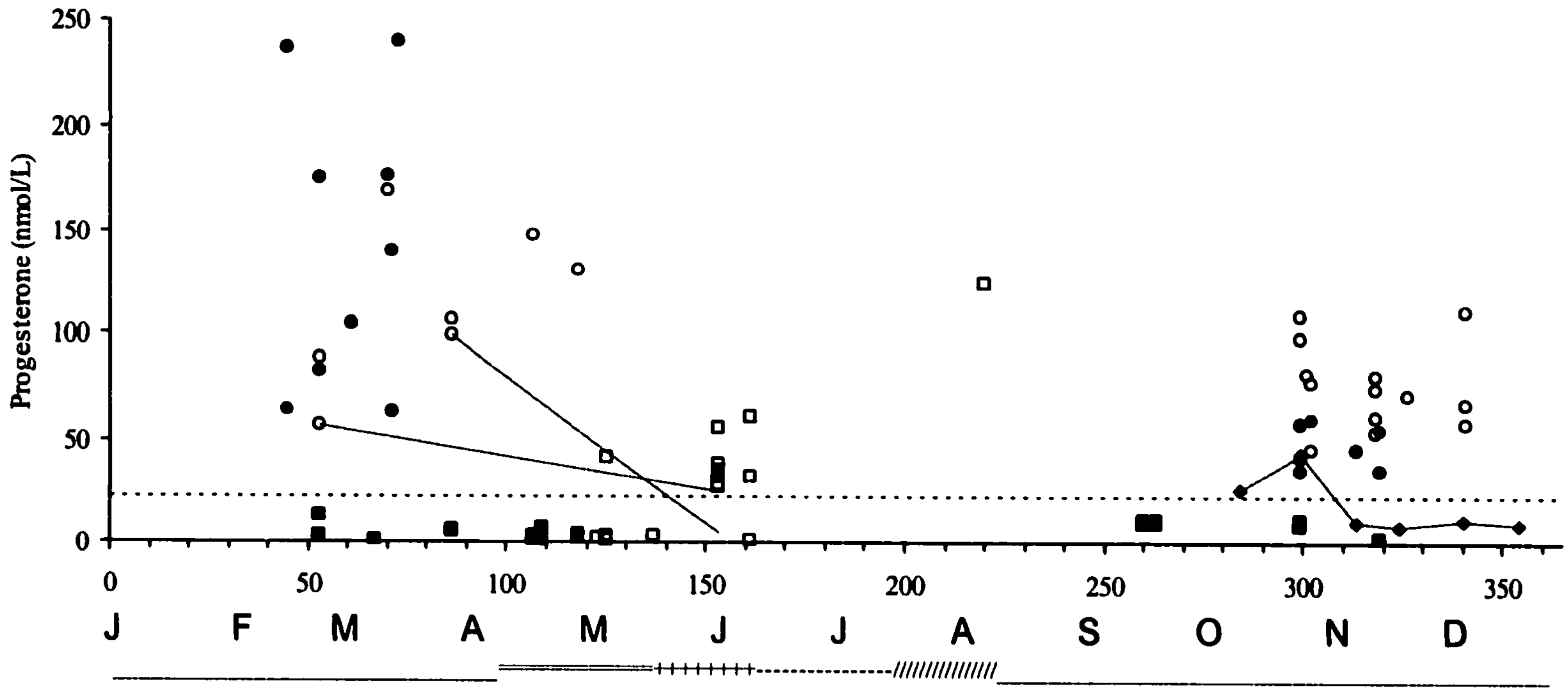

Figure 6. Progesterone concentration (nmol/L) of female harbor seals (n=84) plotted against date of sampling: closed circles = known pregnant (i.e. observed with pup), open cirlces = pregnant based on progesterone concentration, closed squares = non-pregnant, grey circles have elevated progesterone, but were not thought to have given birth, and open squares were captured May through August (not during gestation). The closed diamonds connected by a line are repeat samples taken from HS 1384. The three lines connect samples from recaptured animals. The x-axis is julian days and the reproductive cycle is pictured beneath: gestation (__), pupping and lactation (==), estrus and mating (++), delayed implantation(--), and implantation(//). The dotted line is plotted along the calculated pregnancy cutoff of 24 nmol/L.

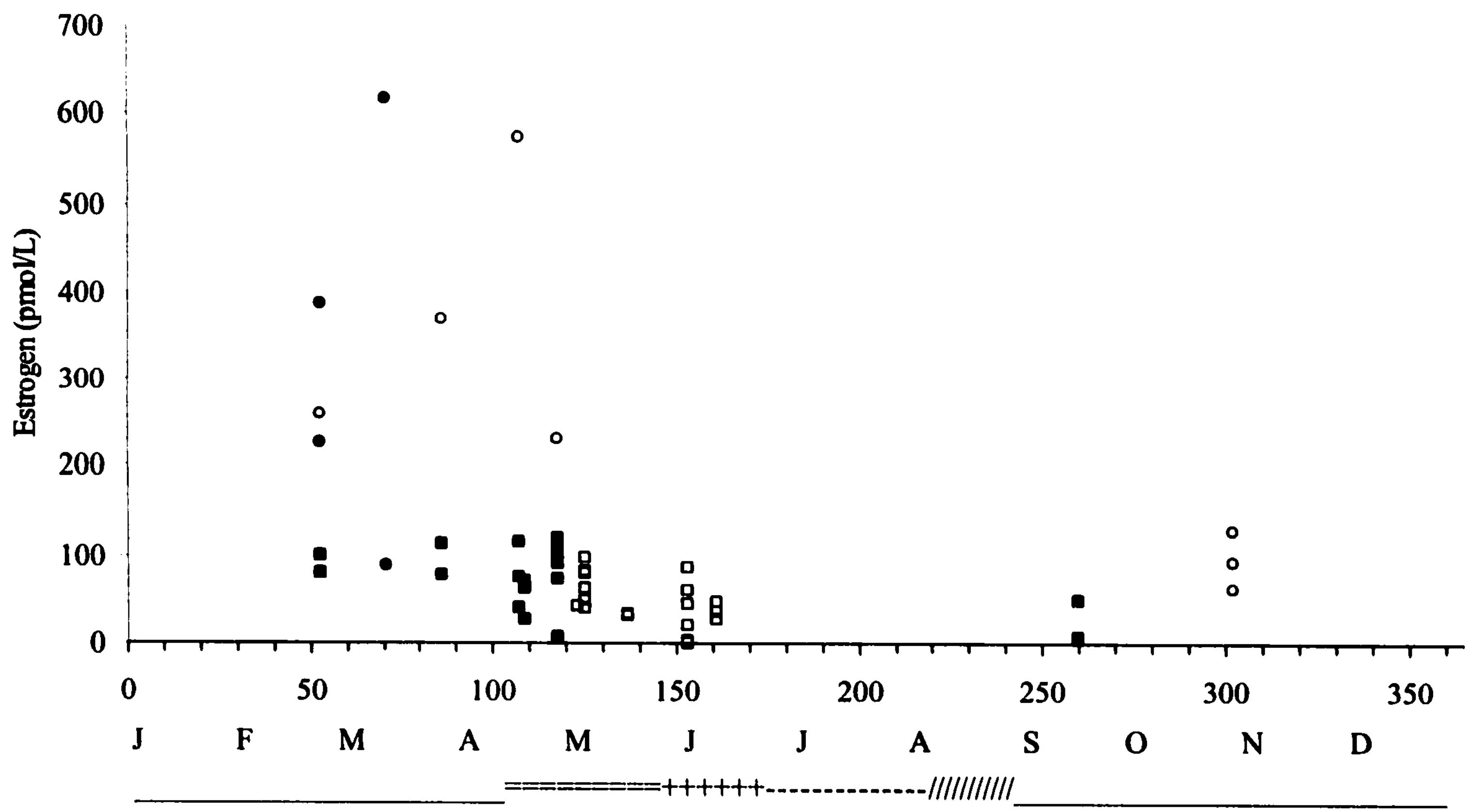

Figure 7. Estrogen level (pmol/L) of female harbor seals (n=50) plotted against date of sampling: closed circles = known pregnant, open circles = pregnant based on progesterone concentration, closed squares = non-pregnant based on observation and progesterone concentration and open squres were captured May through August (after pupping/lactation had begun, but before implantation). Grey lines connect samples taken from the recaptured animals. The x-axis is julian days and the reproductive cycle is pictured beneath: gestation (___), pupping and lactation (==), estrus and mating (++), delayed implantation (--), and implantation (//).

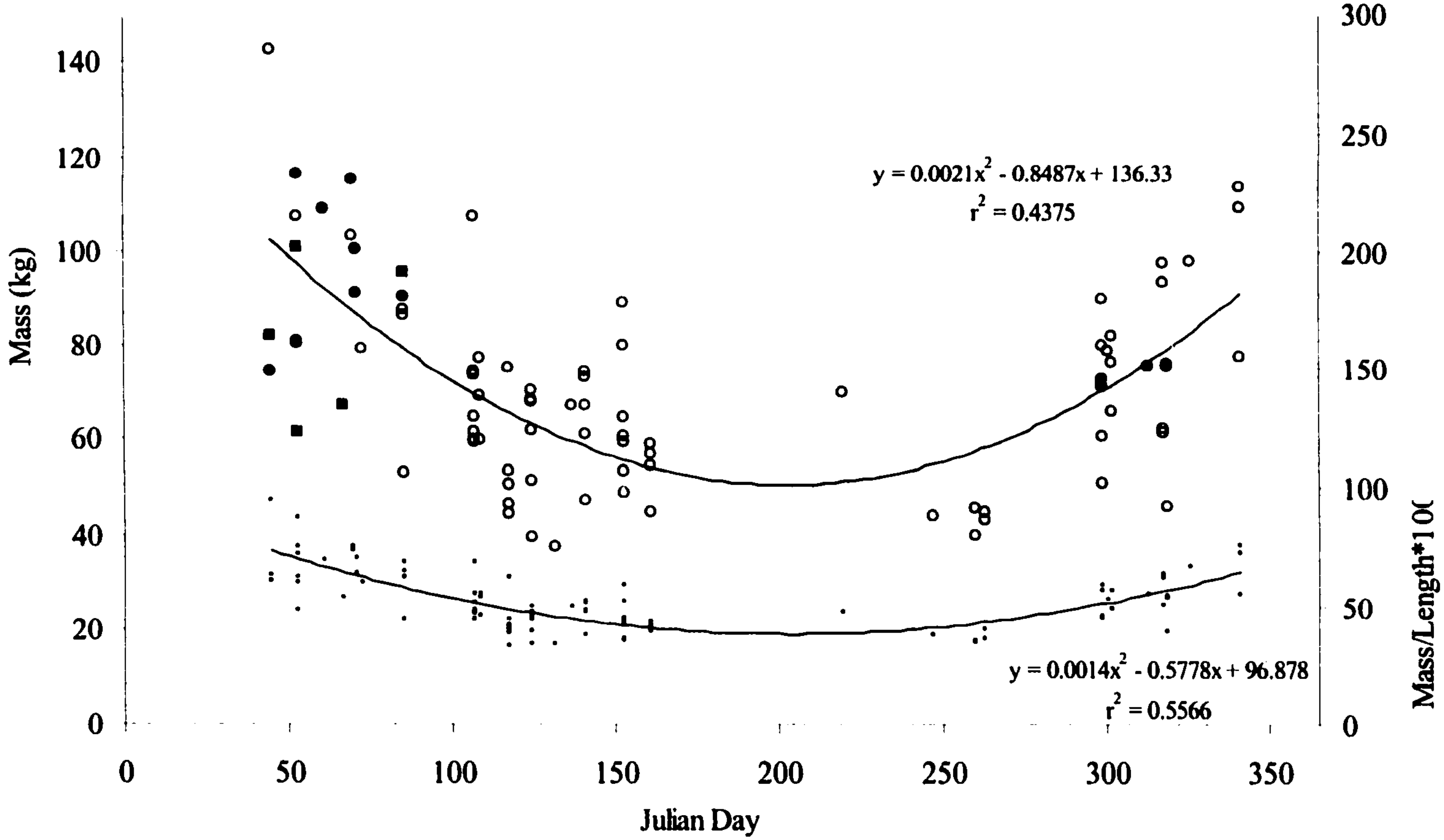

Figure 8. Relationship of adult female mass (n=89) plotted on the left y-axis against date of capture: closed circles are known pregnant animals, and grey squares are non-pregnant females based on progesterone concentration and observation. The lower plot is the relationship of condition (mass/length*100 on the right y-axis) of the same females plotted against date of capture.

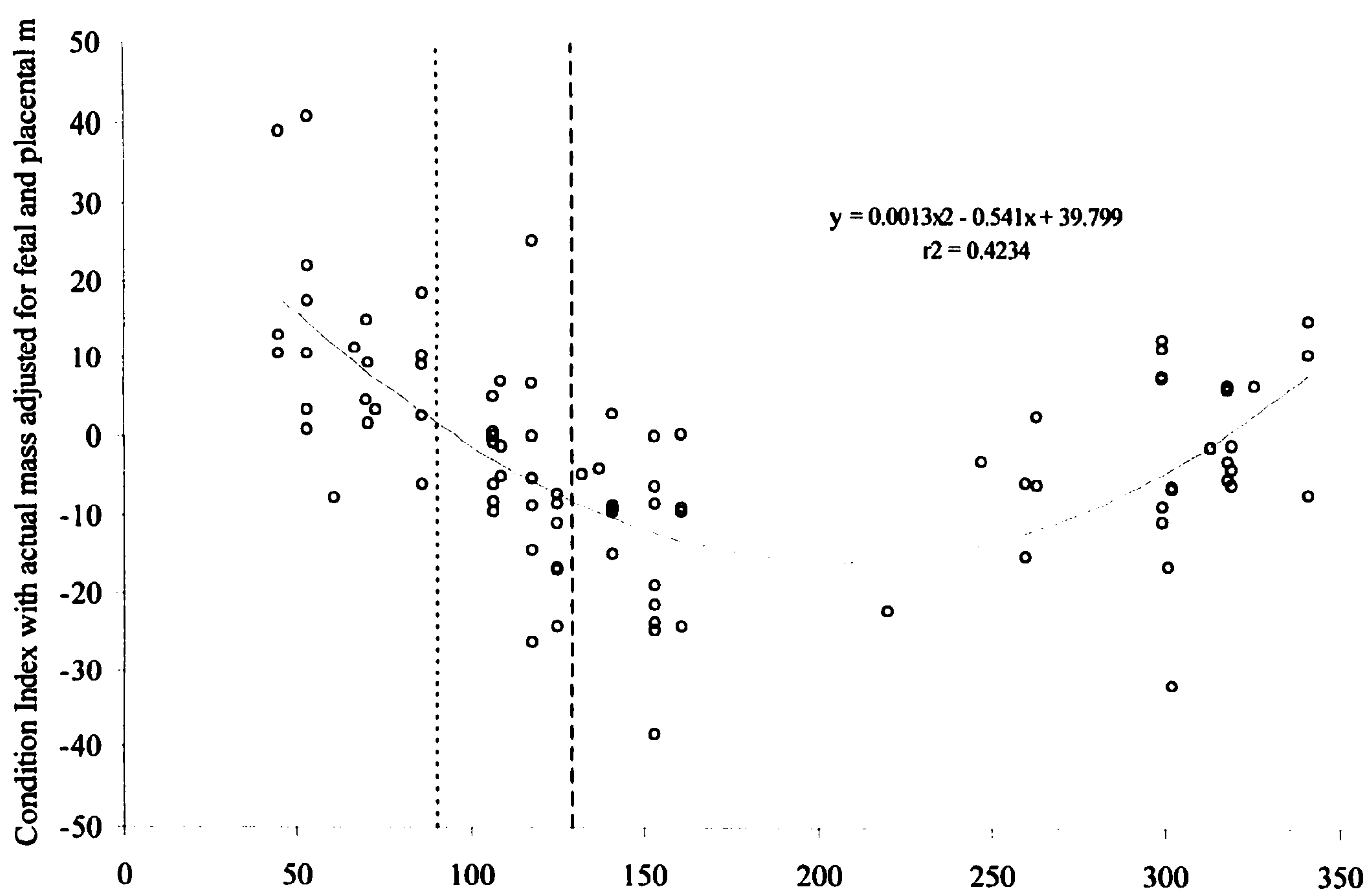

Figure 9. Body condition index, adjusted for fetal and placental mass, of 89 adult females plotted against julian day. Short dashes are day 90 or April 1st when pups first started appearing and long dashes are day 129 or 5/9 when pup numbers were greatest.

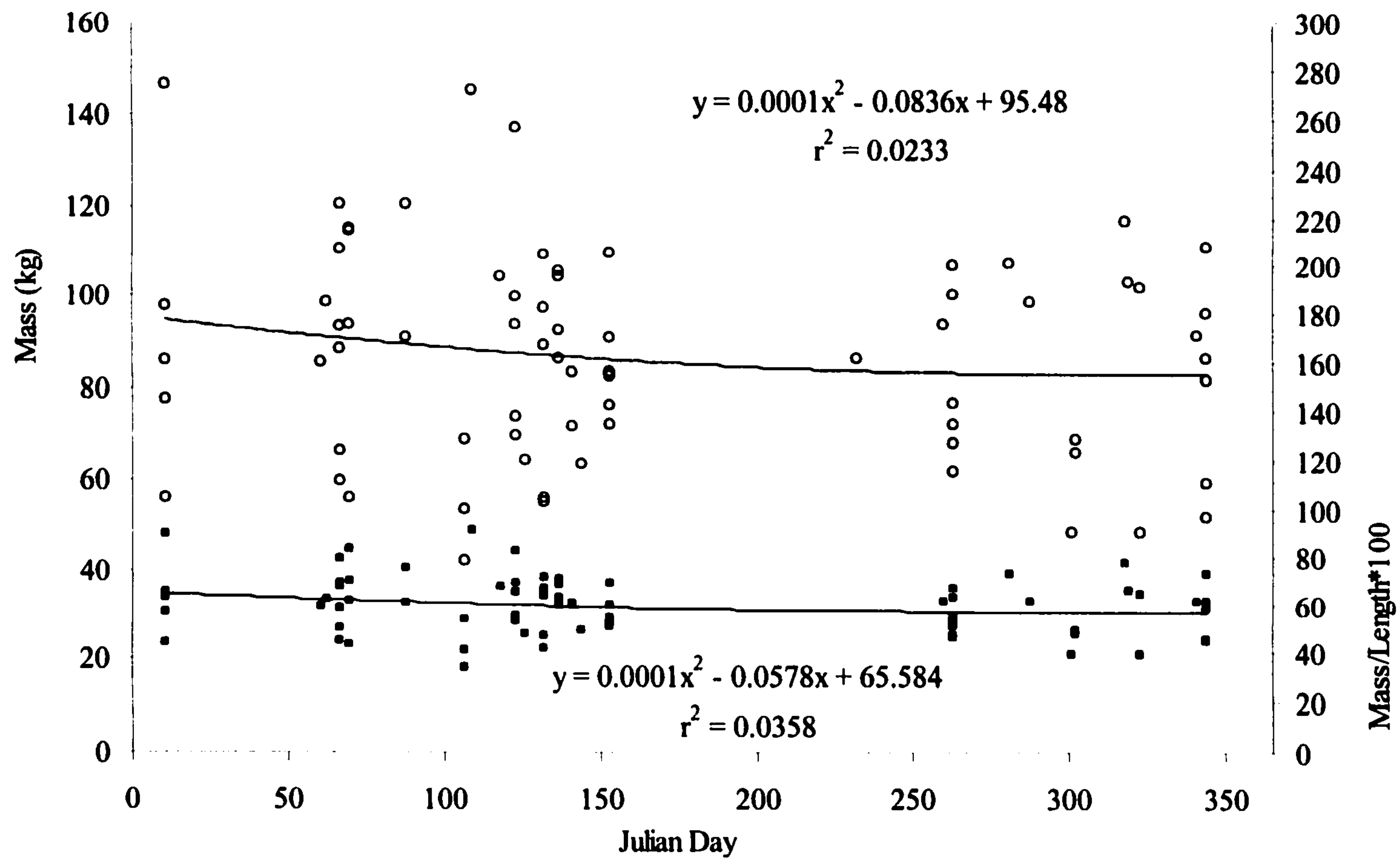

Figure 10. Relationship of adult male mass (n=72) plotted on the left y-axis against date of capture. Squares are relationship of condition (mass/length*100, right y-axis) of the same males plotted against date of capture.

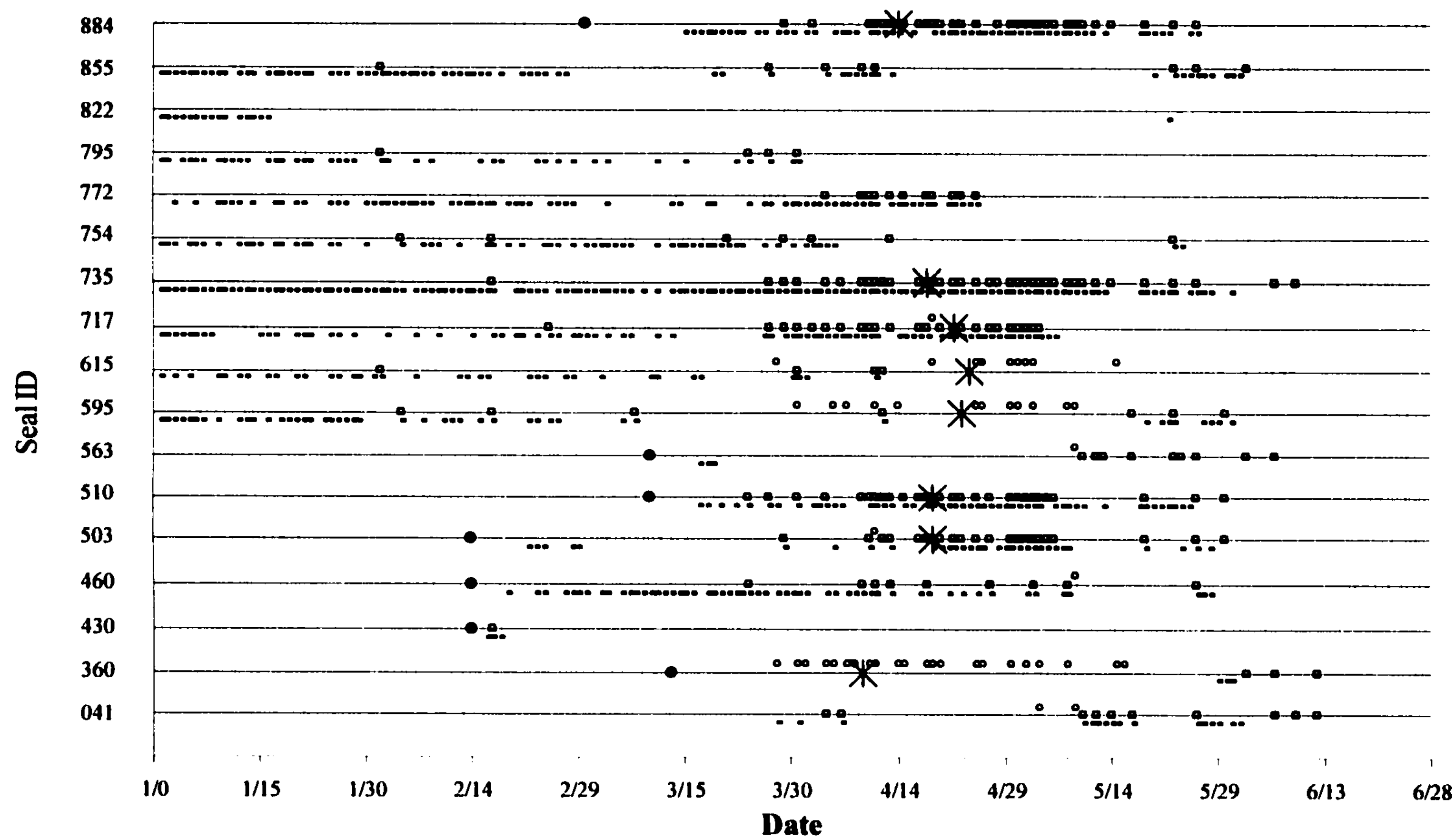

Figure 11. Presence of each radio tagged female from January 1, 2000 to June 12, 2000. Dashes indicate days recorded by the DCC datalogger, squares indicate days the seal was seen or heard during surveys of the slough, open circles indicate days the seals was located outside of the slough, closed circles indicate date of capture, and asterisks indicate days the seals gave birth.

Appendix 1- Locations of head and radio-tagged females

Seal Frequency	Generic Location	Date
1999-2000		
164 041	Elkhorn Slough, Moss Landing	Nov 23; Apr 4, 6; May 10, 12, 14, 17, 26, June 6, 9, 12
	DCC-Elkhorn Slough	Mar 28, 31; April 6, May 10-15, 17, 26-29, 31; June 1
	Point Santa Cruz	May 9 (36 56.572 N, 122 01.506 W),
	Mowry Slough, South SF Bay	May 4,
164.360	Elkhorn Slough, Moss Landing	June 2, 6, 12
	DCC-Elkhorn Slough	May 29-31
	Lover's Point, Monterey	March 28,
	Hopkins Marine Station	March 31, April 1
	Cypress Point, Pebble Beach	April 5,
	Fanshell Beach, Pebble Beach	April 7, 8, 10, 11, 14, 15, 18-20, 25-26, May 2, 8
	Seal Rock, Pebble Beach	April 30; May 4
	Tioga Rd, Marina	May 15,
	Asilomar, Pacific Grove	May 15,
	Moss Cove, Pt Lobos	May 16,
164.430	Elkhorn Slough, Moss Landing	Feb 17, April 12, 18 (faint signal only audible across from dairies)
	DCC-Elkhorn Slough	Feb 16-18
	San Carlos Bay, SF Bay	May 12 (faint beep, circled for 10 min without hearing again)
164 460	Elkhorn Slough, Moss Landing	Mar 24; April 9, 11, 13, 18, 27, May 3, 8, 26,
	DCC-Elkhorn Slough	Feb 19, 23-24, 27-29, Mar 1, 3-4, 6-16, 18-26, 28-31; April 1,4-5, 7-11, 13,17-18, 21, 23, 25, 27; May 2-3, 7-8, 26,27,29
	2 miles E of Sandhill Bluff, Santa Cruz	May 9 (36 57.188 N, 121 08 829 W)
164 503	Elkhorn Slough, Moss Landing	Mar 29, April 10, 12-13, 17-20, 22-23, 25, 27, 30, May 1-6, 19, 26, 30
	DCC-Elkhorn Slough	Feb 22-24, 28-29, Mar 29, April 5, 10, 13, 19-26, 28-30; May 1-8, 19, 24, 26, 28
	Lighthouse Point, West Cliff Dr, SC	April 11 (36 56 678 N, 122 01 340 W)
164 510	Elkhorn Slough, Moss Landing	Mar 24, 27, 31; April 4, 9-13, 15, 17-20, 22- 23, 25, 27- 28, 30; May 1, 4, 5, 8-10, 12, 14, 17, 19, 23, 26
	DCC-Elkhorn Slough	Mar 17-18, 20, 22, 24, 27-28, 31; April 2-6, 10-13, 15-16, 18-30; May 1-4, 6-10, 13, 18-25
164 563	Elkhorn Slough, Moss Landing	May 10, 13, 23; June 2, 6
	DCC-Elkhorn Slough	Mar 17-19
	Cypress Point, Pebble Beach	May 9 (36 34 764 N, 121 59 398 W)
	Offshore, Moss Landing	May 12,
	Behind Moss Landing Marine Labs	May 17, 24, 26,
164 595	Elkhorn Slough, Moss Landing	Nov 3, 23; Dec 27; Feb 4, 17, Mar 8, Apr 12, May 23, 30,
	DCC-Elkhorn Slough	Jan 1-7, 9, 12-14, 16, 18-22, 24-29, Feb 4, 7, 10-12, 15, 17, 22-23, 25-26; Mar 6, 8; Apr 12, May 19, 21-23, 27-29, 31
	Salinas River mouth	March 31,
	Cypress Point, Pebble Beach	April 5, 25 (36 35.121 N, 121 58.724 W), 26
	Seal Rock, Pebble Beach	April 7, 14; May 8,
	N of Cypress Point	April 11 (36 35.692 N, 121 58 496 W)
	Cypress Golf Course, Pebble Beach	April 30, May 1, 9,
	Between Fanshell and Cypress, Pebble Beacl	May 3,
	Behind Moss Landing Marine Labs	May 17,

Seal Frequency	Generic Location	Date
164.615	Elkhorn Slough, Moss Landing	Nov 17, 23, Feb 1; Mar 31; April 11, 12,
	DCC-Elkhorn Slough	Jan 1, 3, 5, 9-10, 12-13, 16-17, 20-21, 25-26, 28-29, 31, Feb 1, 6, 12-13, 15-16, 22-24, 27-28, Mar 3, 10-11, 16-17, 30-31, April 1,11
	Concrete Ship, Capitola	March 28,
	Cypress Point, Pebble Beach	April 19, 25 (36 34.947 N, 121 58.766 W), 26; May 15,
	Seal Rock, Pebble Beach	April 30, May 3,
	Cypress Golf Course, Pebble Beach	May 1, 2,
	Sea Lion Pt, Pt Lobos	May 1,
164.717	Elkhorn Slough, Moss Landing	Dec 27;Feb 25, Mar 27, 29, 31; April 2, 4, 6, 9, 10, 11, 13, 17, 18, 20, 22, 23, 25, 27, 28, 30; May 1, 2, 3, 4,
	DCC-Elkhorn Slough	Jan 1-8, 15-17, 20-22, 25-26, 28; Feb 2, 6, 9, 14, 17-18, 20-21, 23, 25-26, 28-29, Mar 1, 2, 4, 6-7, 11, 13 26-27, 29-31, Apr 1-11, 14-18, 20-30; May 1-6
	Hopkins Marine Station	April 19,
164.735	Elkhorn Slough, Moss Landing	Nov 3, 17, Feb 17, Mar 27, 29, 31; April 4, 6, 9, 10, 11, 12, 13, 17, 18, 19, 20, 22, 23, 25, 27, 28, 30, May 1, 2, 3, 4, 5, 6, 8, 9, 10, 14, 19, 23, 26; June 6, 9
	DCC-Elkhorn Slough	Jan 1-31, Feb 1-4, 6-17, 20-24, 26-29; Mar 1-9, 11, 13-31; Apr 1-30, May 1-13, 18-23, 25-28, 31
	Offshore Moss Landing	May 12,
164.754	Elkhorn Slough, Moss Landing	Feb 4, 17, Mar 21, 29, April 2, 13; May 10?, May 23
	DCC-Elkhorn Slough	Jan 1-3, 5-7, 9, 12-18, 20-22, 25-26, 30; Feb 4, 7-9, 12, 16-17, 19, 21, 24-26, 28, Mar 1-7, 11 13-23, 26, 28, 30, Apr 1-5, May 23-24
164.772	Elkhorn Slough, Moss Landing	Nov 17; April 4, 9, 10, 11, 13, 15, 18, 19, 22, 23, 25
	DCC-Elkhorn Slough	Jan 3, 6, 9, 10-12, 14, 17, 18, 20-21, 25-27, 30-31; Feb 1-8, 11-17, 19-22, 25-28; Mar 13-14, 18-19, 24, 26-27, 29-31, April 1-11, 13-19, 21-25
164.795	Elkhorn Slough, Moss Landing	Feb 1; Mar 24, 27, 31,
	DCC-Elkhorn Slough	Jan 1-2, 4-7, 9-13, 16-18, 20-22, 25-28; Feb 1-2, 6, 8, 15, 17-18, 23-24, 26, 28, Mar 2, 4, 11, 15, 22, 24, 27, 30, 31
164.822	Elkhorn Slough, Moss Landing	Nov 17, 23,
	DCC-Elkhorn Slough	Jan 1-10, 12-16; May 22 ?
	Marina State Beach	one flipper tag found May 26
164.855	Elkhorn Slough, Moss Landing	Feb 1; Mar 27, April 4, 9, 11, May 23, 26; June 2,
	DCC-Elkhorn Slough	Jan 1-10, 12-14, 16-22, 25-27, 29-31; Feb 1-8, 10-16, 18, 21-24, 26-27, Mar 19-20, 27, April 4, 6-11, 13, May 20, 23-28, 30-31; June 1
	Lopez Pt (48km /SE of Pt Sur)	April 25 (36 00.713 N, 121 34.813 W), 28
164.884	Elkhorn Slough, Moss Landing	Mar 29; April 2, 10-13, 15, 17-20, 22, 23, 25, 28, 30; May 1-6, 8-10, 12, 14, 19, 23, 26,
	DCC-Elkhorn Slough	Mar 15-23, 25-26, 28-30; April 1-2, 5-8, 10-14, 16, 19-30; May 1-11, 13, 18-22, 25-26
18	Elkhorn Slough, Moss Landing	tag found Dec 1999
20	Elkhorn Slough, Moss Landing	Nov 3; Feb 4, 17, 25; Mar 24
31	Elkhorn Slough, Moss Landing	Nov 17, Dec 27, Feb 1; Apr 4,
40	Elkhorn Slough, Moss Landing	Feb 17, 25; Dec 27; Feb 1, 4; Mar 24, 29, 31; April 4, 12, 13, 17, May 30
1998-1999		
61	Elkhorn Slough, Moss Landing	
62	Elkhorn Slough, Moss Landing	April 29,
63	Elkhorn Slough, Moss Landing	Mar 2, 9, 21, 22, 24, 31; Apr 7, 8, 9, 13, 14, 17, 20, 24, 29,
64	Salinas River mouth	Mar 6,
	Elkhorn Slough, Moss Landing	Mar 7, 9, 17, 21, 22, 27, 31, April 6, 9

Seal Frequency	Generic Location	Date
	South end of Stillwater Cove	May ?
65	Elkhorn Slough, Moss Landing	Mar 7, 9, 17, April 9, 13,
66	Elkhorn Slough, Moss Landing	Mar 12, 21, Apr 5, 9, 20, 25, 27, 29, 30,
67	Elkhorn Slough, Moss Landing	Mar 2, 9, 17, 21, 22, 27; April 6, 9, 13, 14, 17, 21, 24, 27, 29,
68	Elkhorn Slough, Moss Landing	Feb 23; Mar 9, 17, 21, 22, 27; Apr 4, 6, 9, 20, 21, 25, 30,
69	Elkhorn Slough, Moss Landing	Feb 23; Mar 2, 7, 21, 22, 27, 30, 31,
70	Elkhorn Slough, Moss Landing	Feb 23; Mar 2, 7, 9, 16, 17, 22, 27; April 14, 17,
71	Elkhorn Slough, Moss Landing	Mar 2, 7, 13, 22, 27,
	1 mile offshore Salinas River mouth	Feb 27,
72	Elkhorn Slough, Moss Landing	Mar 30, April 13, 14, 17, 18, 20, 21, 24, 25, 27, 29, 30,
73	Elkhorn Slough, Moss Landing	Mar 16, 17, 21, 22, 24, 30, Apr 4, 9, 13, 17, 18, 20, 21, 24, 27, 29,
Aerial Surveys	Ano to Pt Sur	4/11/2000
(all frequencies)	Sea Otter range	4/25/2000
	Pigeon Pt to Pt Sur	5/9/2000
	Humboldt Bay to Pt Pinos including Farallones and Pt Reyes	5/12/2000