

The Effects of El Niño on Mother-pup Biology in the California Sea Lion

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Abstract – The 1982-1983 El Niño dramatically affected the mother-young relationship and survivorship of young in a California sea lion (*Zalophus californianus*) population that was 35-45° north of El Niño's center. A decreased food supply for lactating females in 1983 was associated with earlier postpartum departures and longer feeding trips. Pups spent less time suckling, obtained less milk, grew more slowly and suffered an increased mortality. Also presented are evidence for a significant, but decreased effect of this El Niño in the subsequent year (1984).

Introduction

The 1982-1983 El Niño had devastating effects on populations of organisms in the southern Pacific Ocean (Barber & Chavez 1983; Limberger *et al.* 1983; Schreiber & Schreiber 1983, 1984, Simon 1983; Trillmich & Limberger 1985). This El Niño also had an impact on more distant populations including marine plants and animals as far north as the California coast (Dayton & Tegner 1984; McGowan 1984). Here we provide evidence that the reproductive performance of a population of California sea lions, *Zalophus californianus*, located 4,500 km from the center (defined as the area of the largest oceanographic deviation, approximately at the equator) of the El Niño, was significantly affected. This study is unique in that both behavioral and physiological components of maternal

reproductive effort were monitored before (1982), during (1983), and after (1984, 1985) a major El Niño event (Oftedal *et al.* 1987; Ono *et al.* 1987; Boness *et al.* 1991; Iverson *et al.* 1991; Ono & Boness 1991).

Fisheries statistics indicate a substantial decrease in stocks of major prey species of the California sea lion during and immediately after the 1982-1983 El Niño. Catches of anchovy, squid, rockfish and mackerel were reduced (Scheffer & Neff 1948; Fiscus & Baines 1966; Antonelis *et al.* 1984; Department of Commerce 1982, 1984). Using a doubly-labeled water technique, Costa & co-authors (1985, 1991) presented evidence suggesting that lactating California sea lions foraged at a greater energetic cost and for a longer duration during the El Niño year. Reduced prey availability and increased foraging effort might be expected to decrease the amount of time and energy that lactating sea lions can invest in their offspring.

In late May to early June pregnant females "haul out" onto island shores and give birth to a single precocial pup. Females nurse their pups for a few days before returning to sea to feed (Ono *et al.* 1987). The interval of time between parturition and departure may reflect the magnitude of reserves a female has at parturition and the consequent ability to withstand the combined demands of fasting and lactation. For the remainder of the lactation period, which may last up to a year or longer, females alternate between nursing their young and foraging at sea. Reduced female attendance on the reproductive areas might be expected to negatively affect suckling behavior, and ultimately the amount of milk transferred to pups. Trillmich (1986) found a correlation between the duration of suckling bouts and the amount of milk transferred in Galapagos fur seals.

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Methods

This study was conducted on San Nicolas Island, California which lies 96 km west of the southern California coast (33° N, 119° W). The behavior study area was located at the northwest tip of the island. Shortly after the peak of births on the study area, pups were weighed, measured and individually marked with hair bleach (62 marked in 1982; 46 in 1983; 45 in 1984; 53 in 1985). Pups were subsequently reweighed, measured and tagged in early August (at approx. 2 mo of age). Adult females were individually marked using a combination of black hair dye and paint pellets. Behavioral data were taken daily between 0600-1800 hrs from a blind within 30 m of the animals from mid-May through early August during the years 1982-1984. Hourly scan samples were taken for a subset of the marked pups in the years 1982-1984. Behavioral data of pups that died during the observation period were omitted from the analyses. The proportion of time a female was away from the reproductive area was calculated for each female for weeks 2-8 postpartum, and a grand mean for each year taken from the means for individual females (for details of methods, see Ono *et al.* 1987).

Minimum mortality was calculated as the percentage of marked pups actually observed dead. Most of these pups were in an emaciated condition up to several weeks before death and were, therefore, watched closely. Healthy pups which disappeared suddenly from the study area were assumed to have moved to another reproductive area.

Studies of milk intake were performed on pups residing on reproductive areas 0.3-8.8 km from the behavior study area. Intake measurements were collected on a total of 22 pups (approx. 1 mo of age) in June of 1982 and 1984, and on a total of 17 pups (approx. 2 mo of age) in July of 1983 and 1984. The deuterium oxide dilution technique was used to estimate milk intake (see Oftedal *et al.* 1987, Iverson *et al.* 1991, for intake measurement

methods). Intake is expressed on the basis of metabolic body size to compensate for size effects on energetics (Kleiber 1975). A scaling factor of body weight (kg) to the 0.83 power is used since it best represents suckling neonates (Oftedal *et al.* 1987).

Statistical analyses of female attendance patterns (feeding cycles) were performed using a one-way ANOVA. *A priori* family-wide significance was determined using the Bonferroni technique. The percentage of time spent suckling was analyzed with the Mann-Whitney *U*-test. An analysis of covariance, with sex and weight as concomitant variables was used to analyze milk intake data and pup growth rate. An ANOVA with the effect of sex removed was used to determine differences in pup weight at two months. Finally, Fisher's Exact-test was utilized in analysis of the mortality data. *P*-values for individual 2-yr comparisons were adjusted for multiple comparisons (Everitt 1977).

Results

The interval between parturition and departure on the first postpartum feeding trip was significantly shorter in the El Niño year than in 1982, 1984 or 1985 (Fig. 1A). Females also spent a larger proportion of their time at sea in 1983 and 1984 than in 1982, and 1985 was intermediate (Fig. 1B).

Pups did not compensate for reduced maternal presence by suckling for a larger proportion of the time that their mothers were present on the reproductive area. Instead, the percentage of total time (total time = all observations of pups including those taken when their mothers were at sea) that pups spent suckling decreased in 1983 and 1984 in comparison to 1982 (Fig. 1C). Pups did, however, increase the frequency of attempts to suckle from females other than their mothers ("sneak suckling"). In 1982 only 6.5% of the marked sample of pups attempted to sneak-suckle. In contrast, the values were 54% in 1983 and 46% in 1984 (1982 *vs.* 1983 and 1982

vs. 1984 both significant at $P < 0.0002$. For all 3 years combined, $X^2=31.62$, $P < 0.001$).

Milk intake data were not obtained for both June and July in all three years, but 1982 *vs.* 1984 comparisons are available for the first month and 1983 *vs.* 1984 for the second month. Milk intake was significantly lower in 1984 compared to 1982 ($P < 0.03$, Table 3 in Ono *et al.* 1987), and there was no difference between samples from 1983 and 1984. From this we infer that milk intakes in the year prior to El Niño were probably larger than those during El Niño or the year thereafter.

Further support for this conclusion comes from differences in pup growth between years. Although initial pup weights (approximate birth weights) were not statistically different among the four years (Table 1, Boness *et al.* 1991), by two months of age the average

weight of El Niño year pups was significantly lower than the average weights of pups in all other years when the effects of pup sex were statistically removed (Table 1). More importantly, the growth rate of pups in the El Niño year was lower than for all other years (Table 1). A strong correlation between growth rate (g/day) and milk intake (kcal/kg^{0.83}/day) ($n = 26$, $r = .72$, $P < 0.01$) substantiates lower intakes for pups during the El Niño year.

The consequences of a decrease in maternal nutritional investment are reflected in pup mortality. Pup mortality (between birth and 2 mo of age) for the marked pup population was greater during 1983 (10.8%) than 1982 (0%) ($P < 0.02$). Mortality in 1984 and 1985 were lower, but not significantly different than 1983 (2.2% and 2.0%, respectively).

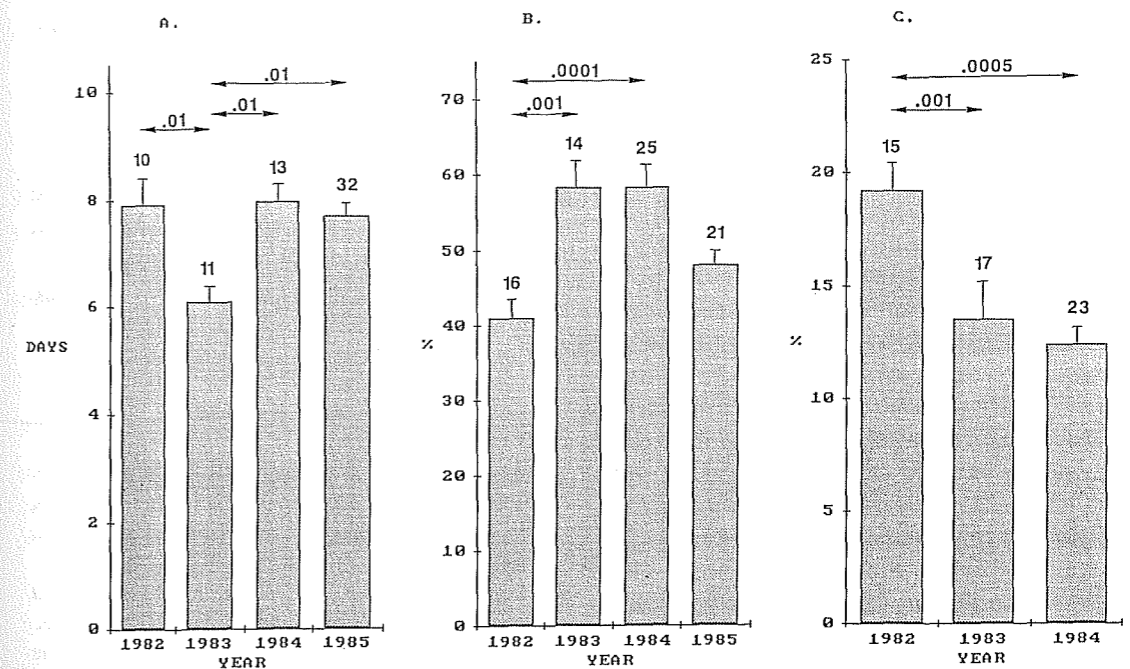


Figure 1. Behavioral components for suckling female and pup California sea lions. A. The number of days females remained with their pups immediately postpartum prior to leaving on the first feeding trip, for the years 1982-1985. Vertical lines above bars indicate 1 SE, the numbers over SE indicate sample size. Arrows show SD with *P*-values given above each. Adjustments for multiple comparisons were made using the Bonferroni technique. B. The percentage of time females were away at sea during the first 2 mo postpartum, labels as in A. C. Percentage of observations that pups were observed suckling during the first 2 mo postpartum, labels as in A.

Table 1. Comparison of weight parameters for California sea lion pups 1982-1985 (extracted from Table 4, Ono *et al.* 1987). NS denotes $P > 0.05$.

Activity ^{test}	1982			1983			1984			1985			Significance
	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n	
\bar{x} weight (kg) < 7 days of age ¹ :													
Males	9.0	0.9	21	9.0	1.1	16	9.0	1.0	14	9.6	0.7	9	NS
Females	7.8	0.8	32	7.3	0.8	20	7.8	0.7	10	8.1	1.1	16	
\bar{x} weight (kg) approx. 2 mo ² :													
Males	17.2	1.9	16	14.8	2.8	14	15.7	1.8	14	16.5	2.4	25	83<84 .05
Females	14.1	2.0	10	11.8	2.5	13	13.3	2.1	18	13.2	1.6	13	83<82,85 .005
\bar{x} growth rate (kg/day) ³ :													
Males	0.15	0.04	16	0.12	0.04	14	0.14	0.04	14	0.15	0.03	25	83<84 .05
Females	0.12	0.04	10	0.08	0.05	13	0.11	0.03	18	0.11	0.03	13	83<82,85 .005

¹Multiple Regression: weight dependent, sex independent.

²Multiple Regression: weight dependent; sex and initial weight independent.

³Multiple Regression: growth rate dependent; sex and initial weight independent.

Discussion

Our data imply a consistent impact of the 1982-1983 El Niño on all aspects of the reproductive biology of the California sea lion that we examined. Given the increased time and energy costs of foraging during the El Niño year (Costa *et al.* 1985), it appears that these changes may have been a consequence of fluctuations in food availability which began prior to the 1983 breeding season (McGowan 1984). We suggest a cascade of effects beginning with a decrease in food supply for pregnant and lactating females. This led to a decrease in the time spent with the pups immediately postpartum and an increase in the amount of time spent away from pups during subsequent feeding cycles. A decrease in time spent suckling probably reflected a decrease in milk available for pups. Less milk generated a drop in the average pup weight and growth; pups which did not receive enough milk from their mothers died as reflected in the increased mortality during the El Niño year. Our findings also demonstrate that the biological perturbation caused by El Niño had not fully dissipated by the subsequent (1984) breeding season, which concurs with oceanographic data gathered in this area (McGowan 1984). A major El Niño event, thus, can have a widespread and long-lasting influence on populations far from its center.

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