CALIFORNIA SEA LION PUP DEMOGRAPHY

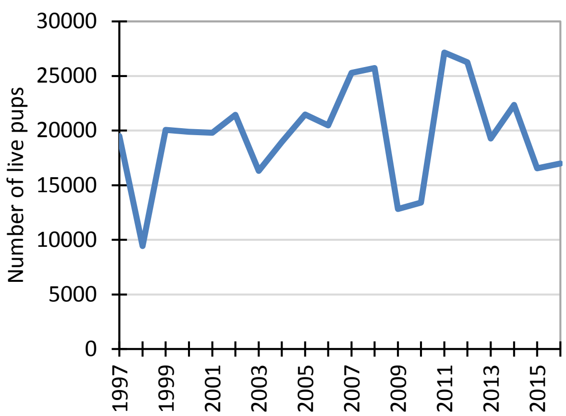
Unusually warm sea surface temperatures have been associated with declines in pup births, increased pup mortality and poor pup condition among California sea lions.

The California sea lion (*Zalophus californianus*) is a permanent resident of the California Current System. Females give birth to a single pup between May and June. For about 11 months, lactating females travel to sea for 2-5 days to feed and return to nurse their pup.

The Point Bennett Study Area at San Miguel Island (off Santa Barbara) is a large sea lion breeding area used as a long-term index colony for monitoring pup production and mortality.

Photo: Eric Boerner, NOAA

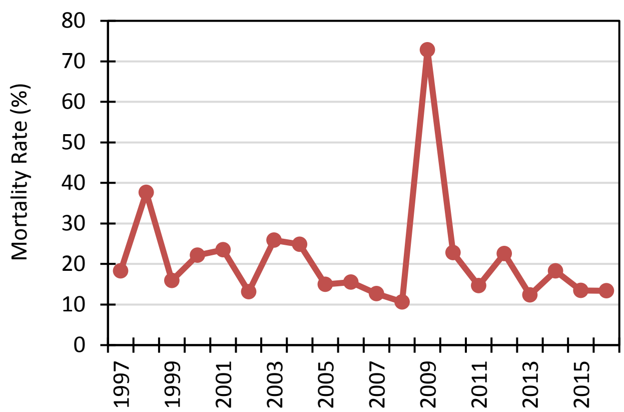
Figure 1. Sea Lion Live Pup Count*



** Based on live pups counts conducted July 20-30 annually*

Source: Harvey et al., 2017

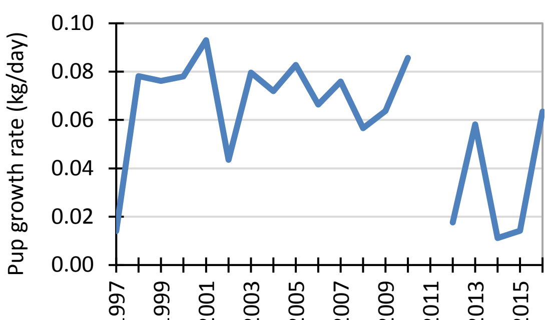
Figure 2. Sea Lion Pup Mortality Rate*



** At 5 weeks of age in the Point Bennett Study area*

Source: NMFS, unpublished data

Figure 3. Female Sea Lion Pup Growth Rate*



**Estimated mean daily growth rate of female pups between 4 and 7 months of age; no count was conducted in 2011.*

Source: Harvey et al., 2017

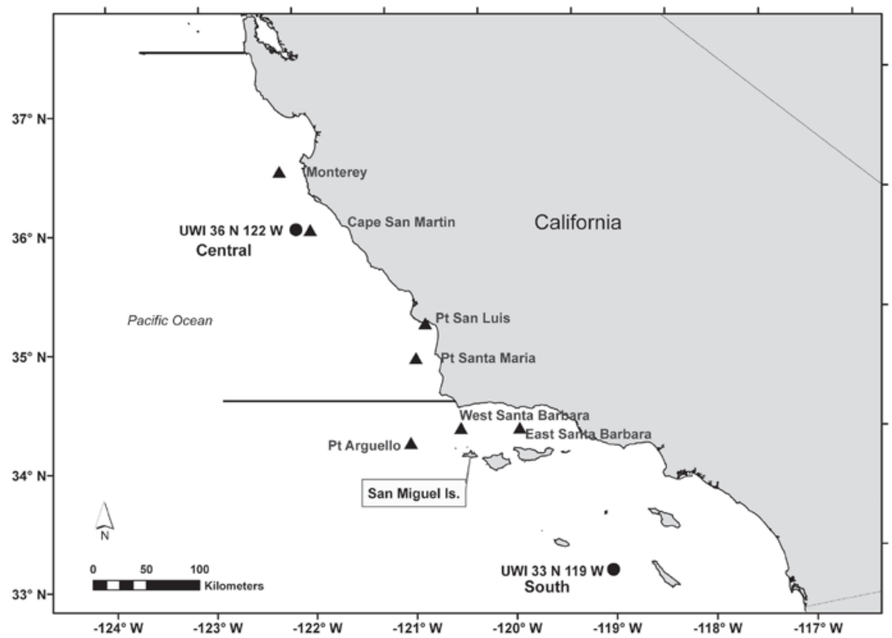
What does the indicator show?

Sea lion demographic parameters fluctuate with oceanographic conditions, particularly warm surface water temperatures. The indicator consists of three metrics based on monitoring of California sea lion population indices (pup births, pup mortality, and pup growth) and oceanic conditions between 1997 and 2016 at San Miguel Island's Point Bennett Study Area (see map, Figure 4). (Melin et al., 2010).

Annual pup counts at San Miguel Island between 1997 and 2016 ranged from a low of 9,428 to a high of 27,146 (Figure 1). The greatest declines occurred in 1998, 2009, and 2010, all years characterized by warm ocean conditions (Wells et al., 2017).

Pup production is a result of successful pregnancies and is an indicator of fish and cephalopods that serve as prey for sea lions. The high pup counts in 2011 and 2012 suggest that pregnant females experienced good foraging conditions in these years when cooler ocean conditions prevailed. The number of births declined again in 2015 and 2016 in response to warmer ocean waters due to a marine heat wave and El Niño conditions in 2015 (McClatchie, 2016; Wells et al., 2017).

Figure 4. Location of San Miguel Island



Source: Melin, et al., 2010

Figure 2 shows that in 2009, early pup mortality among sea lions during the first 5 weeks of life was exceptionally high, almost four times greater than the long-term average (73 percent in 2009, compared to about 20 percent long-term). The high pup mortality rates in 1998 and especially 2009 were associated with anomalously high sea surface temperatures (SSTs). However, during more recent warm ocean events in 2014-2015, pup mortality was near average, while pup growth rate during this period was low. This suggests that lactating females were able to support their pups for the short-term (first 5 weeks) but that females could not provide enough energy for long-term growth of their pups.

Pup growth from birth to 7 months of age is an indicator of the transfer of energy from the mother to the pup through lactation, which is related to prey availability during this time period. The lowest female pup growth rates occurred in 1997, 2014, and 2015 (Figure 3). (No data are available for 2011; researchers were unable to conduct a count that year.) These years were characterized by unusually warm ocean temperatures that were associated with El Niño conditions (1997, 2015) and a marine heat wave (2014-

2015) (Wells et al., 2017). Pup growth for the 2014 cohort was the lowest observed over the time series. As ocean conditions returned to near-normal in 2016, pup growth improved, returning to the long-term average (Wells et al., 2017). The very low growth rate for the 2012 cohort occurred during an unusually cold period of ocean conditions during winter 2012/2013 that normally would have resulted in good growth rates; the causes of the low growth rates for the 2012 cohort remain unexplained.

Why is this indicator important?

Sea lions and other marine mammals are prominent animals that reflect ecosystem variability and degradation in the ocean environment. Animals at higher levels in the food chain provide insights into relationships among marine community structure and oceanographic conditions (Weise, 2008). Scientists use marine mammals as sentinels of ocean production and changes in food webs, and increasingly include them in studies of changing oceanographic conditions (Moore, 2008).

Sea lions are among the most abundant top predators of the food chain in the coastal and offshore California waters. They are vulnerable to the seasonal, annual and multiyear fluctuations in the productivity of the ocean. Sea lion prey such as fish and cephalopods are also influenced by particular sets of environmental conditions along the California coast.

One of the greatest threats to the California sea lion comes from changes in their food resources due to climate and other influences (Learmonth et al., 2006). Air and ocean temperatures are warming and projected to continue to warm, especially in the summer. The biological impacts of these changes may be a lower rate of ocean productivity and thus less food for many species. This can lead to shifts in the geographical distributions of marine species (for example to higher latitudes or deeper waters), and cause changes in community composition and interactions (IPCC, 2014). More resilient species may gain predominance and abundance while others become less competitive or easier prey. Shifts in the abundance and distribution of prey have had serious consequences for sea lion reproduction and survival.

Tracking pup population indices provides insight into how the California sea lion population is responding to environmental and anthropogenic changes. Although the population of California sea lions in coastal waters from the United States-Mexico border to southeast Alaska has steadily increased since the early 1970s, recent declines in pup production and survival in this area suggest that the population may have stopped growing (Laake et al., 2018).

What factors influence this indicator?

The California Current System (CCS) has a large impact on the food supply and survival of sea lion pups along the coast. A regional process known as “upwelling” carries the deep, cooler waters transported by the current upward, closer to the surface where photosynthesis by phytoplankton occurs. This productive zone supports important commercial fisheries as well as marine mammal and sea bird populations. CCS waters are influenced by large-scale processes resulting from the

El Niño-Southern Oscillation (ENSO). El Niño conditions associated with the warm phase of ENSO occur irregularly at intervals of two to seven years, often leading to a weakened upwelling, low-nutrient waters and higher SSTs. Increased summertime SSTs due to decreased upwelling strength of ocean currents is reported to reduce availability of prey in the sea lion foraging zone.

Sea lion pups are solely nutritionally dependent on their mother's milk for the first six months of their lives. Sea lion pup survival is highly dependent on the lactating mother's ability to find food in in coastal waters near the colony. While their mothers are at sea on feeding trips, the pups are fasting at the colony. When prey availability is reduced near the colony, lactating females must travel farther to obtain food, resulting in longer periods away from their pups. Consequently their fasting pups are more vulnerable to starvation. Further, if the female does not obtain enough prey for her own nutritional and energy needs, she may not be able to provide sufficient energy for her pup to grow. Newly weaned pups just learning to forage on their own may also be vulnerable when prey availability is low because they have less fat to sustain periods of poor feeding conditions and fewer behavioral options to acquire food (e.g., limited diving ability). During periods of reduced prey conditions, increased numbers of malnourished sea lion pups are found stranded along the coast.

The low pup count, highest pup mortality rate and record number of strandings in 2009 were associated with anomalous oceanographic conditions along the California coast between May and August. During that year, upwelling was the weakest in the past 40 years; this was accompanied by uncharacteristically warm June SSTs. Negative upwelling patterns and warmer SSTs during the summer required lactating females to take longer than average foraging trips (averaging 7 days, approaching the maximum duration for which pups survive without nursing, 9 days). Additionally, the diet of California sea lions in 2009 varied significantly from other years, with cephalopods and rockfish occurring more frequently. The combination of longer foraging trips and a diet principally of rockfish and cephalopods did not provide adequate energy for lactating females to support their pups.

Since 2013, fisheries surveys confirm that the primary prey fish of sea lions (e.g., anchovy, sardine, hake) have not been abundant in the foraging area, probably in response to warmer ocean conditions (McClatchie, 2016; Wells et al., 2017). This was especially evident in 2014-2015, when the Pacific Coast experienced unusually warm SSTs due to the marine heat wave and El Niño conditions (Leising et al., 2015). Consequently, nursing females were not able to provide enough energy for their pups to grow, pups weaned too early or weaned in poor condition, and large numbers of pups stranded along the California coast in 2015 (McClatchie, 2016). When ocean conditions began returning to neutral conditions in 2016, sea lions responded fairly quickly with higher numbers of pup births, reduced pup mortality and improved pup condition and growth, further supporting their utility as an indicator of CCS conditions.

Harmful algal blooms periodically occur along the California coast, especially during years when water temperatures are unusually warm. During the 2014-2015 marine heatwave, a record-breaking algal bloom extended across the entire west coast, and included the phytoplankton *Pseudo-nitzschia*, which produces the neurotoxin domoic acid. This toxin can enter the marine food web, contaminate sea lion prey species and pose a threat to foraging sea lions and their offspring. Although incidents of sea lion poisoning from domoic acid have been reported, scientists have not quantified the effects of this toxin on sea lion pup births and growth. However, in a warming marine environment, harmful algal blooms and related toxins may become an increasingly important threat to the coastal food web, including the sea lion population.

Technical considerations

Data characteristics

San Miguel Island, California (34.03˚N, 120.4˚W), contains one of the largest colonies of California sea lions. The Point Bennett Study Area contains about 50 percent of the births that occur on San Miguel Island and provides a good index of trends for the entire colony. This site has been used as a long-term index site since the 1970s for measuring population parameters.

Population indices (live pups, pup mortality, pup growth) were measured by observers at San Miguel Island. Because of the large size of the colony, index sites were used to estimate population parameters.

Live pups were counted after all pups were born (between 20–30 July) each year. Observers walked through the study area, moved adults away from pups, and then counted individual pups. A mean of the number of live pups was calculated from the total number of live pups counted by each observer. The total number of births was the sum of the mean number of live pups and the cumulative number of dead pups counted up to the time of the live pup survey.

Pup mortality was assessed to calculate mortality at 5 weeks of age, 14 weeks of age, and the total number of pups born. Pup mortality surveys conducted every 2 weeks from late June to the end of July were used as an index of pup mortality at 5 weeks of age and to calculate total births for the study area. A final survey was conducted the last week of September to estimate pup mortality at 14 weeks of age. On each survey, dead pups were removed from the breeding areas as they were counted. The total number of observed dead pups for each survey described the temporal trend in pup mortality and was an estimate of the cumulative mortality of pups at 5 weeks or 14 weeks of age. Cumulative pup mortality rate was calculated as the proportion of the number of pups born in each year that died by 5 weeks of age or 14 weeks of age of the total number of pups born in each year.

Female sea lion **pup growth rates** are shown in Figure 3. Data for male pup growth rates (not presented) show the same trend over this 18-year period. To estimate sea lion pup growth rate, between 310 and 702 pups were selected from large groups of California sea lions hauled out in Adams Cove (part of the Point Bennett Study Area) over 4–5 days in September or October in each year (pups about 14 weeks old). Pups were sexed, weighed, tagged, branded, and released. Because the weighing dates were not the same in each year, the weights were standardized to an October 1 weighing date. A mean daily weight gain rate multiplied by the number of days from the weighing date to October 1 was added or subtracted from the pup weight based on the number of days before (–) or after (+) October 1 when the pup was weighed. The number of days between October 1 and the actual weighing day was included as a parameter (days) in models to describe the annual variability in pup weights. Similarly, pups were recaptured in February a second time and weights were adjusted to a February 1 date to determine growth rate between October 1 and February 1. Growth rate data are missing in 2011 because the investigators were unable to conduct field sampling in February of that year.

The response of sea lions to warmer ocean conditions was determined from models of SST and the sea lion population indices (Melin et al., 2012). Sea surface temperature anomalies were calculated from seven buoys along the central coast (from San Luis Obispo to the San Miguel Island area). This length of coastline represents the foraging range of the juvenile and lactating female sea lions. The buoy data were obtained from the NOAA National Data Buoy Center (http://ndbc.noaa.gov/rmd.shtml). The mean daily SSTs from the seven buoys were used to calculate mean monthly SSTs and averaged to create monthly sea surface temperature anomaly indices for the years 1997 to 2016 used in the analysis.

Strengths and limitations of the data

The study area represents about 45 percent of the US sea lion breeding population (Melin et al., 2010), thus providing a representative measure of trends in population responses to changes in the ocean environment. Because the area is large, index sites across the colony were used to measure population parameters. Instead of using total counts for pup production and mortality, mean values were used to estimate these parameters.

The use of SST from buoys represents a very localized view of ocean conditions at the surface but does not reflect more complex oceanographic processes occurring offshore or deeper in the water column that also may influence prey availability and the resulting population responses.

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