Ontogeny of Foraging Behavior of the Immature California Sea Lion (*Zalophus californianus*): Spatial Patterns & Oceanographic Variables

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ABSTRACT

The California sea lion (*Zalophus californianus californianus*) is a marine mammal that leads an amphibious existence. During their ontogeny they undergo a purely terrestrial phase after birth relying on their mother's milk and with age they gradually forage independently in the aquatic environment. During this transition, the animal is able to store more oxygen in its lungs, blood, and muscles as it grows, which allows it to dive to greater depths, travel longer distances, and forage on a greater variety of prey. As part of a multidisciplinary study to determine some of the ecosystem factors that influence ontogeny of juvenile sea lions, we characterized oceanographic variables (sea surface temperature (SST), near-surface chlorophyll-*a* concentration (CHL*a*), and bathymetry) with sea lion observed location data on a monthly basis. These variables, which were obtained using remote sensing satellite imagery, were used as proxies for marine resources. Satellite transmitters (SirTrack KiwiSat Platform Transmitter Terminal (PTT), Havelock North, New Zealand) were attached to immature (pup, yearling, and 2-year old) sea lions (n = 12, 10, 4, respectively) at San Miguel Island, California (34.03ºN, 120.44ºW) to determine if patterns differed spatially among ages classes. Instrument deployment began during 2002 and individuals from the same age cohort were subsequently instrumented during 2003 and 2004. Preliminary results indicate that sea lion at-sea locations were distributed in warmer, more productive, and shallower waters compared to the range of variation that was available to them. Further examination of the data will provide a better insight on the relationship between spatial use patterns of maturing sea lions with oceanographic features that influence their prey distribution.

Juvenile California sea lions were captured and instrumented at San Miguel Island, Channel Islands during 2002 through 2004.

OBJECTIVE

The objective of this study is to determine if the relationship between immature sea lion spatial patterns and oceanographic variables can be used to characterize sea lion development.

METHODS

DATA PREPARATION:

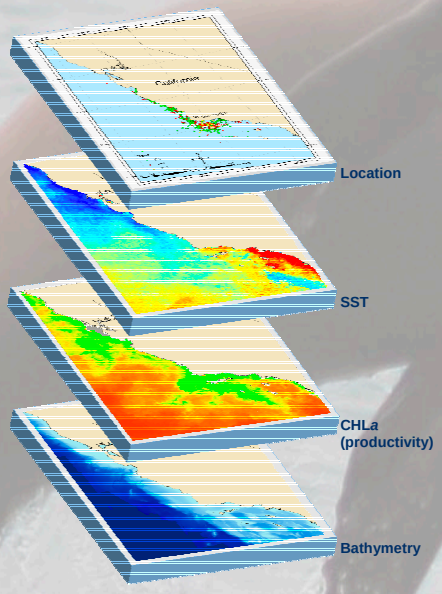
Spatial distribution. Monthly location data of each sea lion equipped with a PTT were obtained from Service Argos Inc. Only at-sea location data were used in analysis.

Oceanographic variables. Monthly SST and ocean color/productivity (CHL*a*) data (4km resolution) were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the EOS-Terra satellite from NASA's Goddard Earth Sciences, Distributed Active Archive Center website (http://daac.gsfc.nasa.gov). Bathymetry data (1km resolution) were acquired from NOAA's National Geophysical Data Center (http://www.ngdc.noaa.gov).

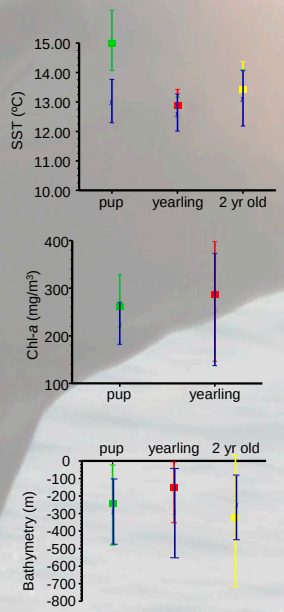
Geographical Information System (GIS). Position data of each age class were converted from point location to raster. Oceanographic variable data were transformed to raster format using ARC Macro Language (AML) scripts in ESRI ArcInfo. All data sets were transformed to the same grid scale (4km x 4km) using the spatial analyst module in ESRI ArcMap 8.3 software.

DATA CHARACTERIZATION:

Cells that contained sea lion location data were combined and characterized as "zones of use". Rectangles were made enclosing all areas that encompassed the spatial extent of sea lion locations. These areas were characterized as "available environmental zones". Zonal statistics were applied to monthly spatial patterns of each sea lion and the corresponding oceanographic variables. Resulting data were pooled and averaged for each age class. Comparisons of "zones of use" and "available environmental zones" were made using Student's t-test.



Data sets in raster format that were included in ESRI Arcmap software for analyses.



Mean values of oceanographic variables underlying zones of spatial patterns of immature sea lions. **Blue bars** indicate mean values of "zones of availability". Error bars indicate standard deviation.

RESULTS

In general, zones representing sea lion at-sea locations had higher SST and CHL*a*, and lower bathymetry values compared to mean values of the corresponding "available" areas. Pups used significantly warmer water ($p < 0.025$) that was also more productive and shallower compared to what was available to them. Yearlings and 2-yr olds made maximum usage of environmental variation (with the exception of yearlings using significantly shallower waters than what was available ($p < 0.025$).

DISCUSSION

This study accents the applicability of remote sensing and GIS in examining the spatial relationships between oceanographic variables and sea lion activity patterns. Preliminary results of this study indicate that examination of sea lion spatial patterns along with corresponding oceanographic variables can be useful in providing information about the development of sea lion foraging behaviors.

Noteworthy was a preferential use by pups for warmer SST compared to the range of variability available to them. One could speculate that they are constrained to these waters because of thermoregulatory or physiological reasons.

Further examination of the data will provide a better insight on whether the spatial and temporal patterns of distribution and habitat preferences of conspecifics differ because of variation in their physical capabilities, biological requirements, past experiences, and life-history strategies.

Future work. Further analysis includes examining if there are correlations between spatial patterns of diving (i.e. foraging) activity of immature sea lions with the aforementioned oceanographic variables along with current flow, sea surface height, and distance to foraging location. Additionally, quantitative spatial modeling techniques (e.g. fractal dimension index) will be used to compare movements of conspecifics to determine important foraging zones and perhaps identify areas with important oceanography.

Juvenile sea lion instrumented with a Platform Terminal Transmitter (satellite instrument).

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Background photo provided by J. London