California sea lions: Historical diet patterns in relation to environmental changes

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California sea lions are one of the top predators in the California Current Ecosystem. Distributed from British Columbia, Canada to central Mexico. The U.S. population has been growing at an average annual rate of 4.1% since 1965. The U.S. population in 2012 was estimated at 340,000. No current estimate for population in Mexico and no current estimate for U.S. after 2013-2015 decline in pup production. 4 rookery-islands in southern California produce 99.7% of U.S. pups.
What did sea lions eat while the population increased?
What did sea lions eat while pup production decreased?
California sea lion diet study

• 1981-2015 diet study at San Clemente Island (SCI) and San Nicolas Island (SNI)
  • Seasonal scat collections
  • 16,449 scat samples processed
  • 1981-2009 analyzed and 2010-2015 partially analyzed;
• Environmental variables
  • Multivariate El Niño Index (MEI)
• Presence/absence of prey in scat samples.
  • Frequency of occurrence (FO%)
  • Split sample frequency of occurrence (SSFO%)
• Length of prey estimated from size of cephalopod beaks and fish otoliths.
  • Otoliths size corrected for erosion
• Anomalies derived from 1981-2007 seasonal mean values in FO%.
• Pup counts from literature and SWFSC surveys
California sea lion prey

- 133 species identified
  - Fish = 103
  - Shark = 4
  - Cephalopods = 25
  - Crustacean = 1

Mean SSFO% of sea lion prey

- Market squid
- Northern anchovy
- Pacific hake
- Shortbelly rockfish
- Pacific sardine
- Jack mackerel
- Pacific mackerel
- Non-common
Occurrence of prey in diet, 1981-2007, San Nicolas Island

- Anchovy dominated in 1980s
- Market squid dominated in 1990s and 2000s; and increased over time.
- Appearance of sardine in early 1990s replaced anchovy.
- Hake declined over time.
- Non-common taxa increased during El Niño's and decreased in La Niña's
Other 1981-2007 highlights

- More market squid eaten in autumn and winter than other seasons.
- During spring more anchovy consumed at San Clemente Island and more sardine consumed at San Nicolas Island.
- More non-common prey consumed in summer.
- More non-common prey consumed at San Clemente Island.
- More hake consumed at San Nicolas Island
Prey switching (1981-2007)

- Consumption of non-common taxa increased when pup production decreased—associated with El Niño conditions.
- When consumption of predominant prey decreased (e.g., anchovy and squid), other prey take over.
Size of common prey

- Size of prey varies by species (Mean = 13.4 cm)
- Mackerels are their largest prey.
- Will also consume very small prey (e.g., shortbelly rockfish).
Passage of prey cohorts in sea lion diet through time, San Nicolas Island

- Shortbelly rockfish cohorts: 3 to 6 years.

- Pacific hake cohorts: 2.5 to 3 years
Change (%) in FO% from 1981-2007 seasonal mean

- Drop in consumption of hake, anchovy, and sardine at both islands.
- Drop in consumption of mackerel at San Nicolas Island, but increase at San Clemente Island.
Increased consumption of non-common cephalopods and non-common fish at both islands during spring 2013 and spring 2015 UME.

Increased consumption of shortbelly rockfish at both islands in 2013 and 2015.

Increased consumption of market squid in 2012 and 2013, and average or below average consumption in 2015.
California sea lion trends (1975-2015)

GLM Stepwise Analysis

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<th>Effect</th>
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<tr>
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Multivariate El Niño Index (MEI)

California sea lion pup counts (U.S. stock)

California sea lion net pup production (U.S. stock)
El Niño (MEI) effect on California sea lion diet

La Niña vs. El Niño

- **Market squid**
  - La Niña: $y = -6.8x + 53.3$, $R^2 = 0.04$
  - El Niño: $y = -8.7x + 53.8$, $R^2 = 0.09$

- **Northern anchovy**
  - La Niña: $y = -4.9x + 29.2$, $R^2 = 0.03$
  - El Niño: $y = -2.2x + 32.8$, $R^2 = 0.005$

- **Pacific hake**
  - La Niña: $y = -4.8x + 29.3$, $R^2 = 0.07$
  - El Niño: $y = -0.5x + 19.7$, $R^2 = 0.001$

- **Non-common prey**
  - La Niña: $y = 4.8x + 34.9$, $R^2 = 0.06$
  - El Niño: $y = 5.4x + 31.0$, $R^2 = 0.08$

- **Pacific sardine (1992-2015)**
  - La Niña: $y = 5.7x + 28.3$, $R^2 = 0.05$
  - El Niño: $y = 2.5x + 28.9$, $R^2 = 0.01$

- **Shortbelly rockfish**
  - La Niña: $y = 3.1x + 16.8$, $R^2 = 0.04$
  - El Niño: $y = 0.3x + 10.8$, $R^2 = 0.001$

Locations:
- San Nicolas Island
- San Clemente Island
Summary

• Diet of California sea lions is never (quite) the same.
• Diversity in their diet varies with time – sometimes less diverse, sometimes more diverse.
• ENSO cycles influence what sea lions eat and how many pups are produced.
Acknowledgements

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