Developing marine food web models to evaluate blue whale, Cassin's auklet and salmon responses to long- and short-term variability in oceanography in the California Current

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Introduction:

- Regional upwelling delivers nutrients to the Gulf of the Farallones, California Current
- Productive blooms of phytoplankton, zooplankton, and predators characterize the region
- Pacific-basin scale interannual (SOI) and interdecadal (PDO, NPGO) climate set up regional conditions[1] and may lead to fluctuations in wildlife populations[2]

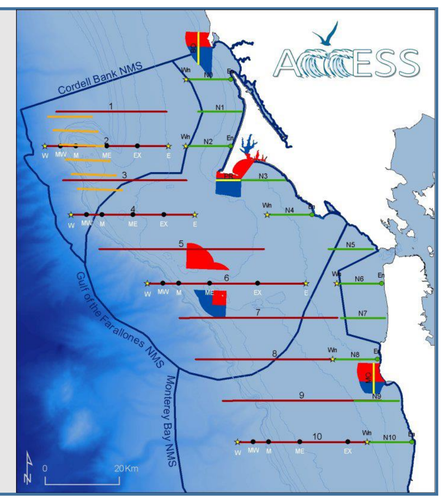
Methods:

- Cruises take an ecosystem approach to monitor from basic oceanographic processes to all levels of the food web
- We used 10 years of data to generate food web models using Path Analysis[3] (structured multiple regressions)
- Path Analyses tested all potential relationships among levels, standardized interactions, and all significant drivers remain below

Study Region:

Research vessels visited stations and surveyed standardized strip transects from Bodega Bay to San Francisco Bay including:

- oceanographic profiles (Temperature & Salinity)
- phytoplankton (chl-*a*)
- seawater samples (NO_3 & Si)
- plankton tows and acoustics (krill)
- observations (marine mammals & sea birds)



Results:

I.

Cassin's Auklet Density

Krill 30m

Chl-*a* 30m

NO_3 | Si

Thermocline ▲

Temp 30m | Salinity 30m

Upwelling

PDO | NPGO

SOI

R^2 = 0.25, n = 26 cruises

II.

Salmon Abundance

Krill 150m

Chl-*a* 150m

NO_3 | Si

Thermocline ▲

Temp 150m | Salinity 150m

Upwelling

PDO | NPGO

SOI

R^2 = 0.71, n = 7 years

III.

Blue Whale Density

Krill 90m

Chl-*a* 90m

NO_3 | Si

Thermocline ▲

Temp 90m | Salinity 90m

Upwelling

PDO | NPGO

SOI

R^2 = 0.32, n = 27 cruises

SOI = Southern Oscillation Index (El Niño = -SOI; La Niña = + SOI; Interannual)
PDO = Pacific Decadal Oscillation (Warm = +PDO; Cool = -PDO; Interdecadal)
NPGO = North Pacific Gyre Oscillation (Warm = -NPGO; Cool = + NPGO; Interdecadal)

Positive Direct Effect *beta* → Negative Direct Effect *beta* - - - ▸

I. Cassin's auklets associate with warm ocean temperatures and weak thermocline gradients. Interannual climate (SOI) influences upwelling, interdecadal climate (PDO, NPGO) and local water mass properties.

II. Salmon annual abundance (Sacramento Index)* modeled by smolt conditions are associated with NPGO, krill and cool nutrient-rich waters. Interannual climate influences interdecadal climate.

III. Blue whales associate with krill and the absence of chl-*a* fluorescence. Upwelling drives cooler temperatures and plankton production.

*Pacific Fishery Management Council Report 2015 Table II-1

Discussion:

- Predators do not respond uniformly to ocean conditions and prey resources
- Pacific basin climate influences predator abundance (Cassin's auklet and salmon)
- Local water mass properties drive all three predator densities
- Standing stock of phytoplankton determine krill biomass in all cases
- Krill is an important food source for all three predators; however according to our model Cassin's auklet depend more on local temperature and thermocline gradient that regulate prey availability than biomass
- The complexity of the marine food web and the traits of the various organisms involved needs inclusion in any model of top predators' responses to changing ocean conditions

References:
1. Di Lorenzo, E. *et al.* Synthesis of Pacific Ocean Climate and Ecosystem Dynamics. *Oceanography* **26,** 68–81 (2013).
2. Jahncke, J. *et al.* Ecosystem responses to short-term climate variability in the Gulf of the Farallones, California. *Prog. Oceanogr.* **77,** 182–193 (2008).
3. Wootton, J. T. Predicting direct and indirect effects : an integrated approach using experiments and path analysis. *Ecology* **75,** 151–165 (1994).

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