Ocean climate conditions, forage species and whale entanglements off California; 2013-2016

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Objective: Provide information on the distribution and abundance of forage species used by baleen whales to address past and future whale entanglement risks

- Evaluate the potential use of forage species indicators to understand whale distribution patterns
  - They go where the food is
- Review past space/time fluctuations of forage species
  - Krill abundance variability
    - Predictable hotspots
    - Shelf and pelagic
  - Anchovy variability and distribution shifts
  - Species indicators of anomalous ocean conditions
- Ocean conditions and forage species occurrence during 2013-2016
  - Indicator monitoring pre-, mid- and post-fishing season

Key Concepts

- Relationship between abundance and distribution
  - Abundance vs. patchiness
  - Fundamental aspect of swarming/schooling organisms
    - krill and forage fish population dynamics (world-wide)
  - May reflects 2 basic states (with gradients in between)
    - High abundance, more patches, greater distribution
    - Low abundance, fewer patches, reduced distribution
- Regional distribution shifts
  - Shelf and oceanic habitats
  - Movements from northern and southern California Current regions
  - Thermal habitat refugia
    - submarine canyons

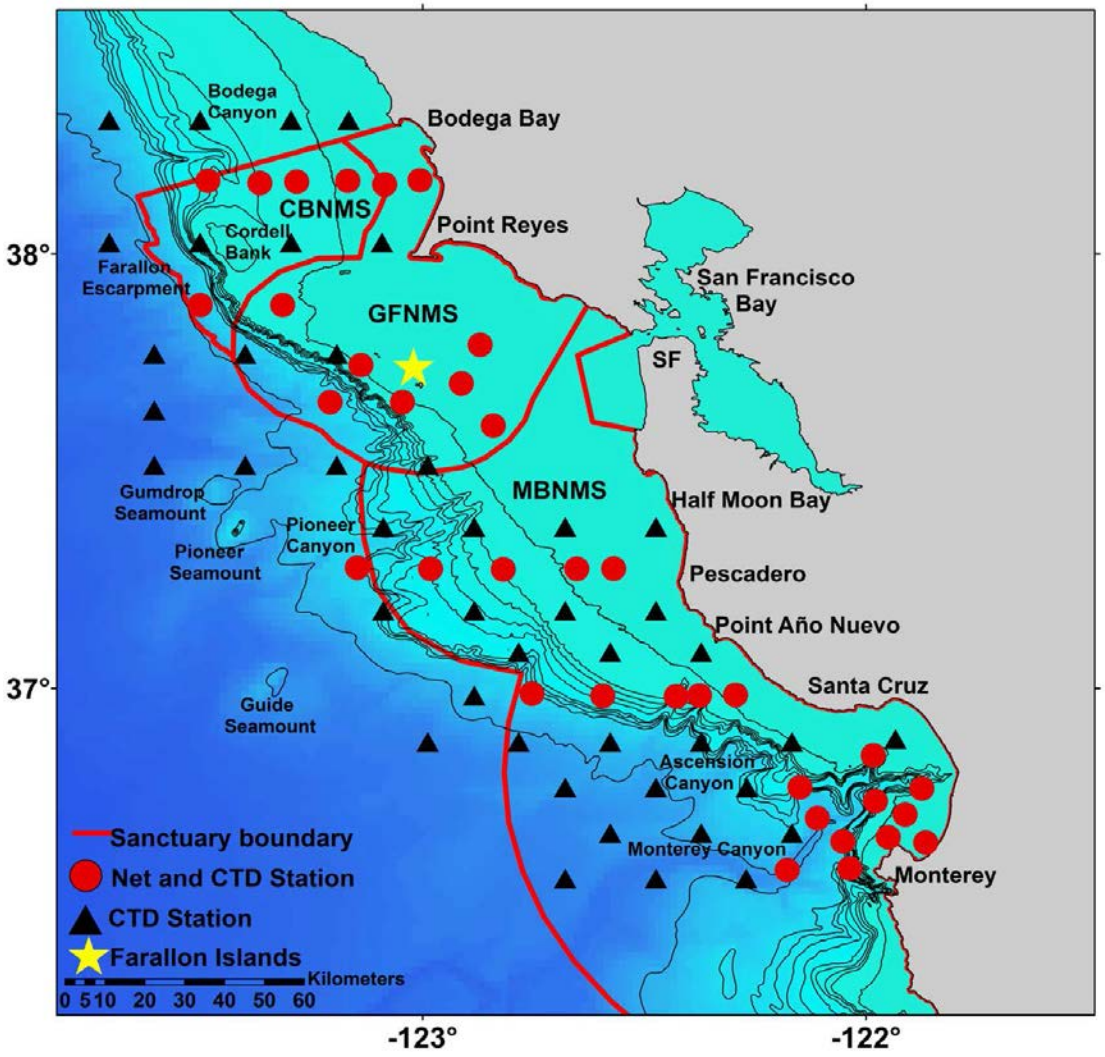
Key Concepts

- Ocean climate conditions drive abundance and distribution of forage species off central California:
  - High Krill abundance: favor cooler/stronger upwelling years, increased strength of California Current and influx of sub-arctic water
  - Anchovy: favor warm/weaker upwelling years, influx from the southern main spawning region in CA bight
    - Expansion
    - Contraction into coastal environments at low population sizes
- **Prey-switching** is a major foraging behavior utilized by highly mobile predators (seabirds, marine mammals)
  - display striking redistribution patterns in response to the availability of their prey
  - Predators display thresholds responses to prey species abundance and patchiness

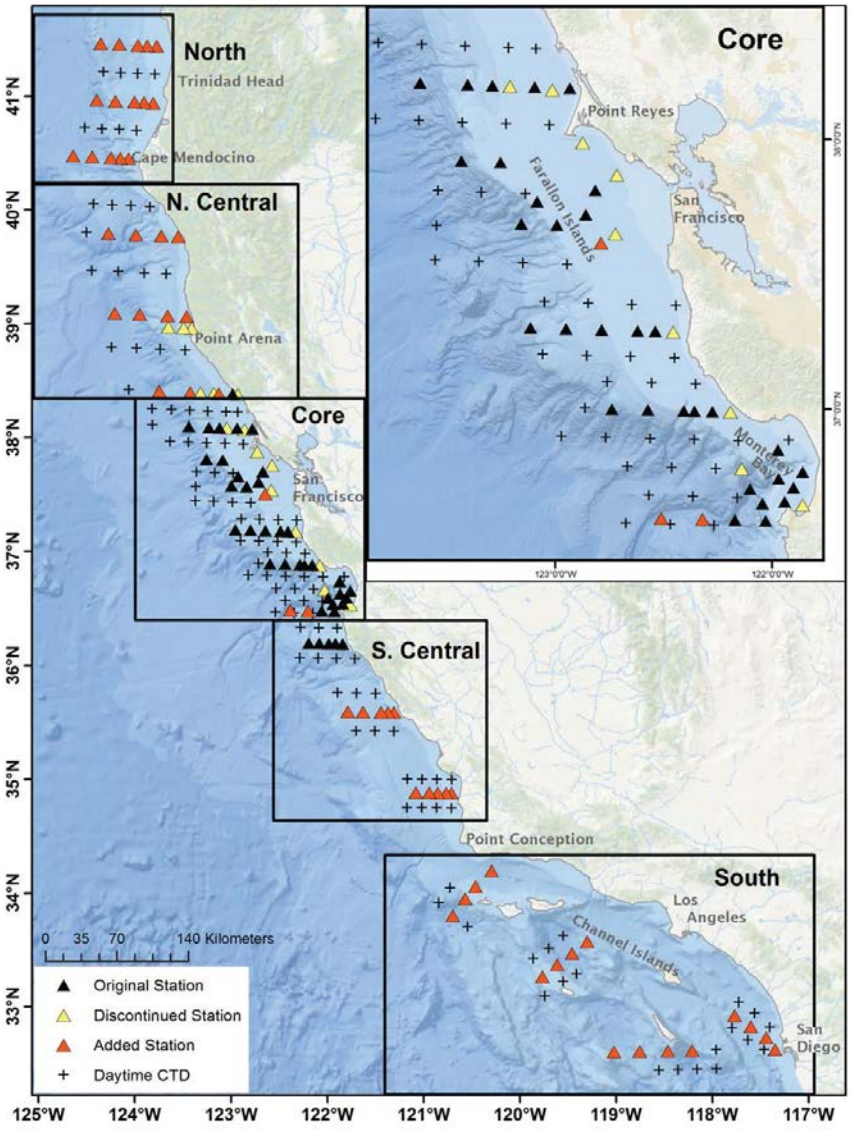
Baseline conditions of ocean climate conditions and forage species distribution and abundance

Rockfish Recruitment and Ecosystem Assessment Survey (RREAS); central California Region

- May-June; 1983-present
- Survey expanded in 2004 to cover entire CA coast
- Net targets 30 m depth; 15-minute haul; hydrographic (CTD) casts
- 35 core stations
- Sampled 2-3 times per survey
- Sub-divisions among Shelf, Oceanic and Monterey Bay sampling areas
- Designed to capture late-larval/early juvenile stages fishes, coastal pelagic species, as well as adult stages of krill (Euphausia), pelagic shrimps (e.g., Seregestidae) and gelatinous zooplankton (e.g., Scyphozoa and Tunicata).



NOAA Rockfish Recruitment and Ecosystem Assessment Survey (RREAS); California



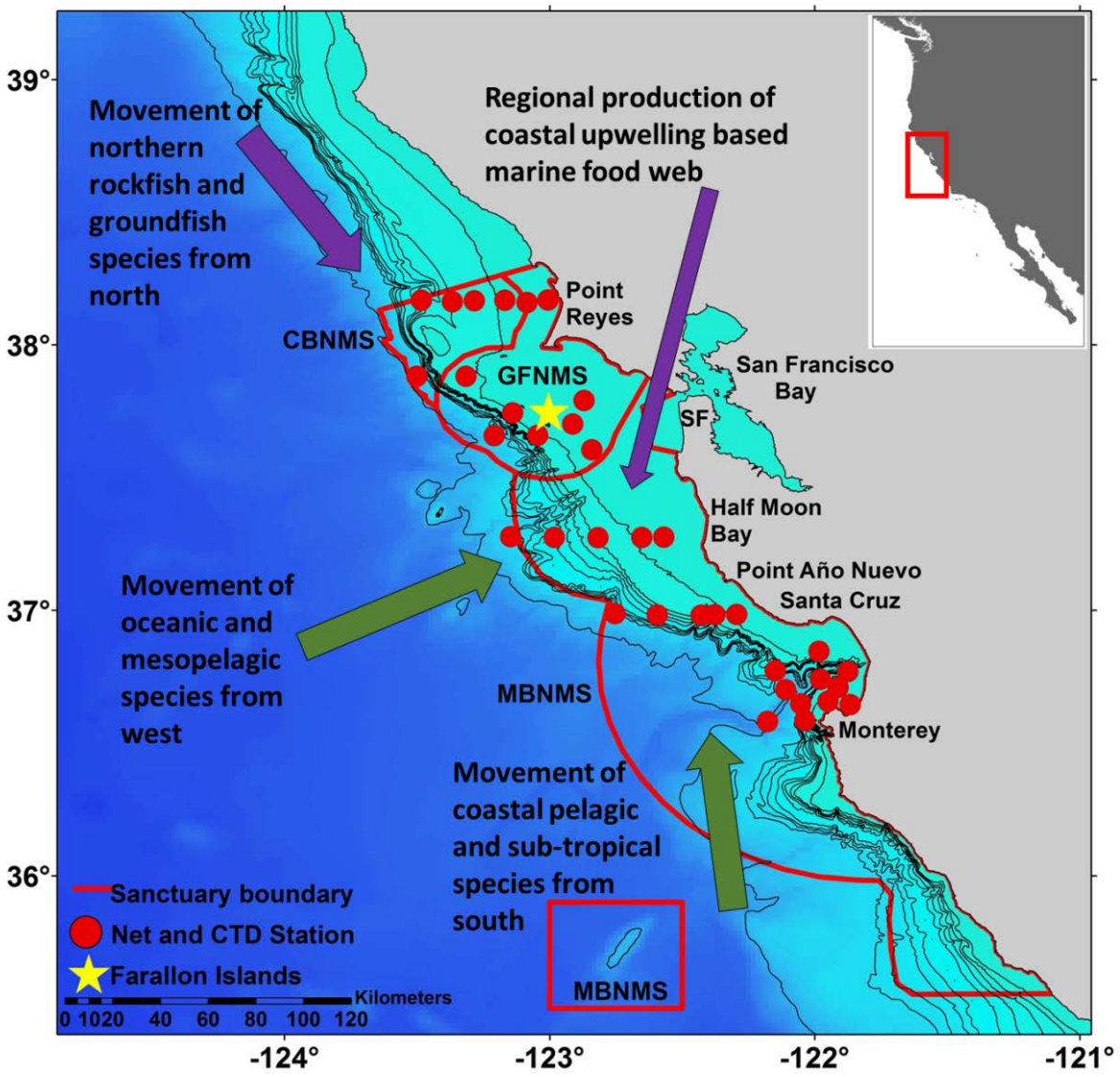
Rockfish Recruitment and Ecosystem Assessment Survey (RREAS); central California Region

Regional ecosystem oceanography: local production and regional shifts in forage species

Time series analysis of species abundance and diversity indicates two major indicators of variance (1) local/regional production of juvenile groundfish and krill populations and (2) coastal pelagic species (e.g., anchovy, squid), mesopelagic fishes and subtropical species

Arrows indicate generalized directional shifts of epipelagic species into the study region, representing northern, western and southern movement patterns.

National Marine Sanctuaries (NMS): Cordell Bank (CBNMS), Greater Farallones (GFNMS) and Monterey Bay (MBNMS).



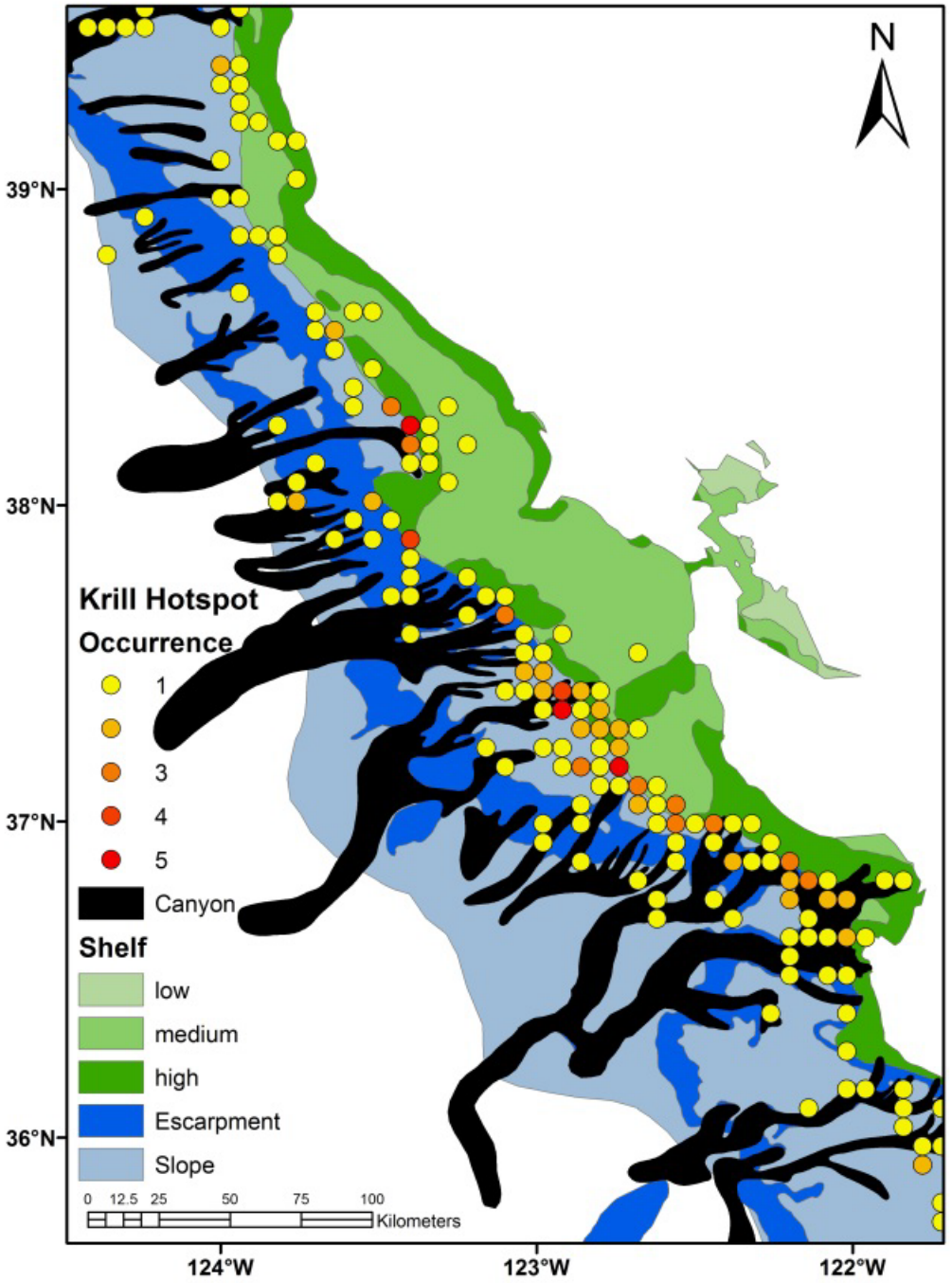
Krill Hotspots

Krill abundance hotpots are strongly associated with the shelf-break and submarine canyon heads. Hotspot intensity varies among years, but krill hotspot locations are predictable and persistent.

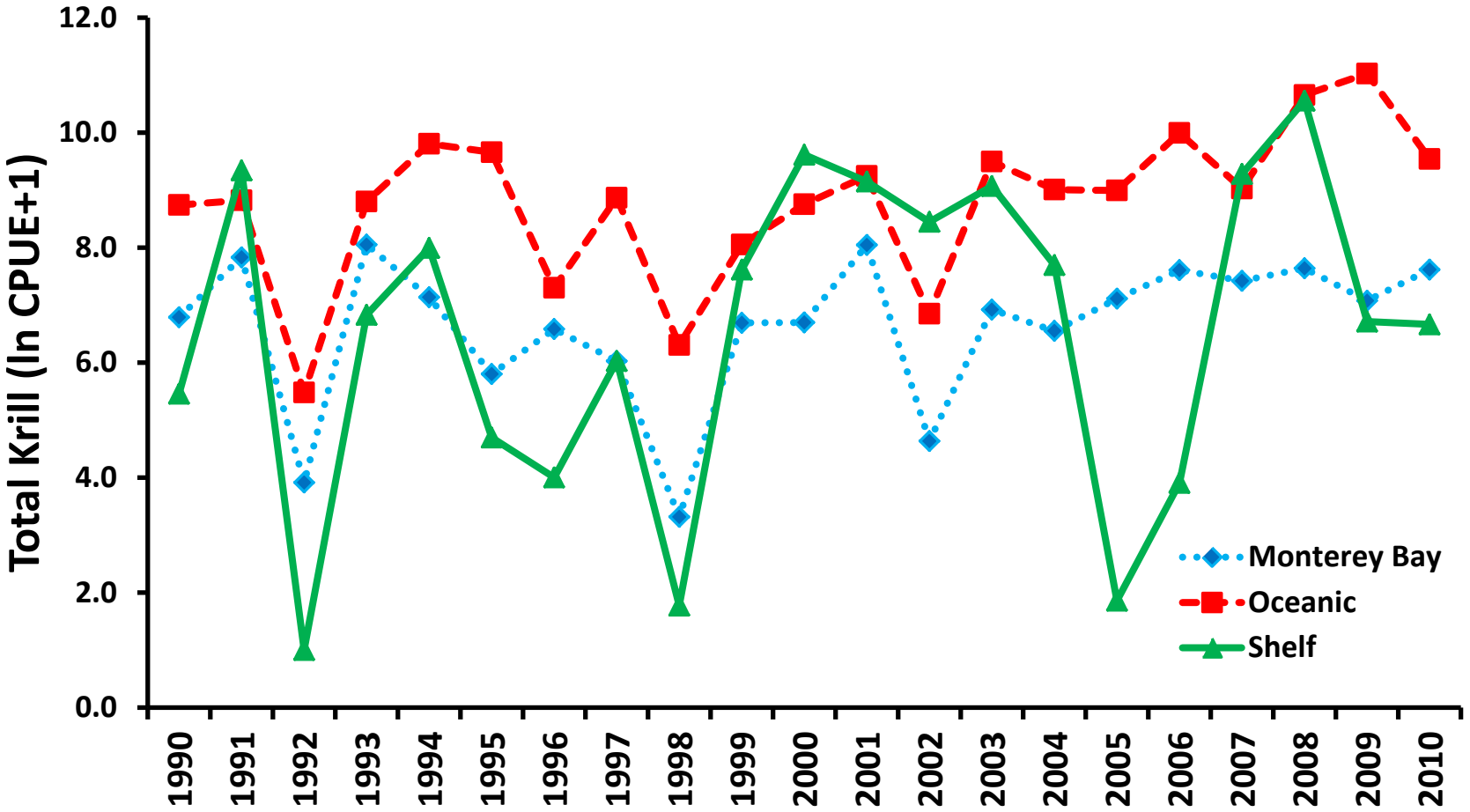
Disassociated from strong upwelling zones.

Predictive models are available.

Data derived from 15 years of hydroacoustic surveys sampled during NOAA-NMFS Rockfish Surveys; 2000-2015 (50K nautical miles sampled); Farallon Institute.

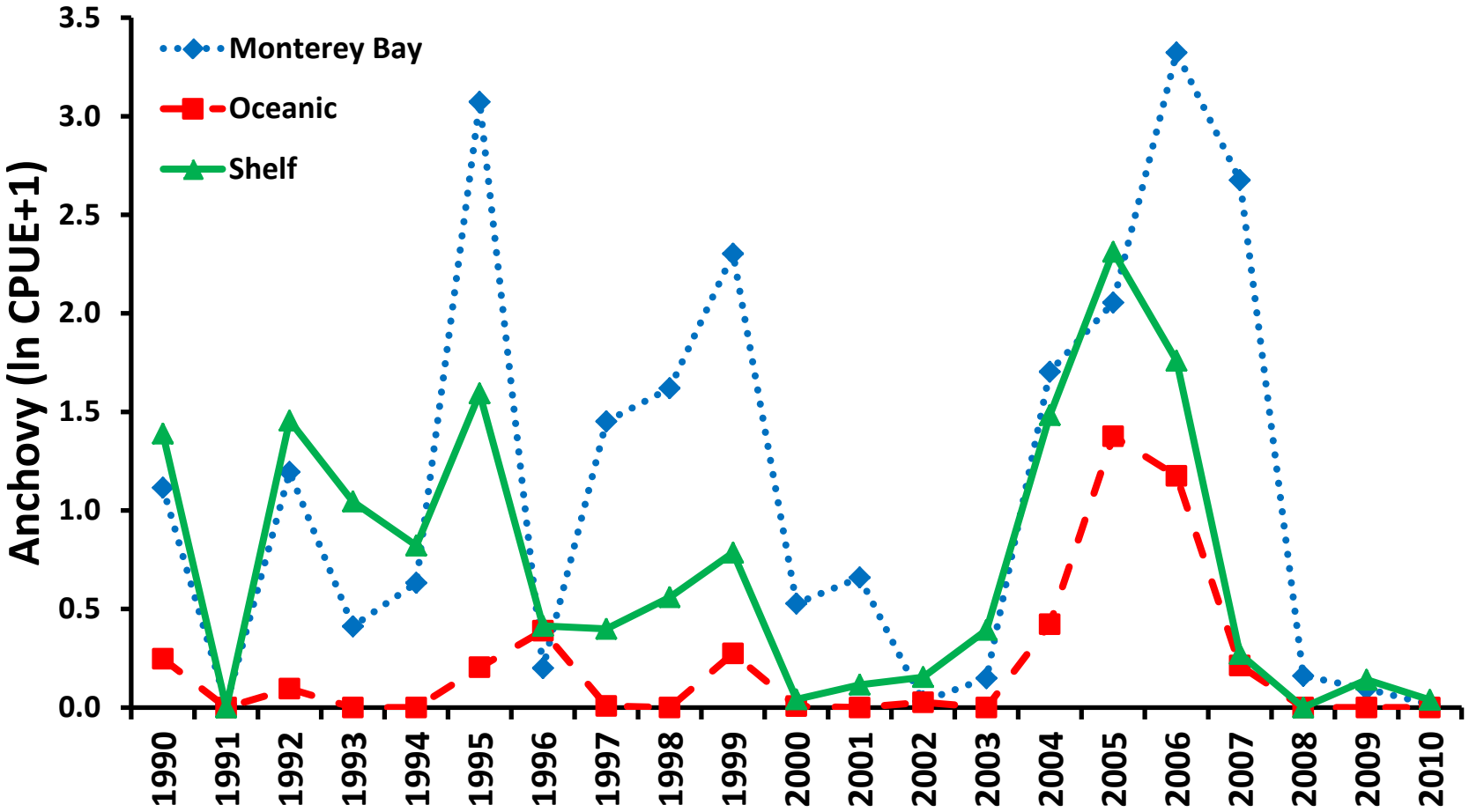


Krill variability (net hauls)



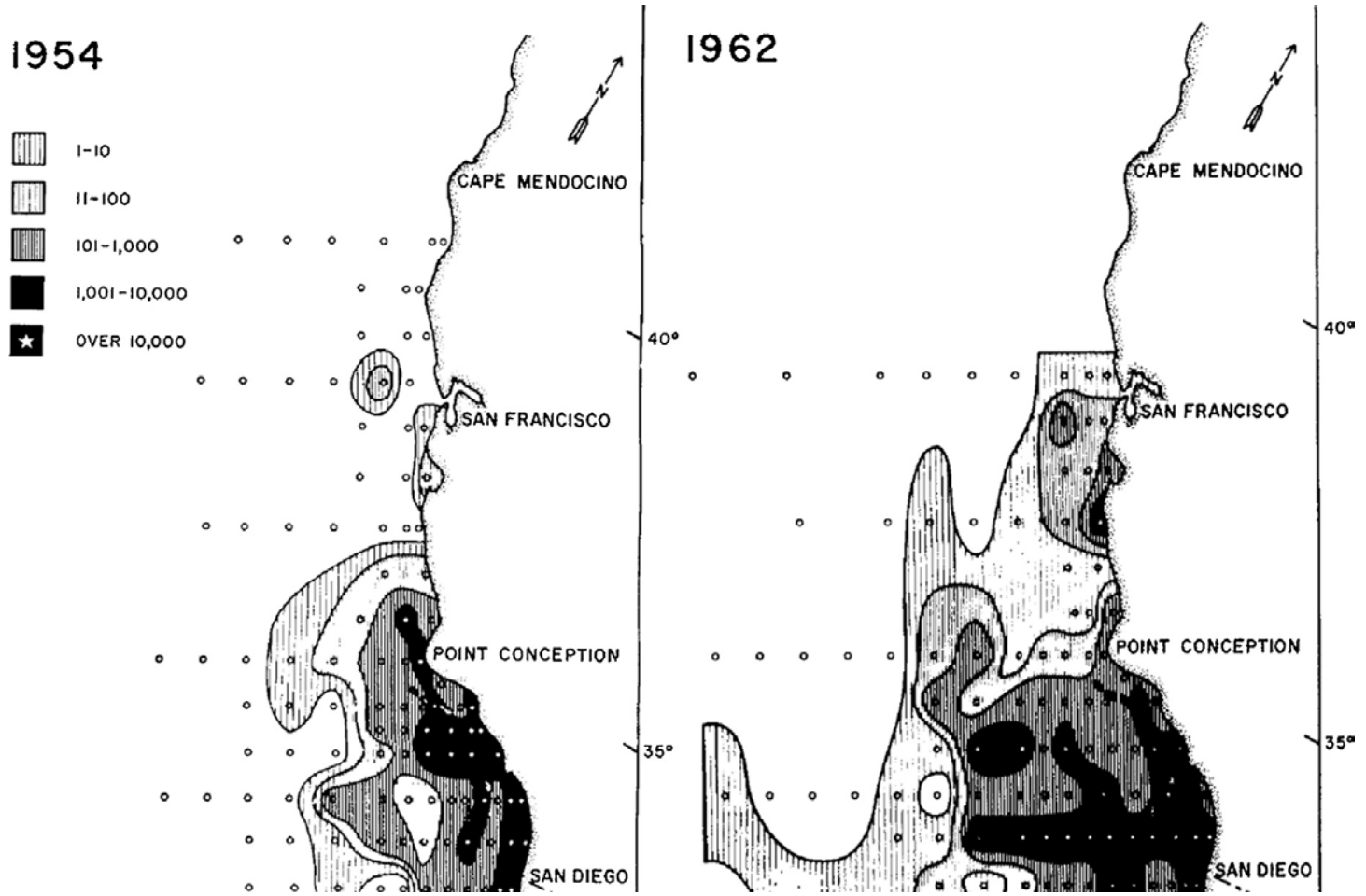
Note: Low frequency variability of shelf krill abundance is linked to variability of winter ocean conditions; declines in warm/weaker upwelling years

Anchovy variability (net hauls)



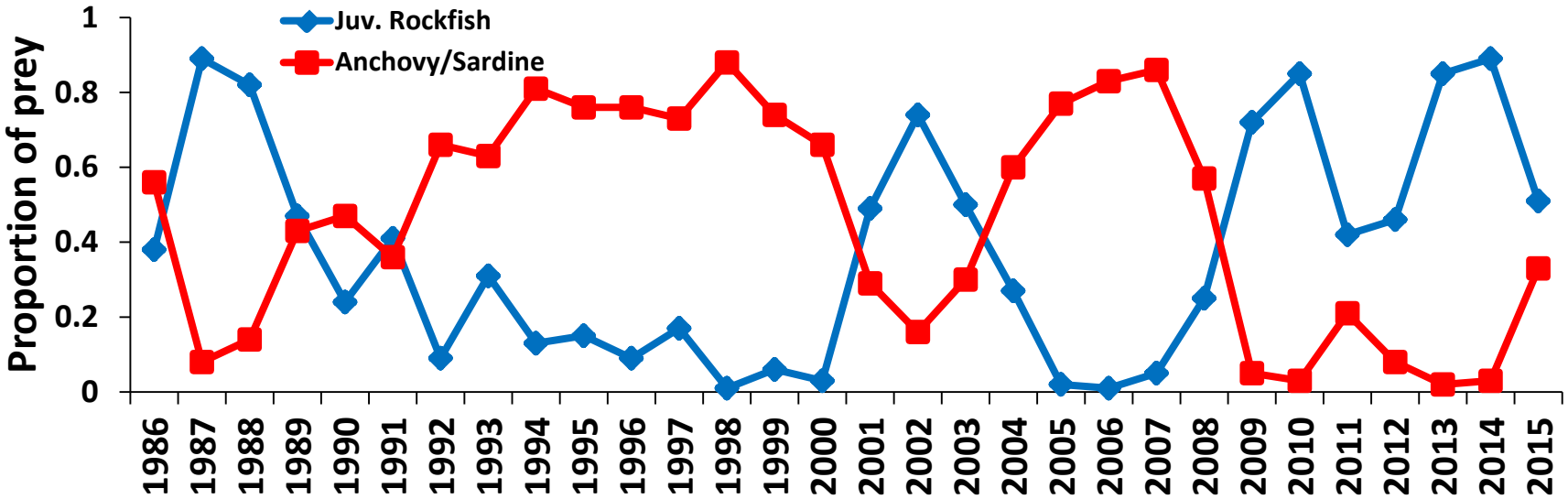
Note: Time series are episodic and variability is linked to warmer ocean conditions

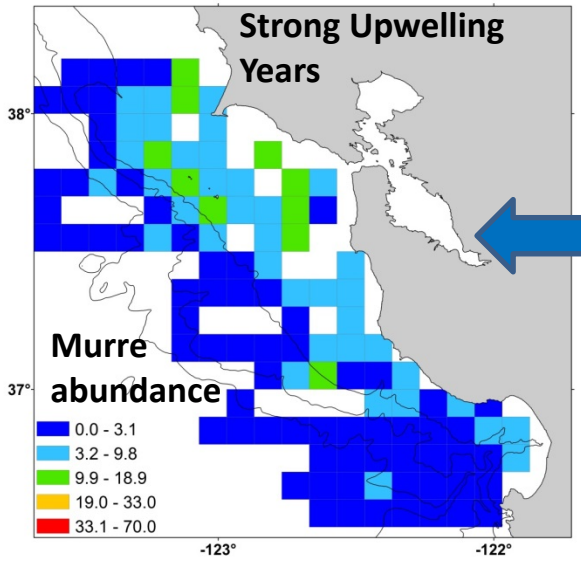
Past shifts in anchovy distribution and abundance



From Kramer and Ahlstrom (1968): Comparison of southern California anchovy larval distributions at low population size (left) and high population size (right) showing areal expansion when the stock is more abundant.

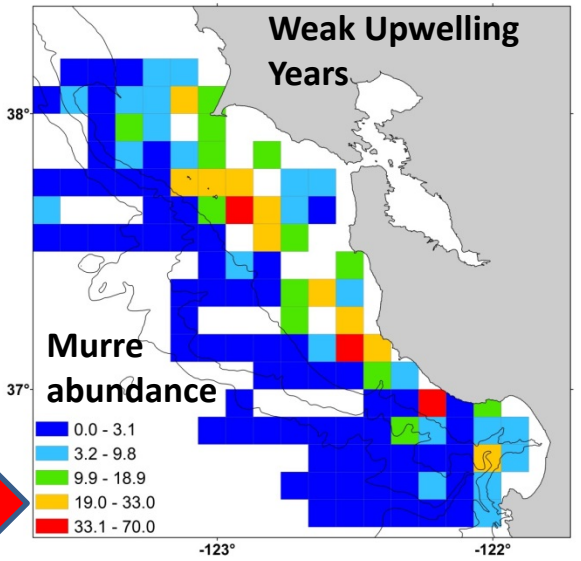
Common Murre diet (Southeast Farallon Island): Prey-switching and foraging distribution shifts





Fewer high density murre aggregations when feeding on juvenile rockfish (co-vary with strong krill years).

More high density murre aggregations when feeding on anchovy (co-vary with low krill years

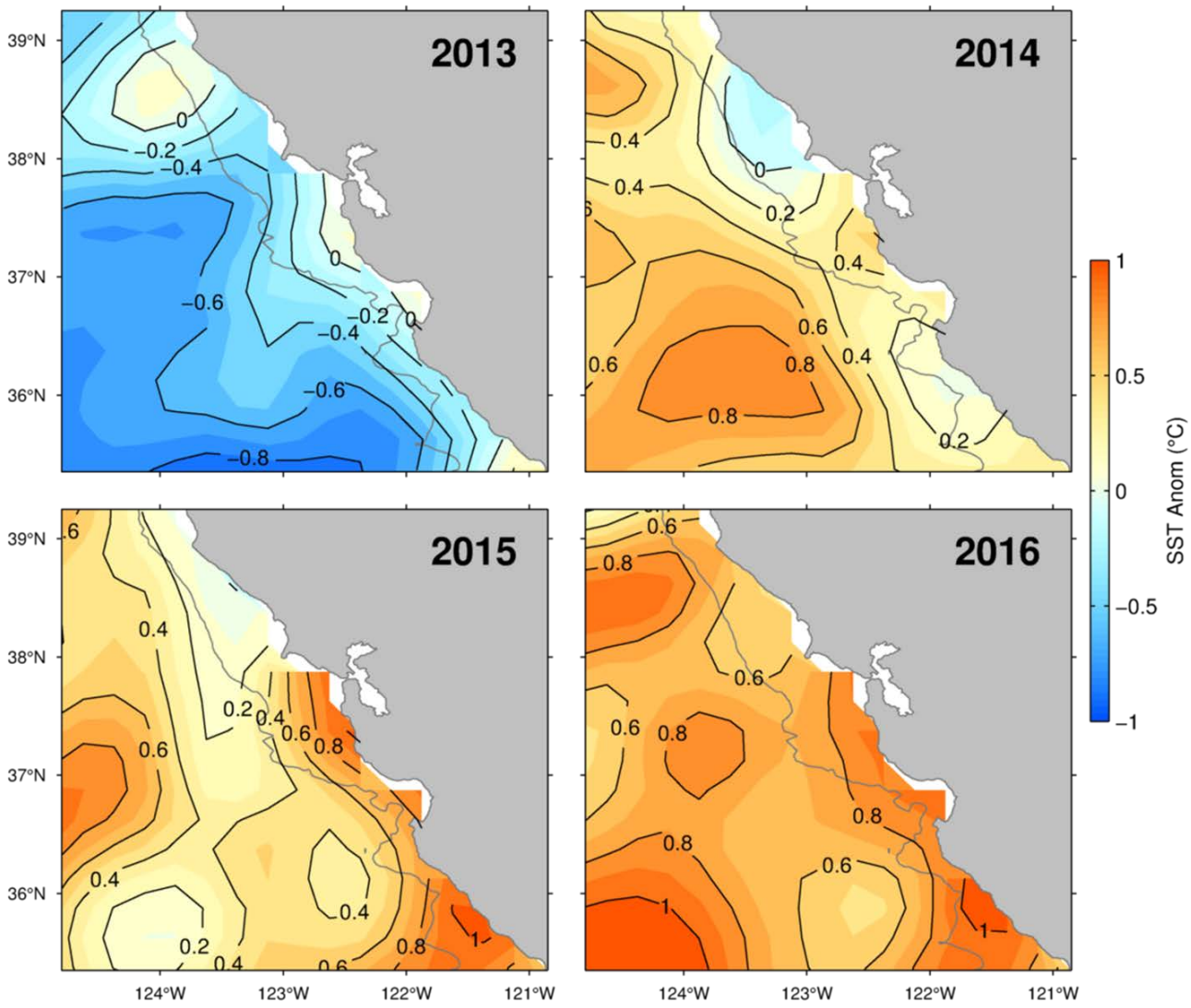


**Diet Data from Point Blue*

Ocean-climate conditions and distribution and abundance of forage species; 2013-2016

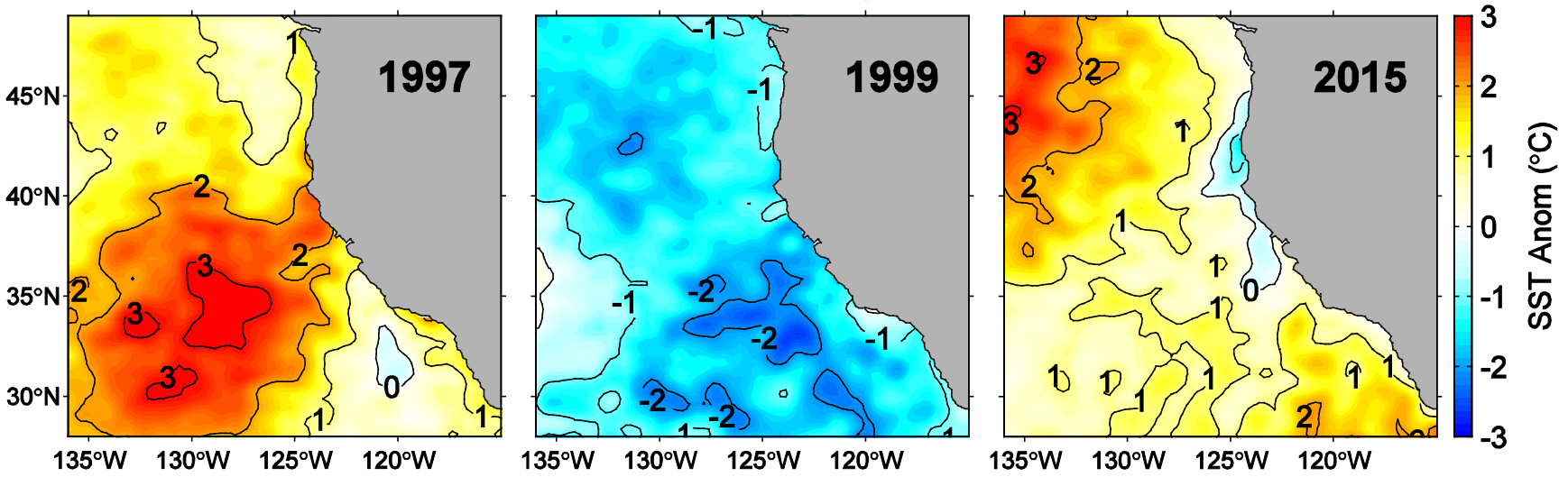
- Objectives:
  - Evaluate ocean temperature conditions
    - Regional and basin scales
    - Relative to past extreme climate events
  - Forage species diversity
  - Acoustic assessment of krill abundance and patchiness
  - Assessment of net-haul catches of krill and anchovy
  - Baleen whale sightings

Satellite sea surface temperature (SST) anomalies derived by subtracting May/June mean for a given year from the long-term May/June mean (1982-2016).

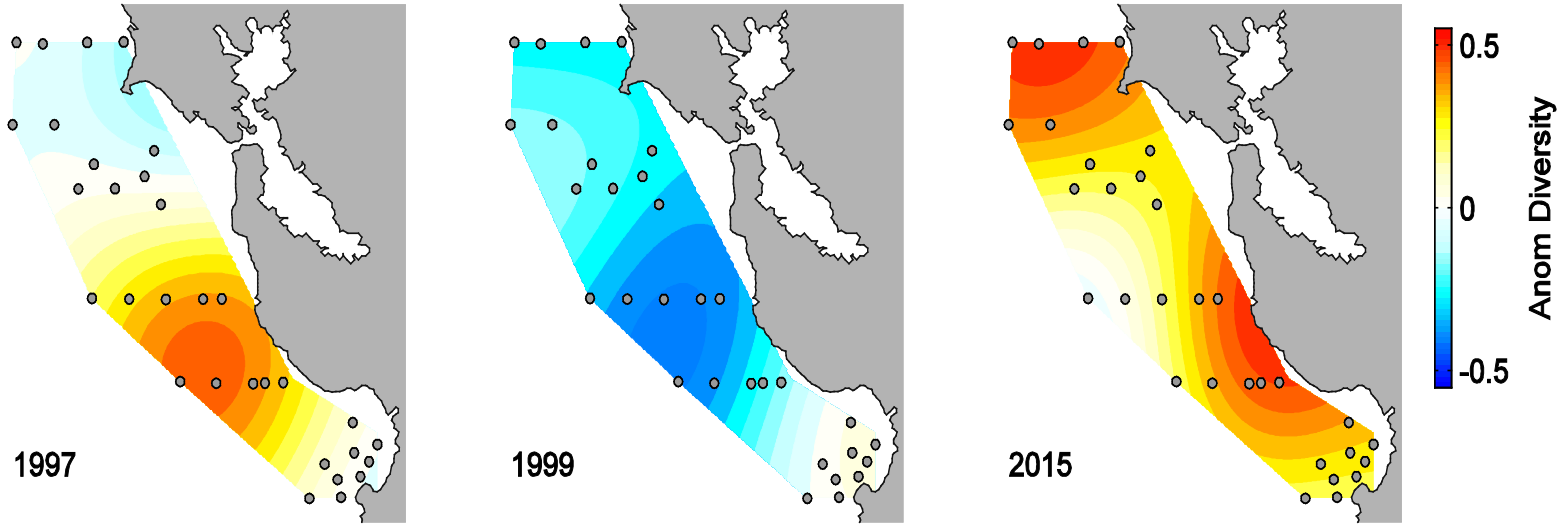


Ocean climate dynamics and forage species diversity

Satellite sea-surface anomalies: El Niño, La Niña and 2015

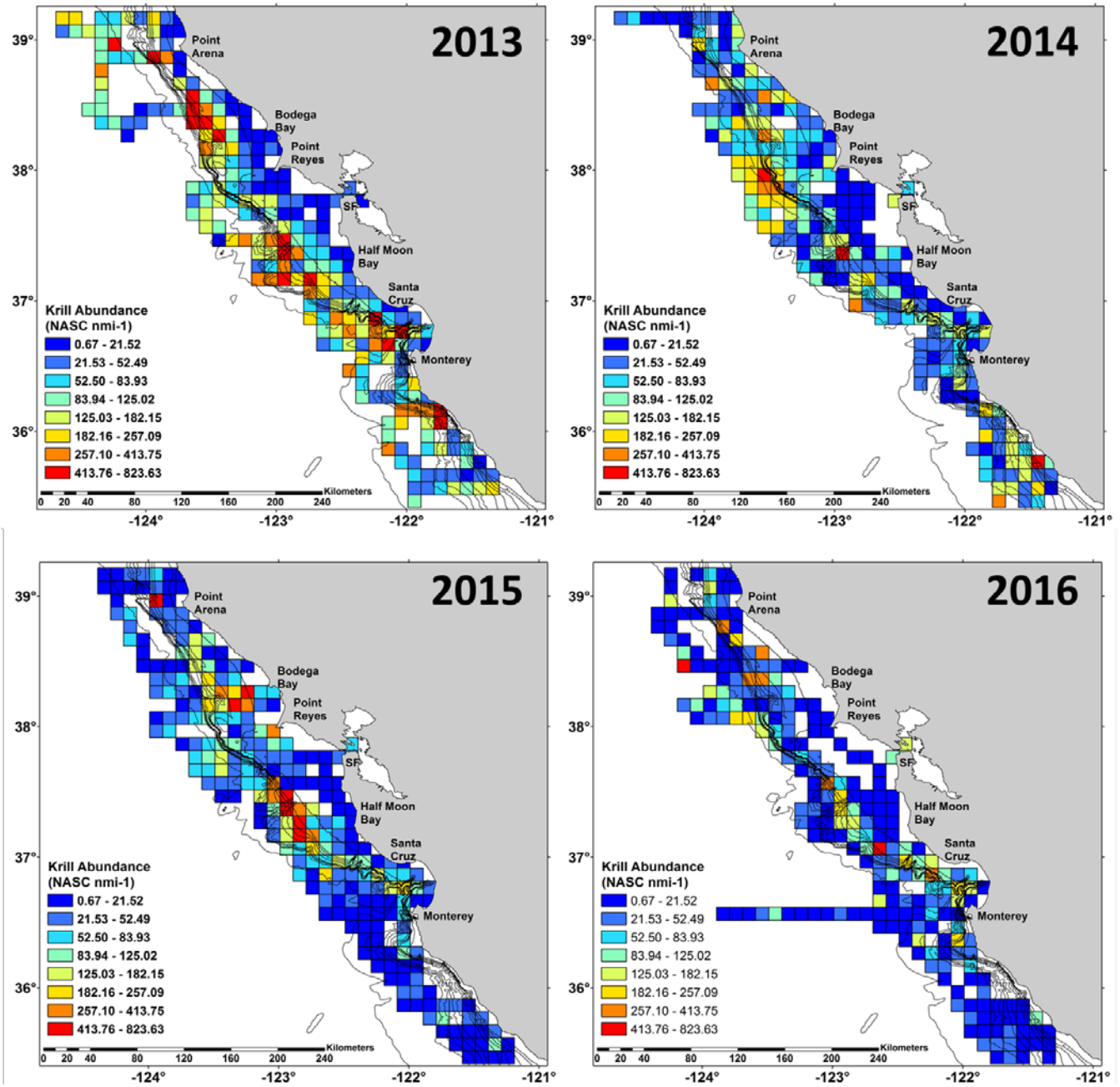


Sub-tropical and southern forage species diversity anomalies



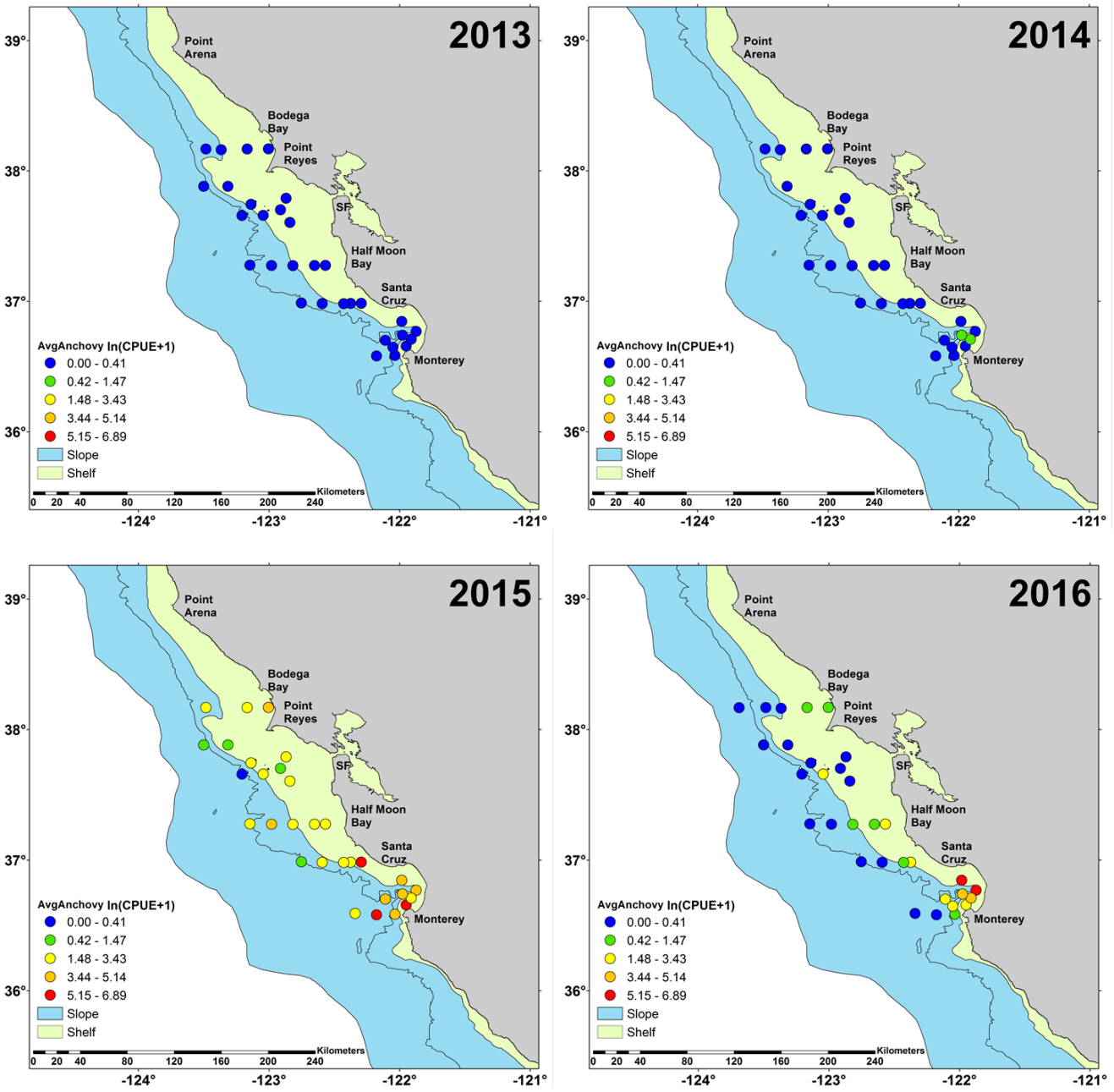
Acoustics Krill distribution & abundance (May-June; 2013-2016):

Recent acoustic observations indicate declines in abundance and spatial intensity



Net-hauls Anchovy distribution & abundance (CPUE, May-June; 2013-2016):

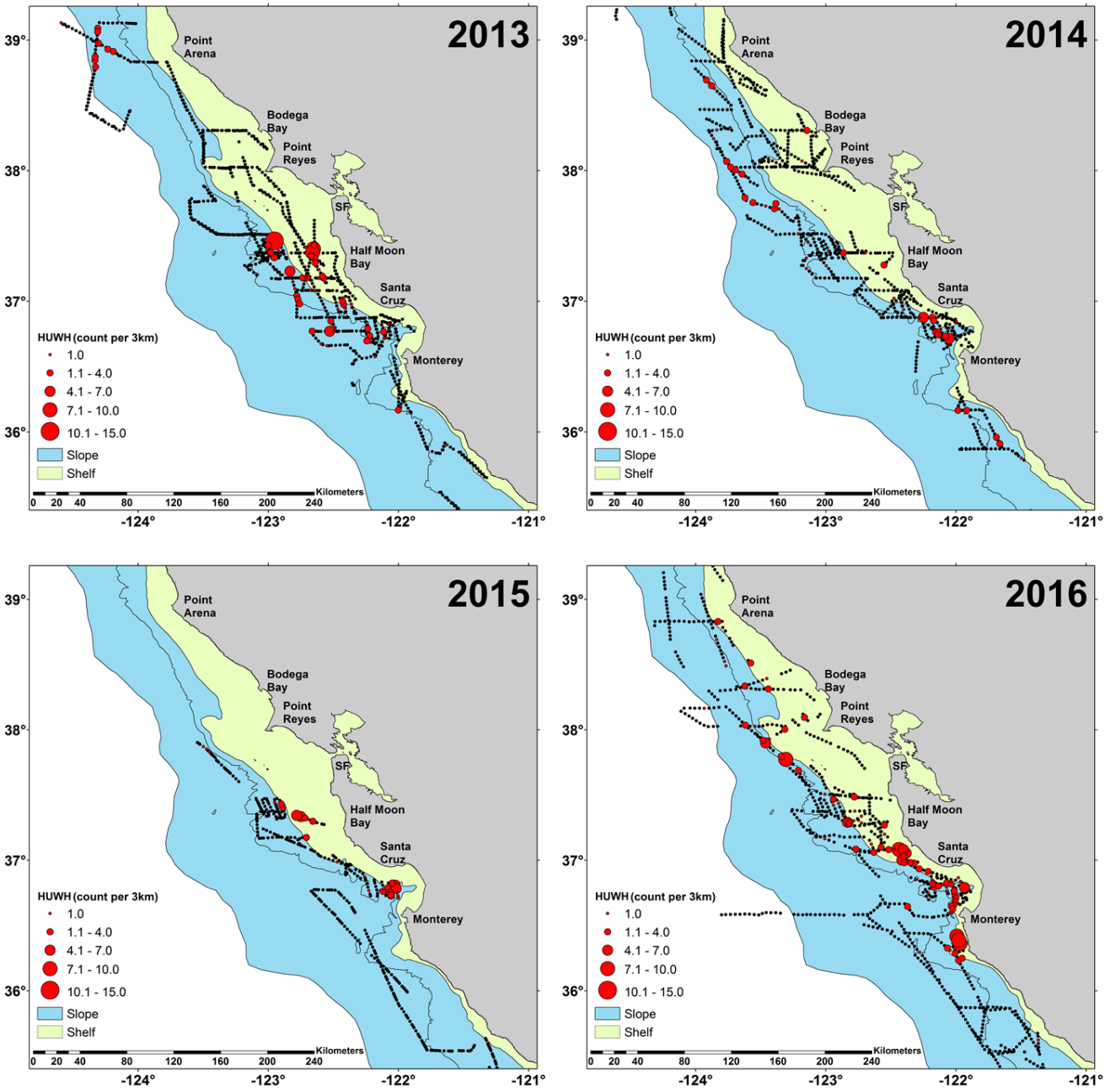
Recent observations indicate increases in abundance and spatial intensity



Humpback whale sightings (#/3km, May-June; 2013-2016):

Recent observations indicate increases in sightings and distribution shifts

Note: must consider whale sighting data from other surveys (incomplete)



Summary: 2013-2016

- Record upwelling in 2013 followed by anomalous warm sea surface temperature trend
  - different compared to previous El Niño's.
  - Influence of "the Blob"
- Krill abundance was high and hotspots were widely distributed during 2013
  - Followed by a decline in abundance and reduction in patchiness (e.g., fewer available patches in the outer shelf-break region) during 2015-2016.
- Unprecedented high diversity of forage species during large marine heatwave event of 2015; results in lower energy/lower abundant food web
- Increases in anchovy abundance, with high concentrations on the shelf; 2015-2016

RAMP
Ocean/Forage Indicators

- North Pacific Ocean Climate conditions
  - El Niño/La Niña state
    - October through January
  - Sea Temperature anomalies
    - December through March
- Forage abundance distribution
  - Krill and anchovy
  - Biodiversity of total forage species

Acknowledgements

- Dungeness Crab Whale Entanglement Working Group
- California Ocean Protection Council
- The Nature Conservancy
- NOAA-NMFS Southwest Fisheries Science Center, Fisheries Ecology Division
  - Rockfish Recruitment and Ecosystem Assessment Survey
- Point Blue Conservation Science
- Farallon Institute – collaborative effort on acoustic surveys and predator sighting information.