Ocean Climate Change and Phenology: Effects on Trophic Synchrony and Consequences to Fish and Seabirds in the North-Central California Current

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What is *Phenology?*

Study of the timing of key events across levels of biological organization from individuals to ecosystems:

- timing of upwelling, stream flow, ice retreat
- spring and fall dates of plankton blooms
- dates of spawning/parturition in fish
- dates of diapause in zooplankton
- dates of egg-laying in seabirds

Why be concerned with phenological climate change ?

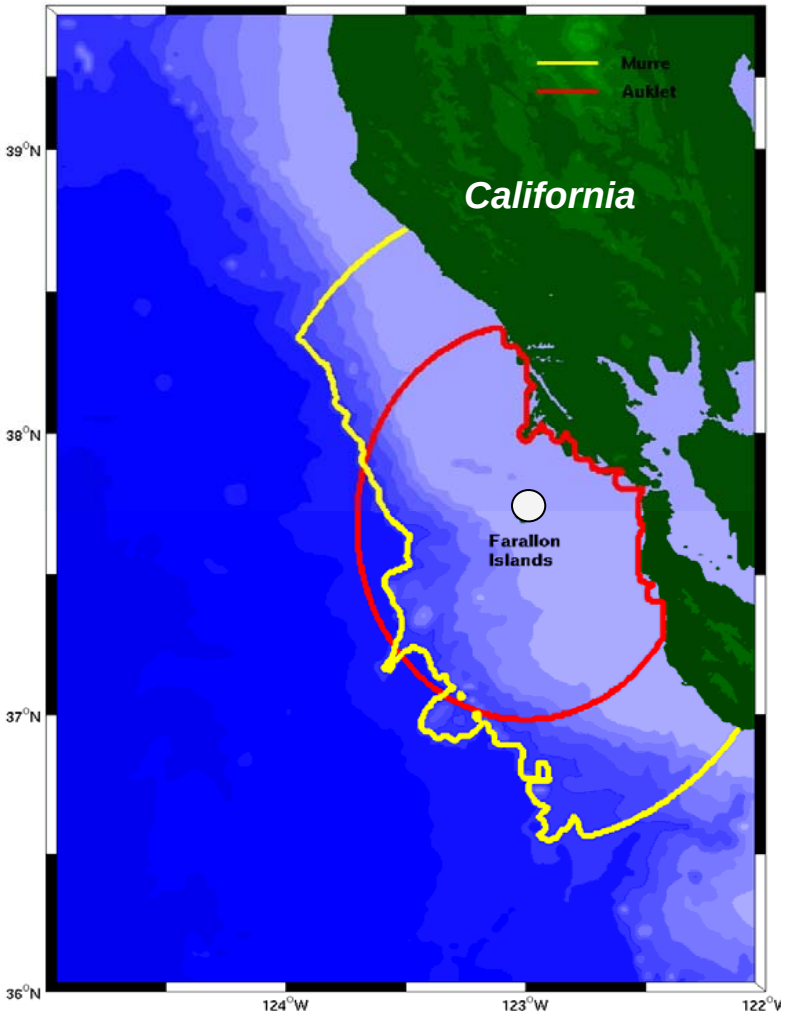
- Arguably the most conspicuous change in terrestrial, freshwater, and perhaps marine ecosystems
  - 10,000s of phenological time series show trends
- Species-specific variations in phenology can disrupt the synchrony of ecological interactions
  - e.g., predator-prey functional relationships, match-mismatch
- Disruptions in ecosystem function, persistence, & resilience of and the services they provide
  - i.e., fisheries, water quality

MOTIVATION FOR RESEARCH IN THE CALIFORNIA CURRENT: INCREASING ECOSYSTEM VARIABILITY (recent timeline of unusual events)

- Increasing seasonal upwelling (Schwing and Mendelssohn, 1997)
- Unusually early and strong upwelling, 1999 (Schwing et al. 2000)
- High salmonid returns, 2000-02 (PFMC, unpubl.)
- Low diatom/dinoflagellate ratio, 2004-2006 (MBARI, unpubl.)
- Delayed and weak upwelling, 2005 (Schwing et al. 2006)
- Unprecedented seabird reproductive failures, 2005-07 (Sydeman et al. 2006, 2009)
- Record low salmon escapement, 2007-2009 (Lindley et al. 2009)
- Invasion of Humboldt squid, 2005-2009 (Field et al. 2008)

Does Climate-Mediated Match-Mismatch Hypothesis explain any of this?

STUDY REGION



PREDATOR DATA SETS

yelloweye rockfish
(piscivorous)

splitnose rockfish
(planktivorous)

→ growth chronologies

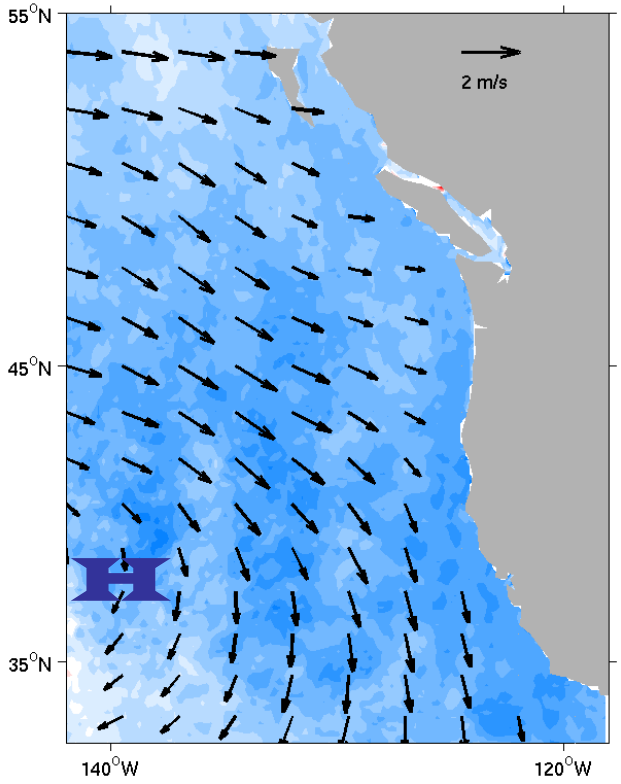
common murre
(omnivorous)

Cassin's auklet
(planktivorous)

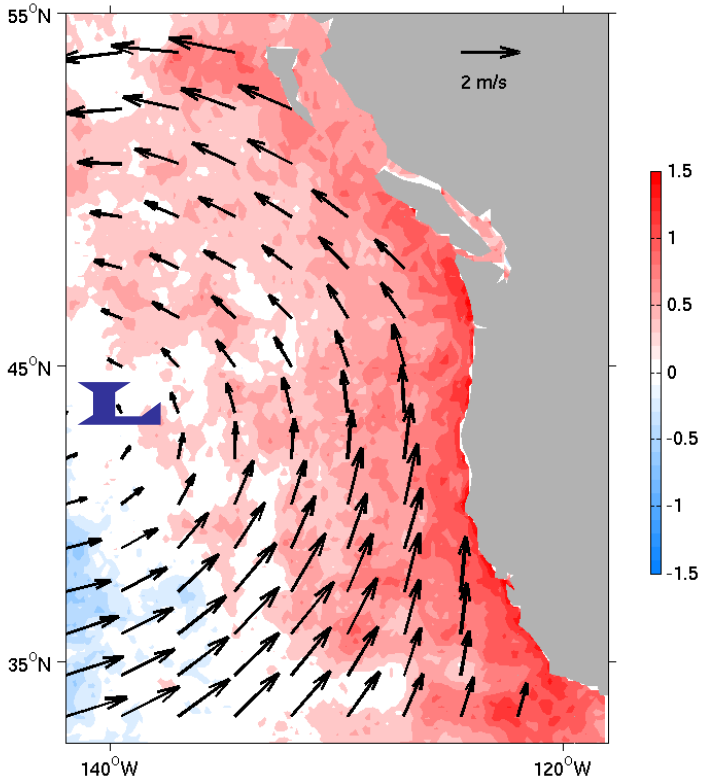
→ egg laying date & breeding success

Good (Early) & Bad (Late) Years for Cassin's Auklet

Four earliest Auklet mean egg-laying years



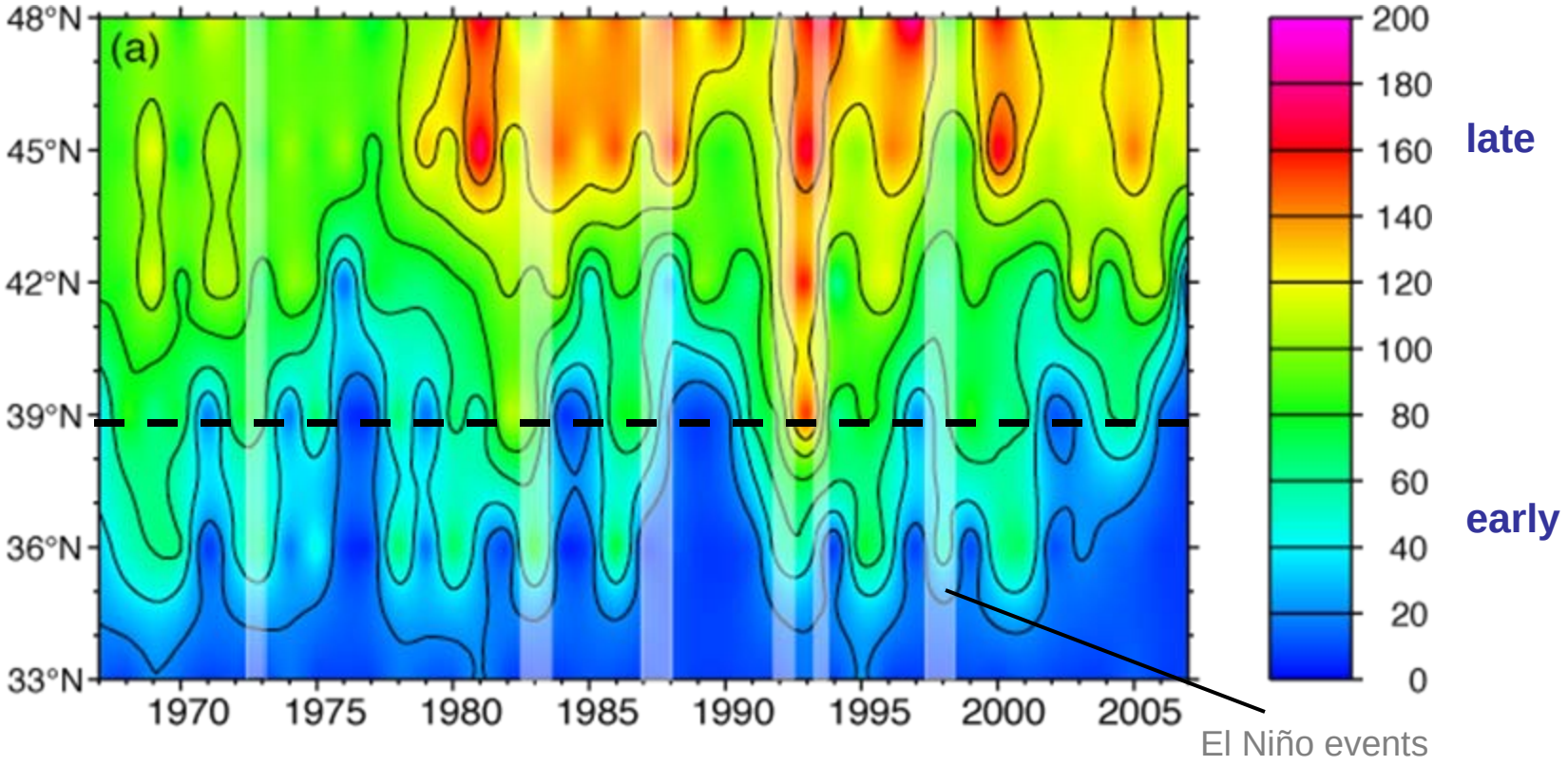
Four latest Auklet mean egg-laying years



- Jan-Feb mean winds (vectors) & Feb-Mar mean SST (colors)
- Good years: strong H, anomalously strong upwelling, cool SSTs
- Bad years: weak H, anomalously weak upwelling, warm SSTs

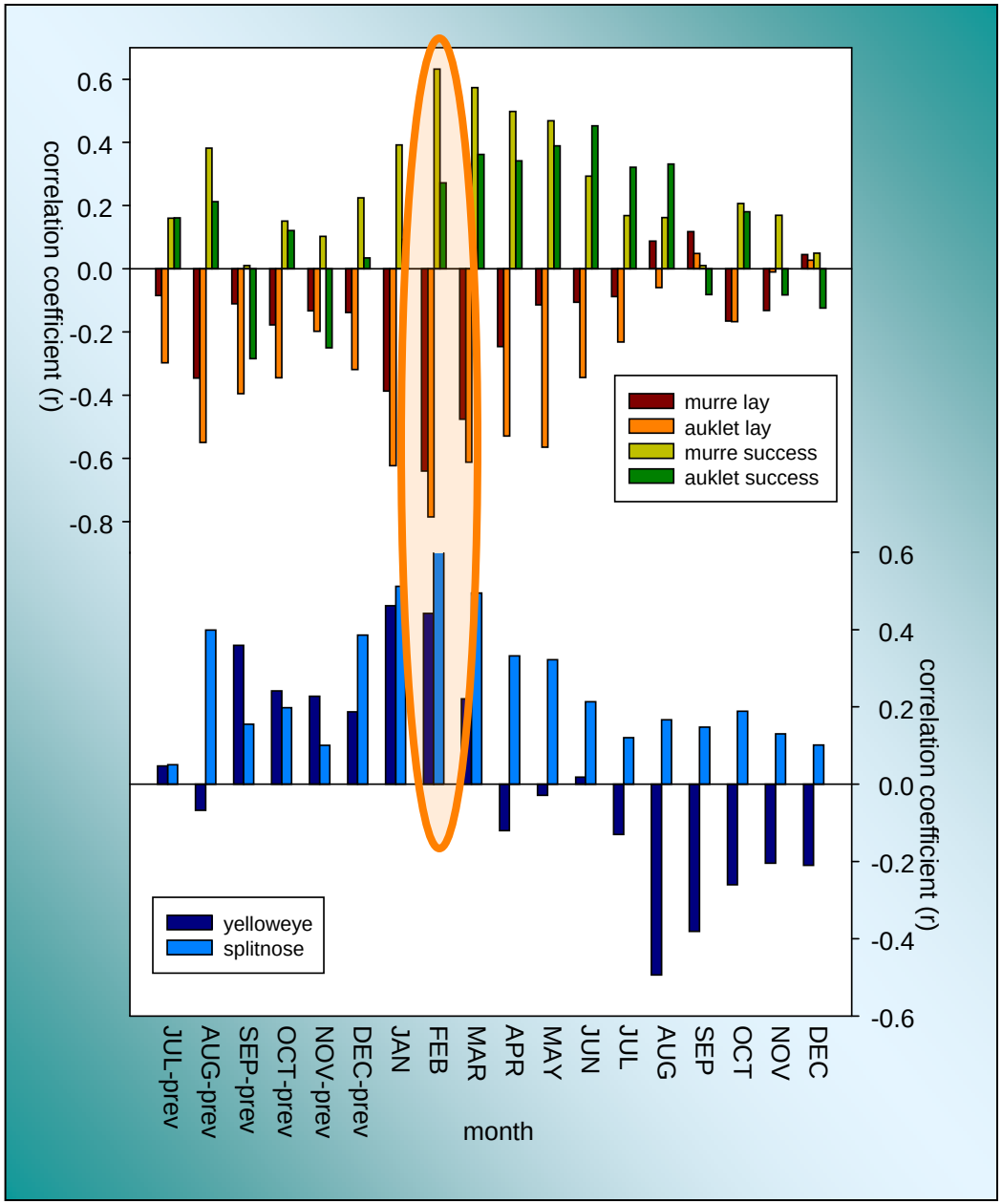
Variability in Onset of Seasonal Upwelling

Spring Transition Index (Julian Day)



- Trend to later spring transition in northern CCS
- Delayed upwelling during El Niño events

Relationships with Upwelling (39° N)

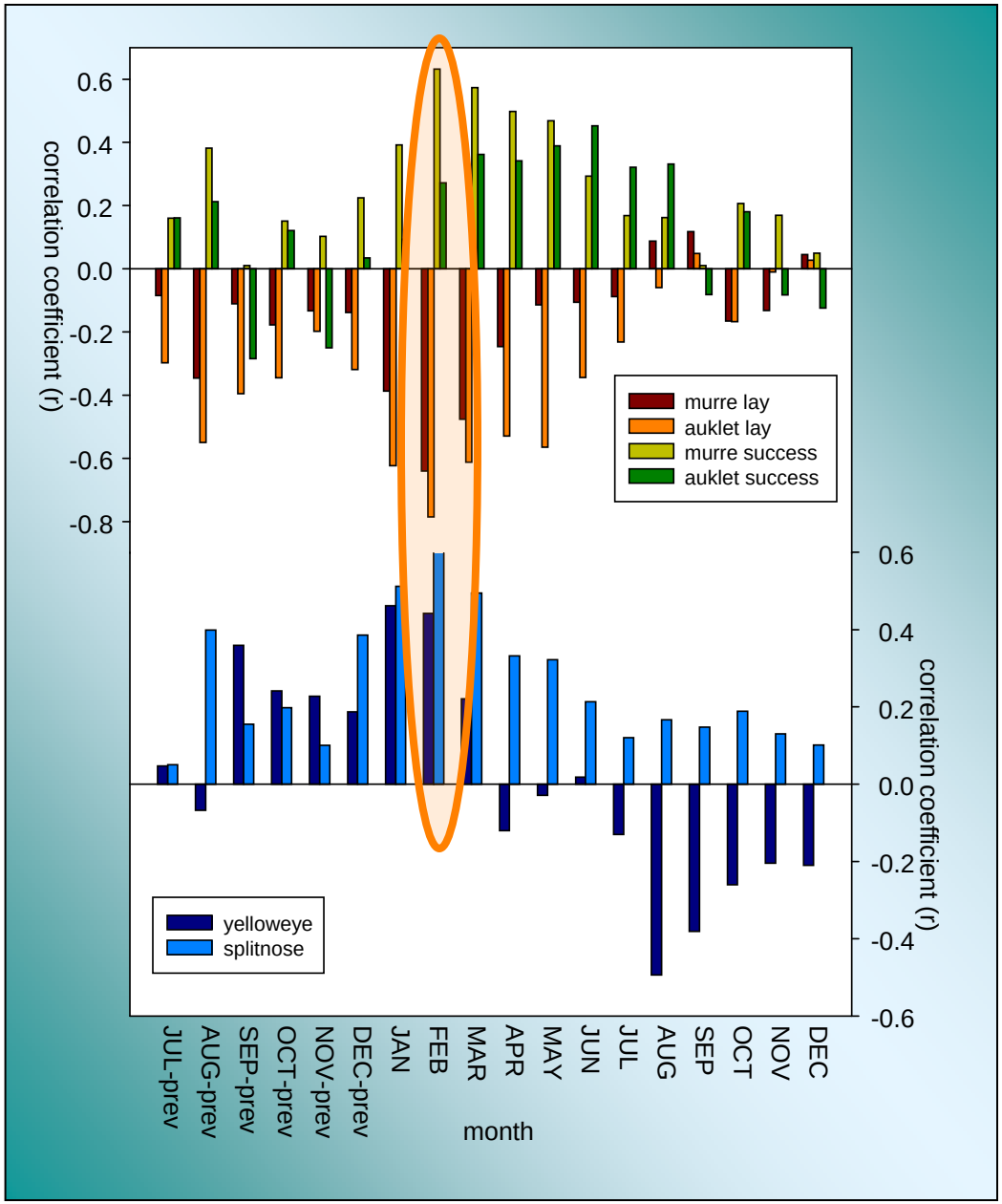


seabirds

rockfish

highest correlation in February

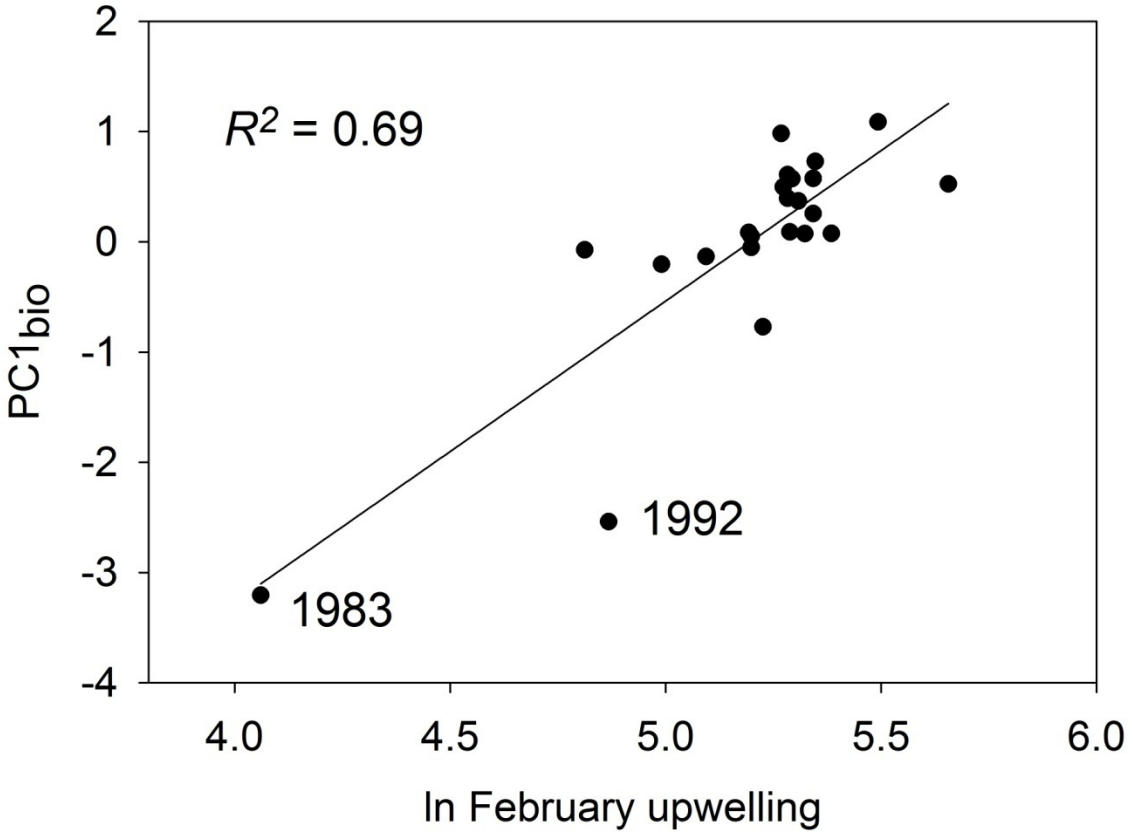
Relationships with Upwelling (39° N)



seabirds

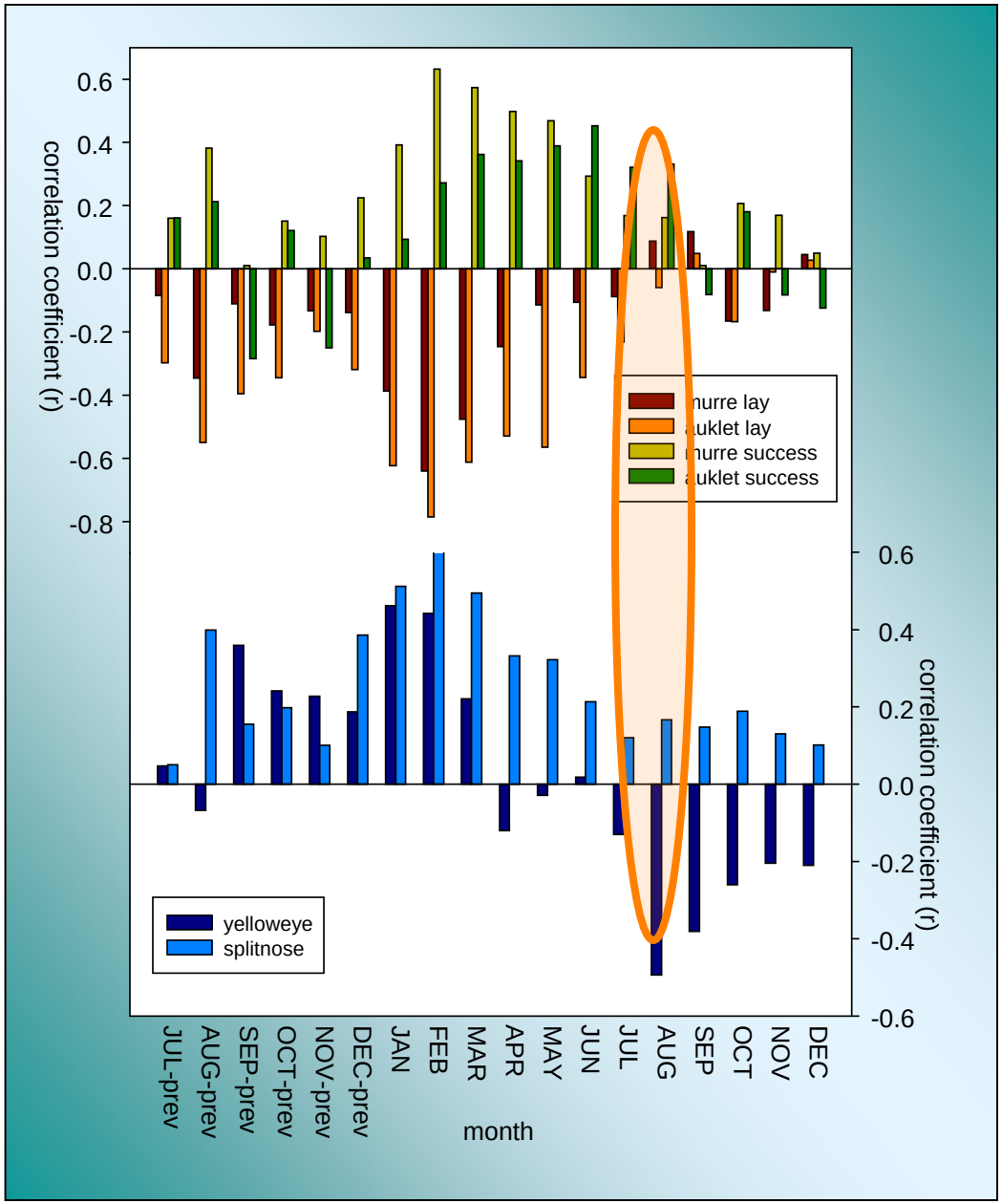
rockfish

Higher upwelling = Higher reproductive success



Black et al. 2010

Relationships with Upwelling (39° N)



seabirds

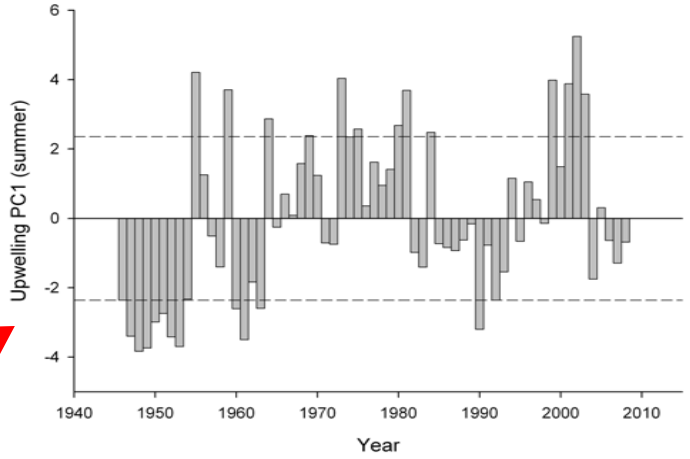
rockfish

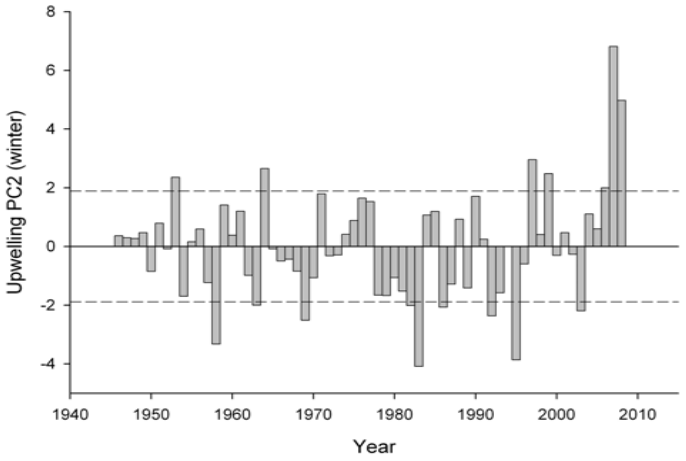
Higher summer upwelling has mixed effects

Modes of Upwelling

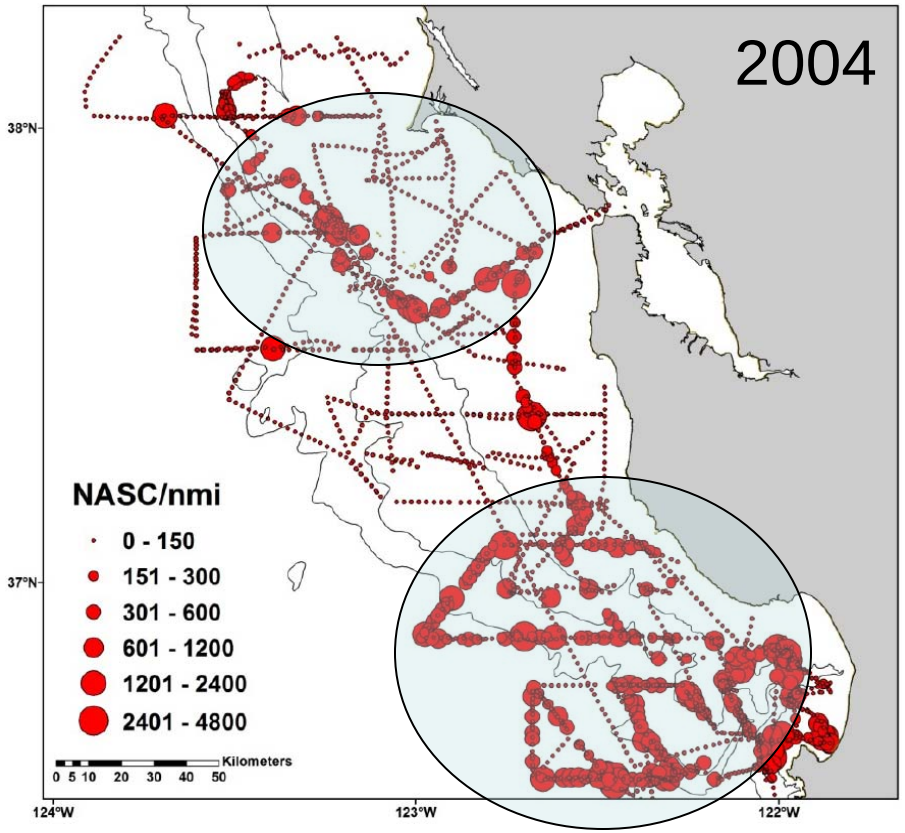
e.g., EOF Loadings

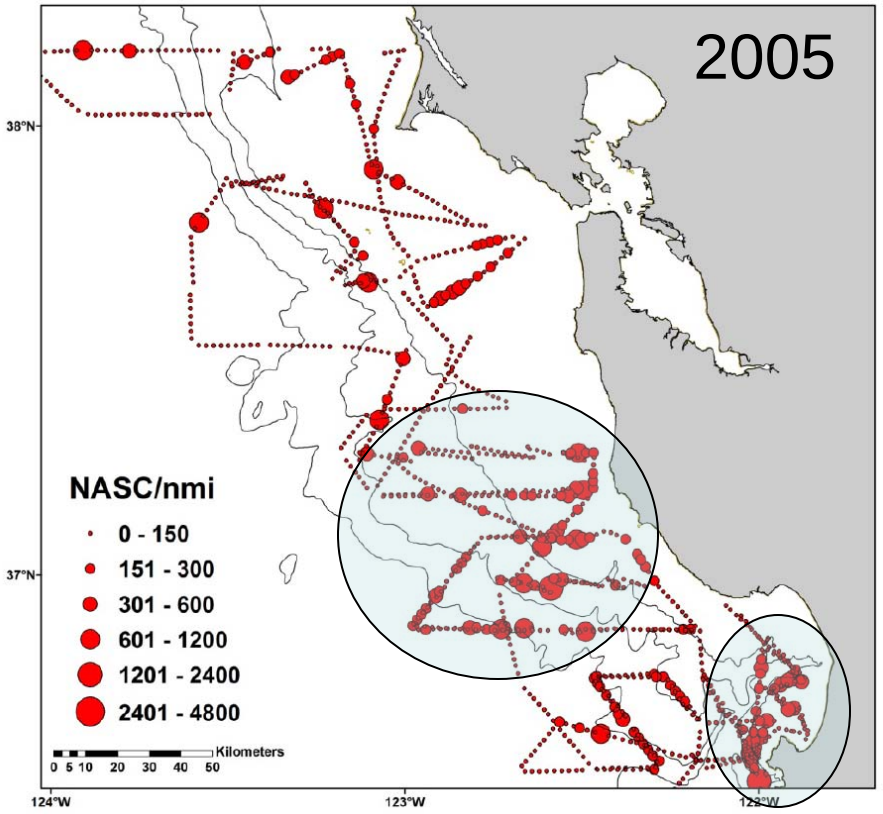
EOF	1 (23%)	2 (15%)
January	-0.029	0.316
February	-0.073	0.354
March	0.077	0.290
April	0.205	0.189
May	0.275	0.032
June	0.320	0.021
July	0.312	-0.110
August	0.318	-0.169
September	0.290	-0.076
October	0.195	0.188
November	-0.038	0.122
December	-0.093	0.308





KRILL PATCHES, 2004 & 2005 (EK500 DATA)





Santora et al. submitted

SUMMARY

- **Upwelling timing is highly variable**
- **Winter pre-conditioning (early upwelling) controls & synchronizes seabird reproductive timing and rockfish growth**
- **Principal ecosystem effects of interannual-decadal climate variability could be phenological**

- **Future climate change impacts:**
  - **Condition of breeding adults?**
  - **Longer growing seasons?**
  - **Common sensitivity to early lower trophic production?**
  - **Biological winners and losers?**
  - **Plastic & anchored populations?**

THANK YOU!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