

The Phenology of Coastal Upwelling in the California Current

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Outline

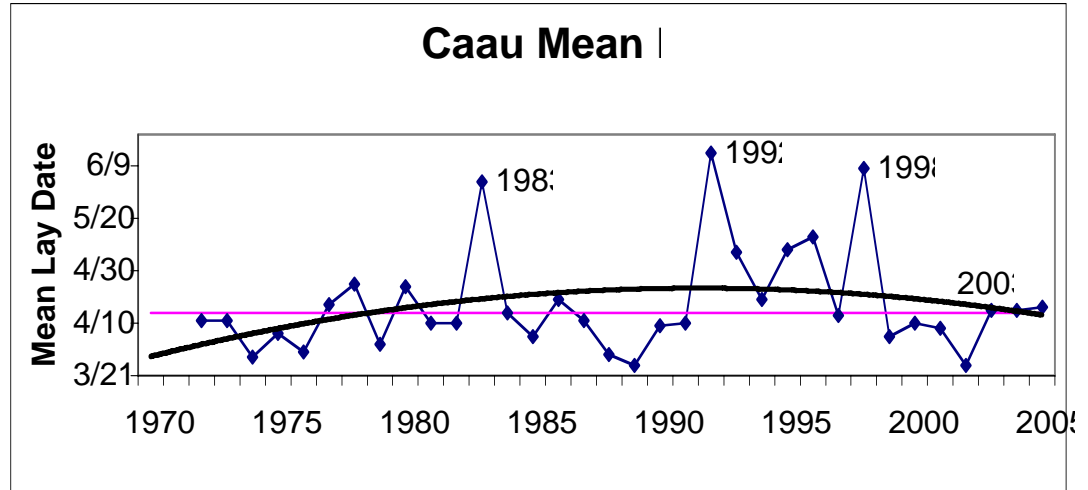
- Phenological observations in the California Current (seabird breeding, thermal stratification)
- Simple indices to describe seasonal upwelling
- Interannual variability in upwelling phenology
- Effects on ecosystem?

TIMING OF SPRING EGG LAYING

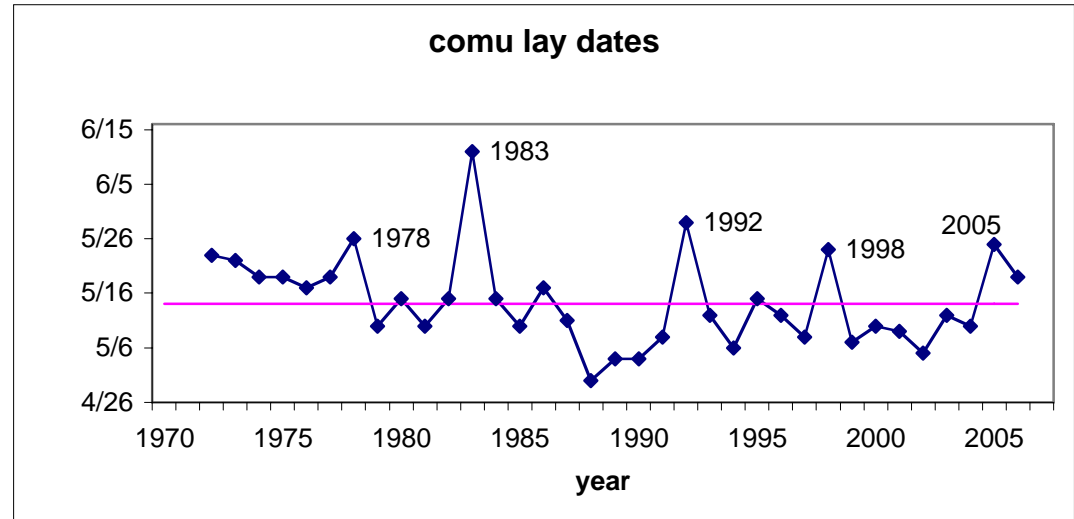


planktivorous

Cassin's Auklet



Comon Murre



piscivorous

PHENOLOGICAL CONSEQUENCES

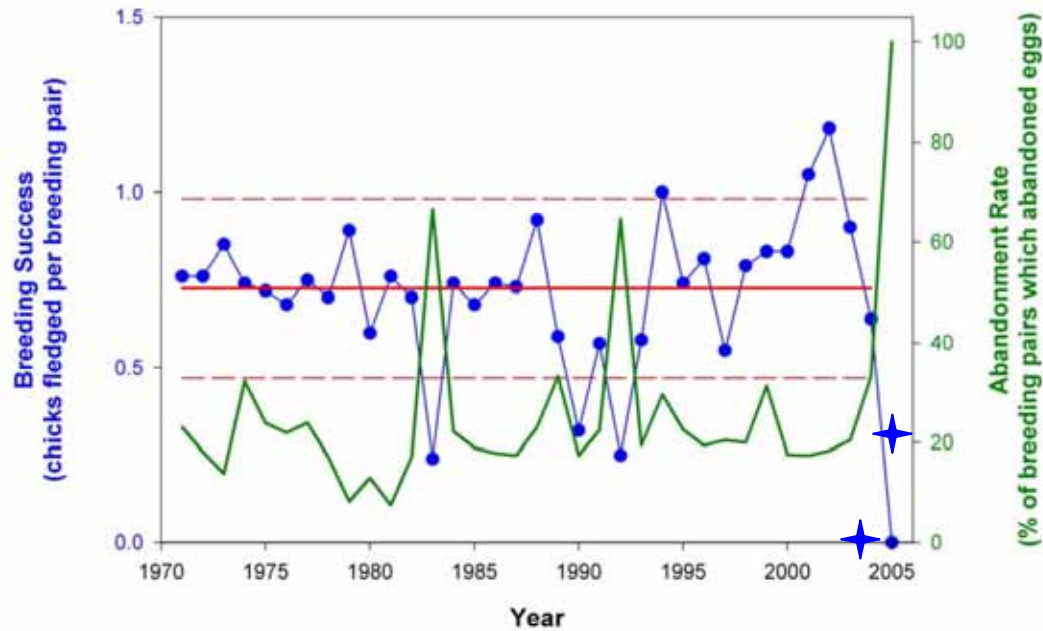
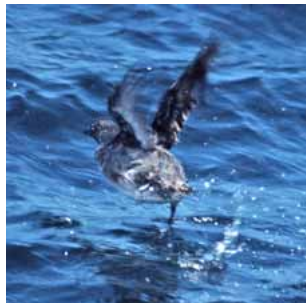
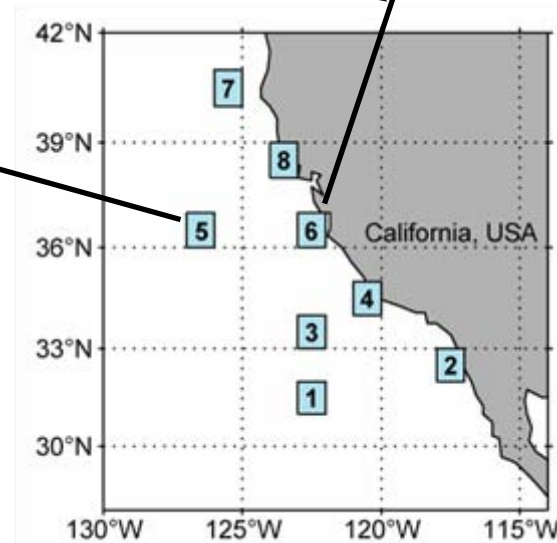
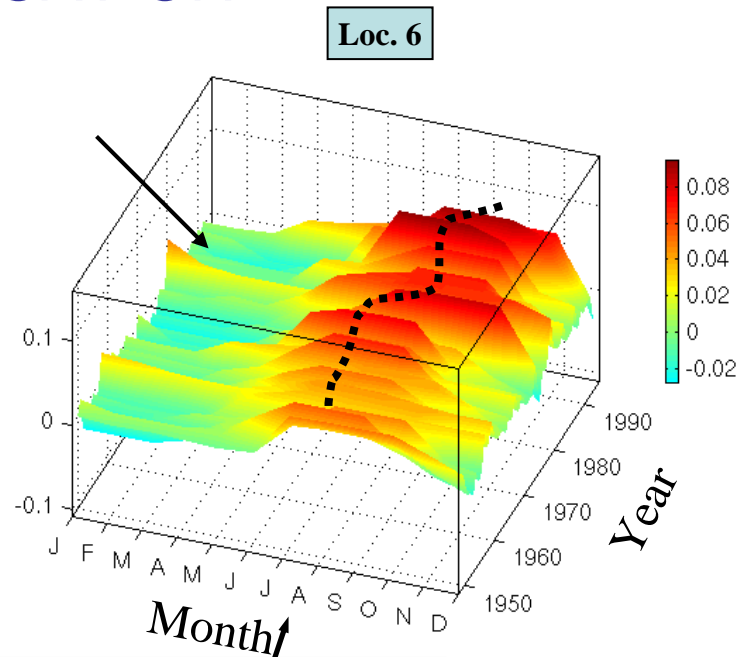
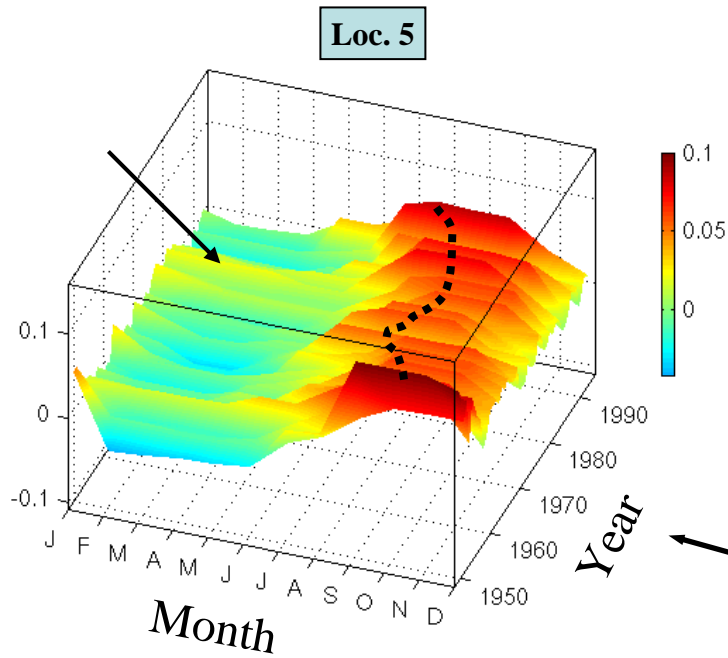


Figure 1. Interannual variability of Cassin's auklet breeding success and abandonment rate at Southeast Farallon Island, California (1971 - 2005), showing the long-term mean breeding success (solid red line) \pm 80% confidence intervals (dashed red lines).

SEASONAL STRATIFICATION

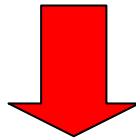
Max. dT/dz



MOTIVATION and OBJECTIVES

Can we develop simple indices that describe the phenology of coastal upwelling in the California Current?

- Timing of onset (spring transition)
- Duration of upwelling season
- Intensity of upwelling (episodic, integrated)
- Intra-seasonal variations in upwelling

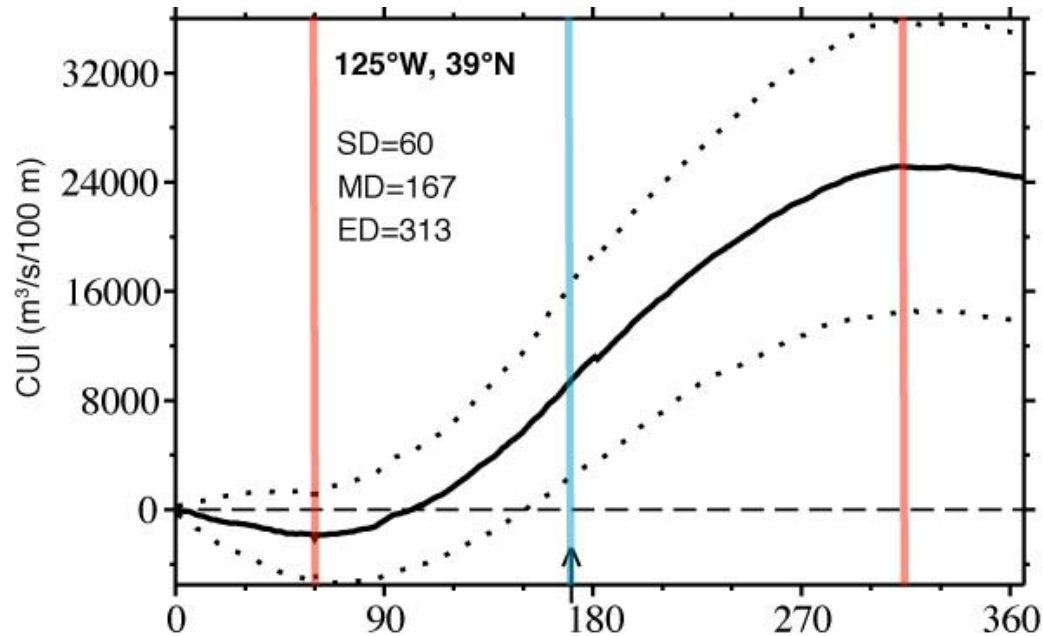


Use classical Bakun Upwelling Index:

- long time series (~40 yrs)
- often used in fish.ocgy
- large-scale context
- *does not resolve cross-shelf variability*

CUMULATIVE UPWELLING INDEX

Example: 39°N (NorCal)
1967-2005



Cumulative Upwelling Index (CUI) = Integrate UI from 1/1 to 12/31

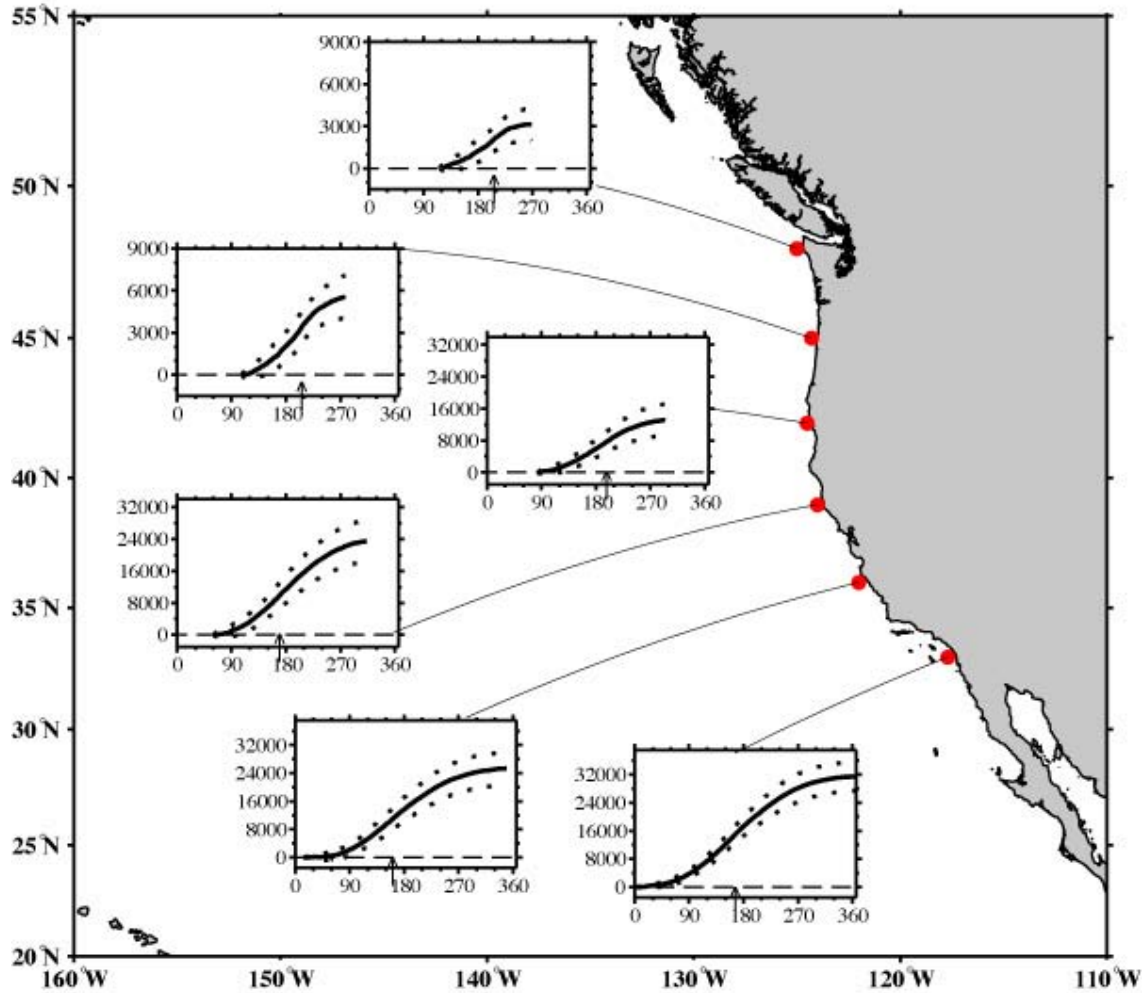
SD = Climatological Start Date of Upwelling Season

MD = Climatological Mid-Point of Upwelling Season (Max. Slope)

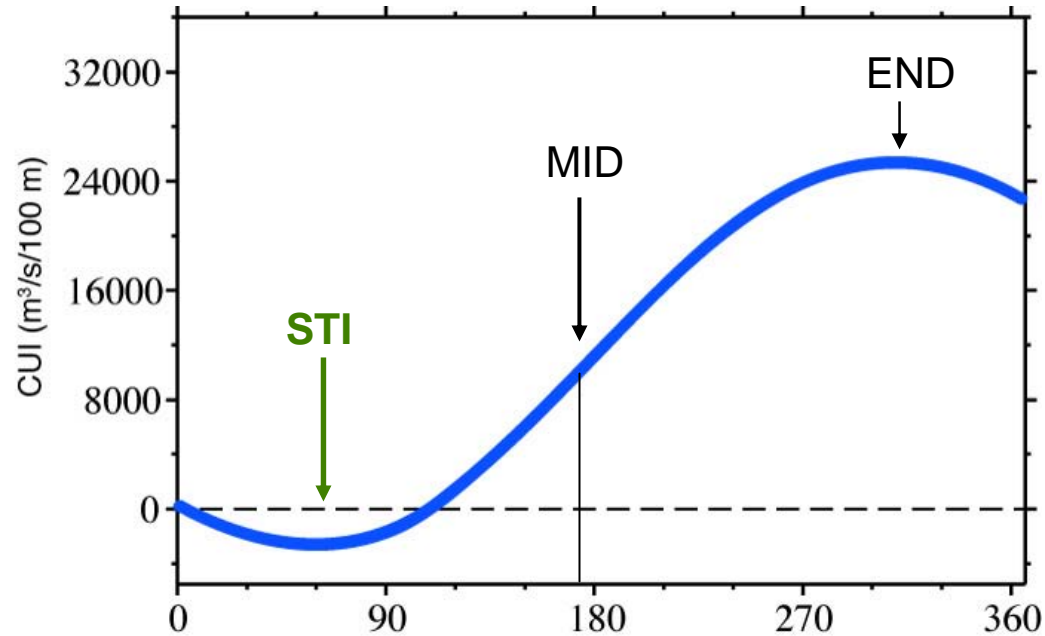
ED = Climatological End Date of Upwelling Season

California Current CUI Climatologies

Climatological CUI

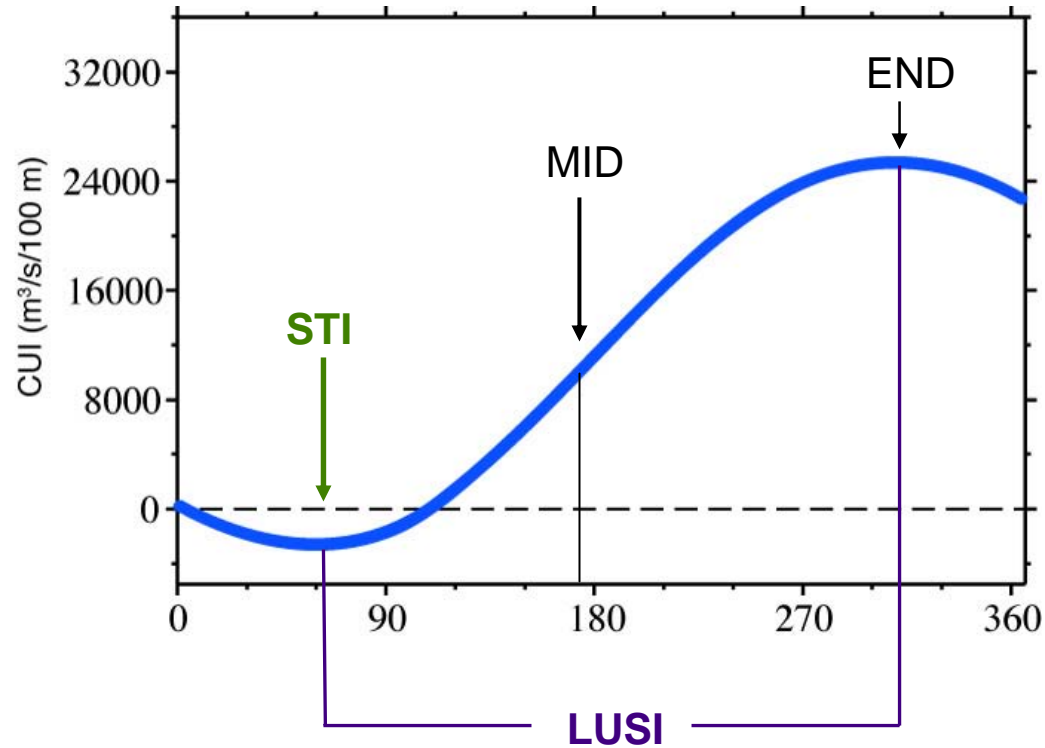


INDICES of COASTAL UPWELLING



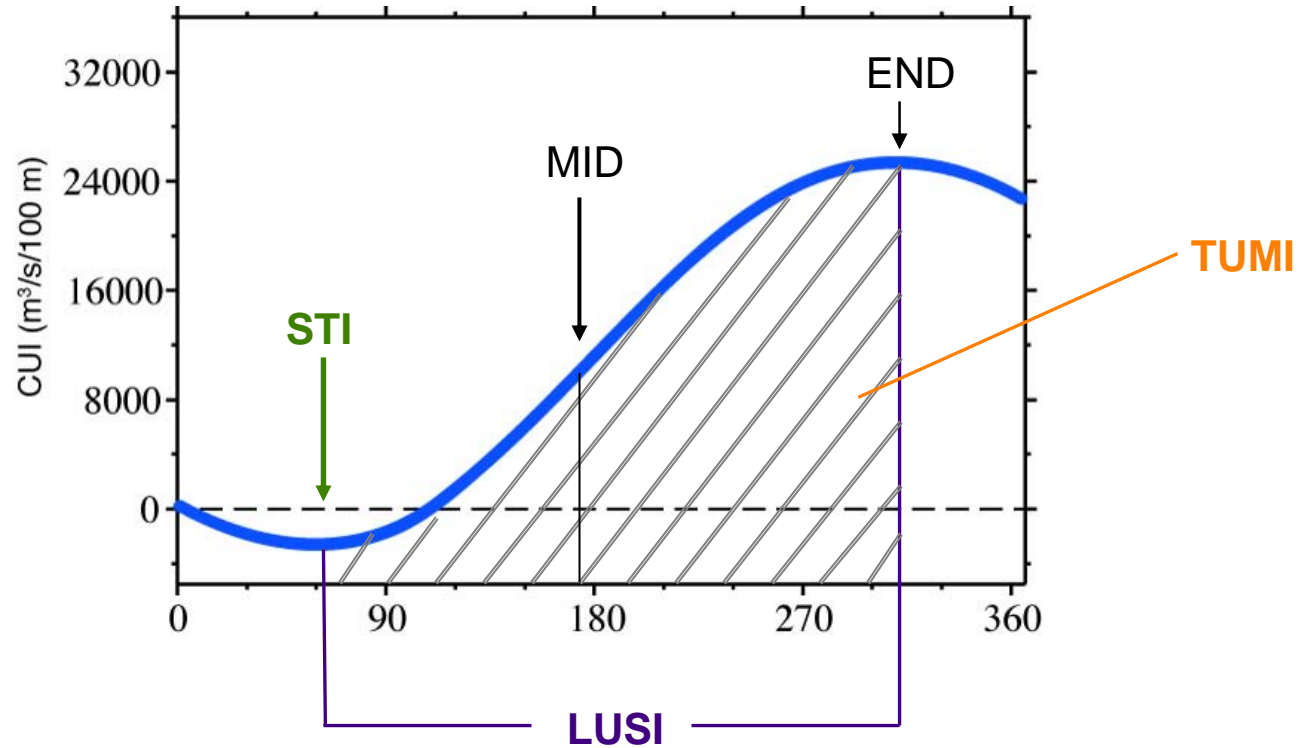
Spring Transition Index (STI) = Date of Minimum CUI
(END = Date of Maximum CUI)

INDICES of COASTAL UPWELLING



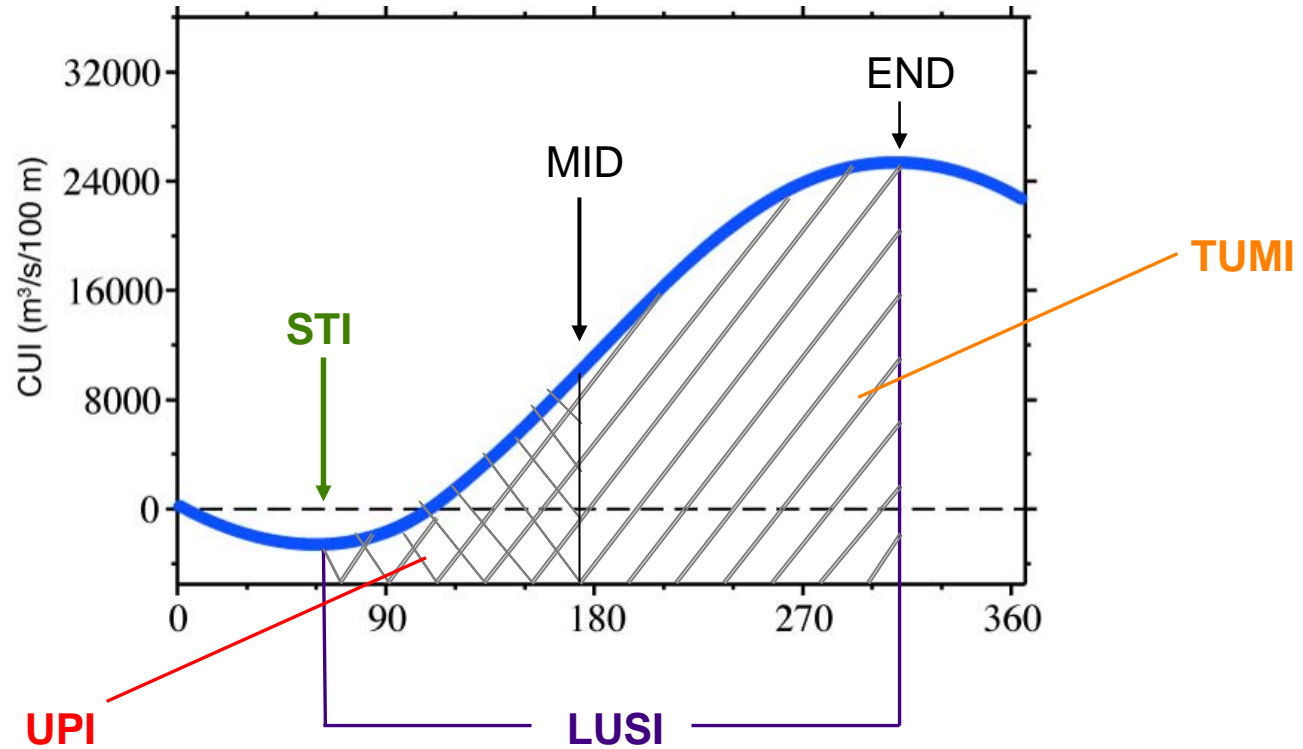
Length of Upwelling Season Index (LUSI) = Total days between STI and END

INDICES of COASTAL UPWELLING



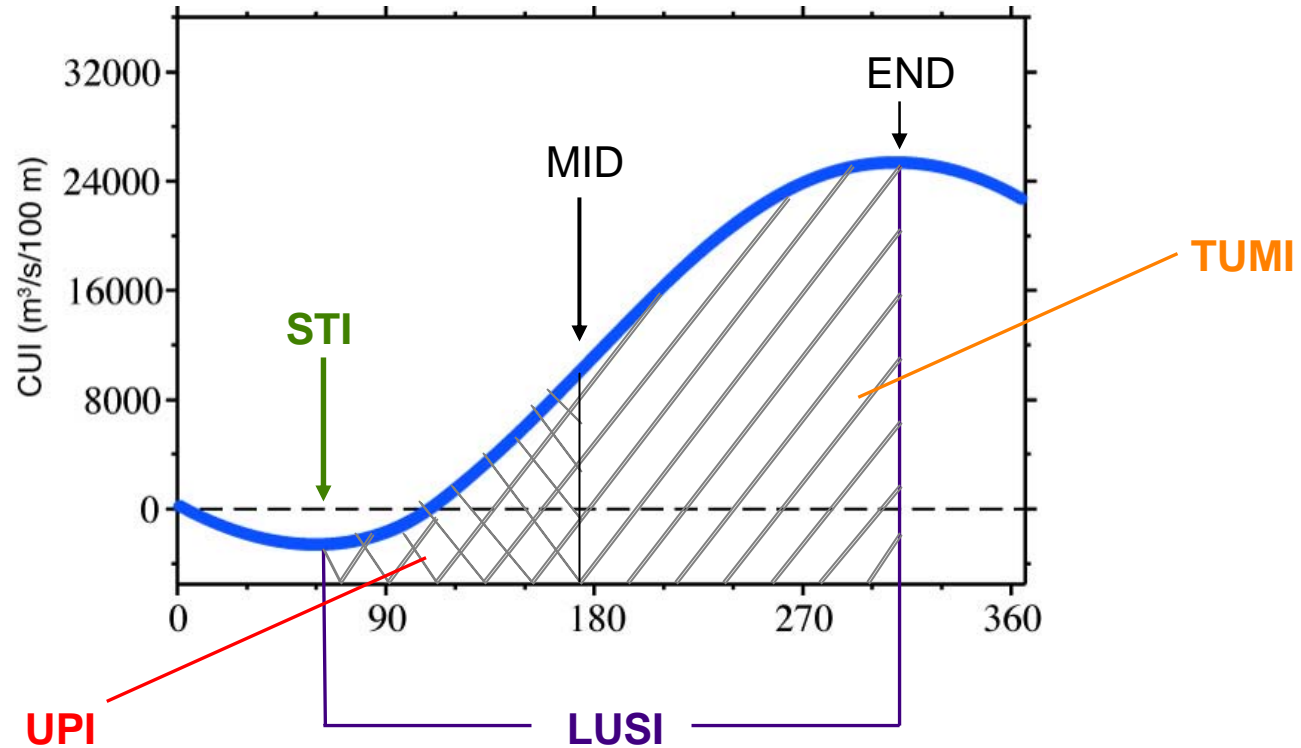
Total Upwelling Magnitude Index (TUMI) = CUI Integrated between STI and END

INDICES of COASTAL UPWELLING



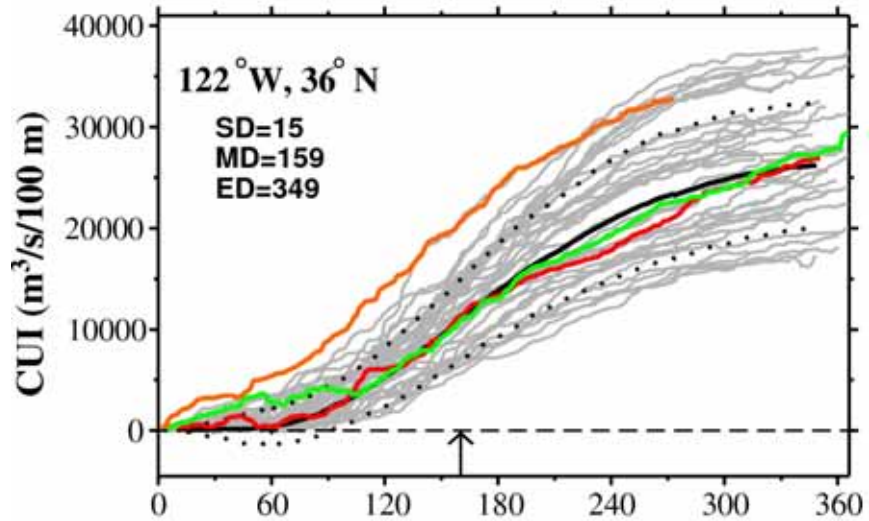
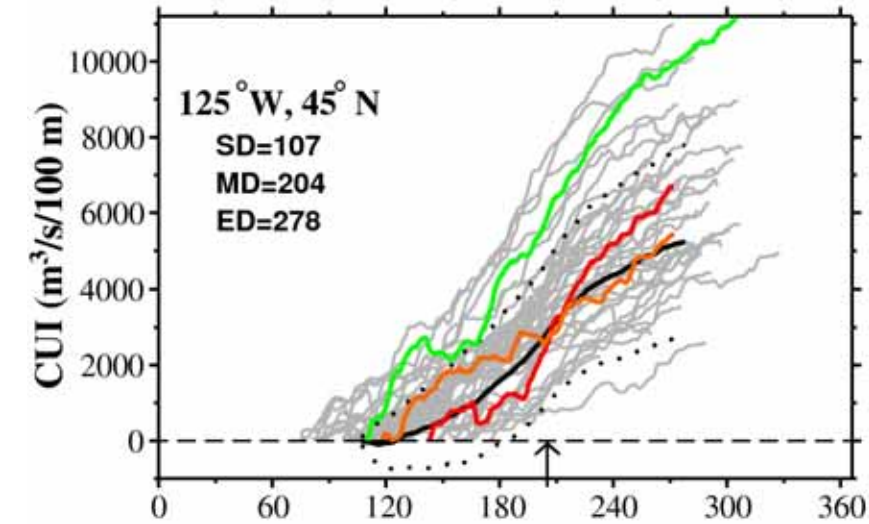
Upwelling Punctuality Index (UPI) = CUI Integrated between STI and MID

INDICES of COASTAL UPWELLING



WARNING: Varying life histories, resilience of species determine relevance of various indices. Use with caution ...

INTERANNUAL VARIABILITY in CUI

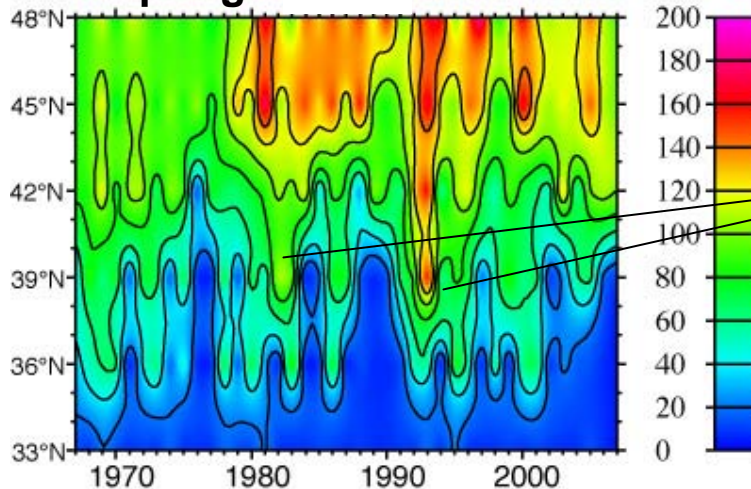


RECENT UPWELLING PHENOLOGY

	2005	2006	2007
Northern CC	STI late	STI early UPI, TUMI high LUSI long	UPI high
Central CC	STI late	STI early UPI, TUMI high	STI very early UPI very high
Southern CC	near-normal	near-normal	STI very early UPI very high

INDICES of COASTAL UPWELLING

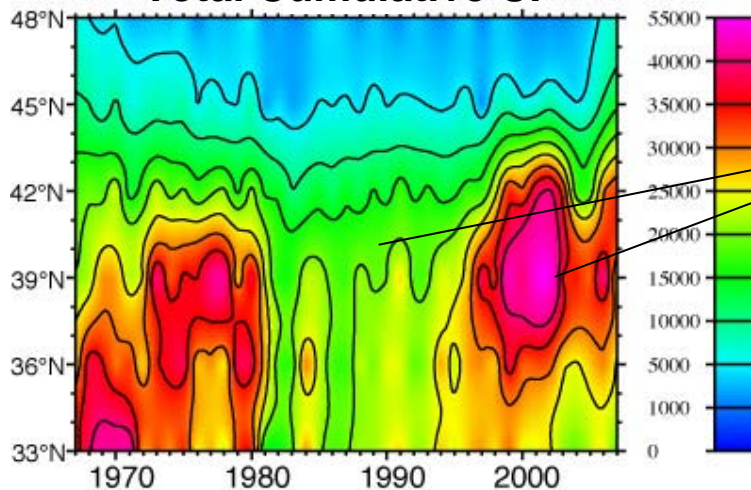
Spring Transition Index



Later spring transition during El Niños

... delayed egg laying in CA Cassin's auklet

Total Cumulative UI



Periods of weaker and stronger upwelling

... weaker rockfish production in late 80s, early 90s

CONCLUSIONS

1. Upwelling timing, strength and duration highly variable in central California Current (36-42°N);
2. Periods of strong upwelling magnitude at 36-42°N in 1967-1980 and 1999-2004;
3. Period of weak upwelling in 1980-1995; **corresponds with low central CA rockfish production;**
4. Trend towards later and shorter upwelling in northern CC (42-48°N);
5. Delayed upwelling in southern/central CCS in El Niño years; **corresponds with delayed egg laying of CA seabirds;**
6. Principal ecosystem effects of interannual-decadal climate variability could be phenological.



NEXT STEPS

1. Determine large-scale forcing associated with different upwelling phenology regimes;
2. Quantify event-scale indices: Lasker events and Relaxation events;
3. Explore multivariate relationships between biological and upwelling series;
4. Distribute validated indices;
5. Include indices in California Current Integrated Ecosystem Assessment;
6. Forecast California Current upwelling from CPC coupled atmosphere-ocean model.



*Thanks to U.S. GLOBEC, NOAA FATE program
and California Sea Grant!*