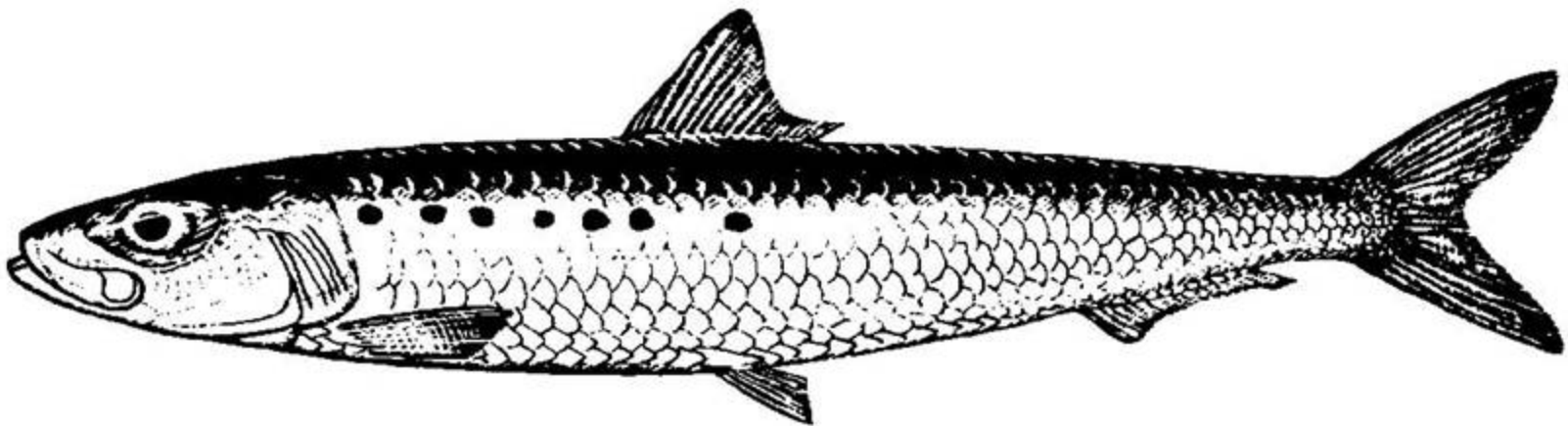


¿Es apropiado incorporar la Temperatura Superficial del Mar (TSM) en el plan de manejo de la Sardina de California?

Is Sea Surface Temperature (SST) an appropriate environmental measure to include in the management of the California Sardine?

David B. Field
Hawai'i Pacific University

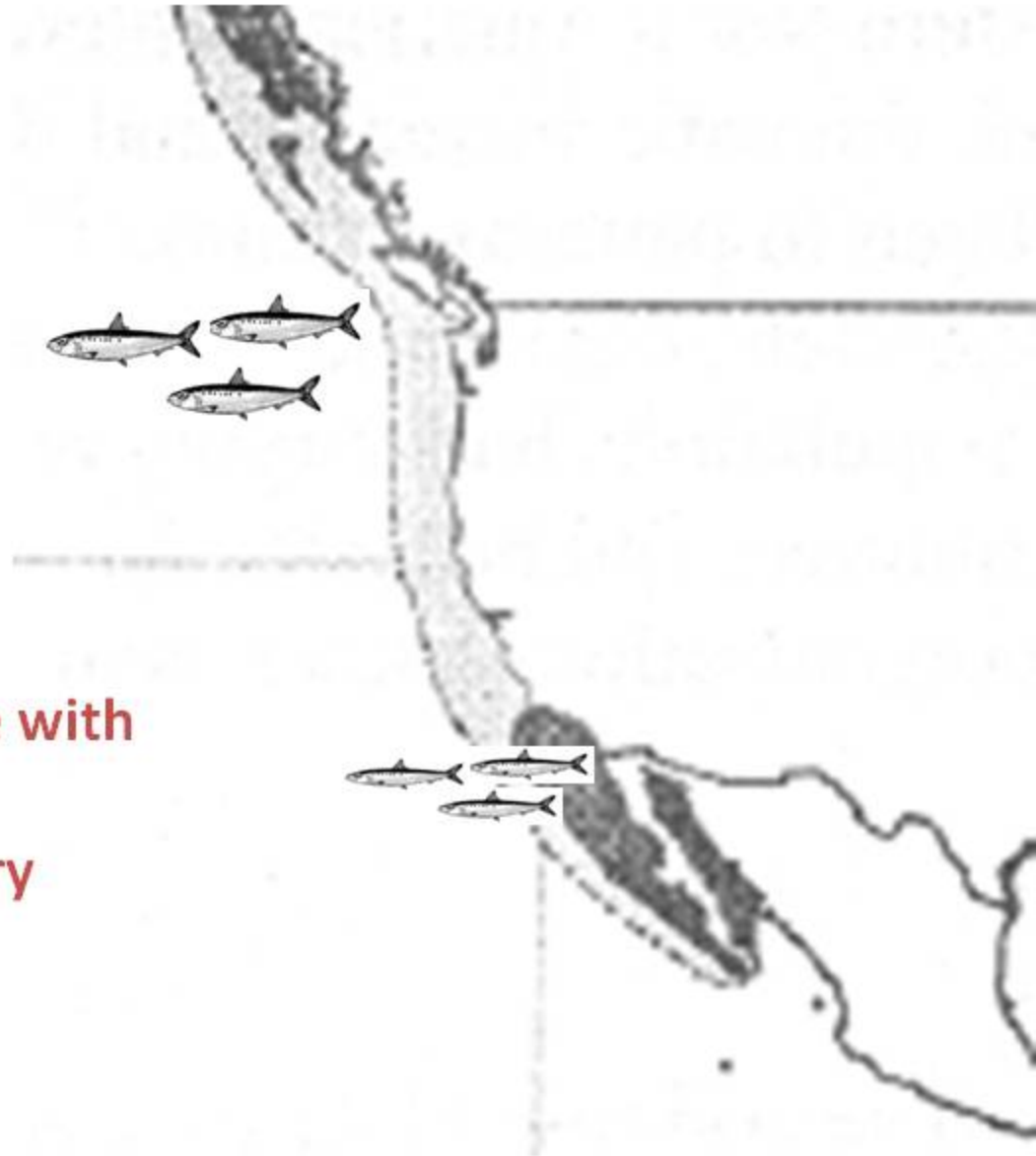


Bosquejo / Outline

California Current Management Plan

Sedimentary records

- Alternations between sardines and anchovy -
- Relationship of sardine with temperature
- Evidence for 20th century warming and beyond
- Evidence off Peru



California Current Sardine Management Plan

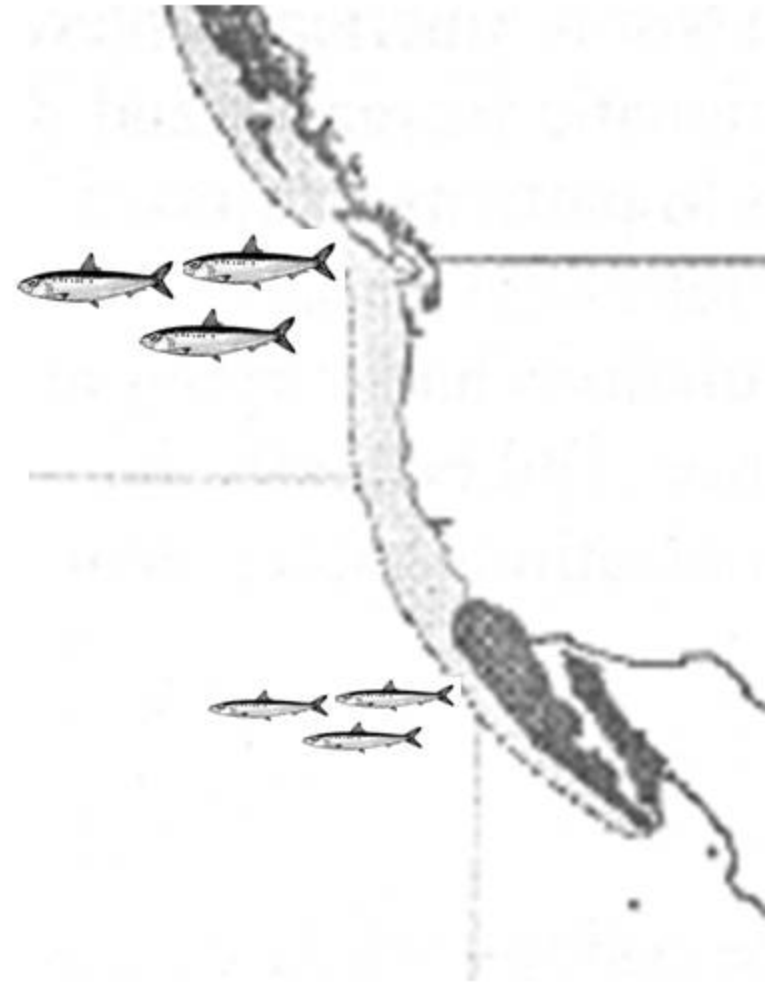
Sardine quota is based on a **stock assessment** and a **FRACTION based on ocean conditions**.

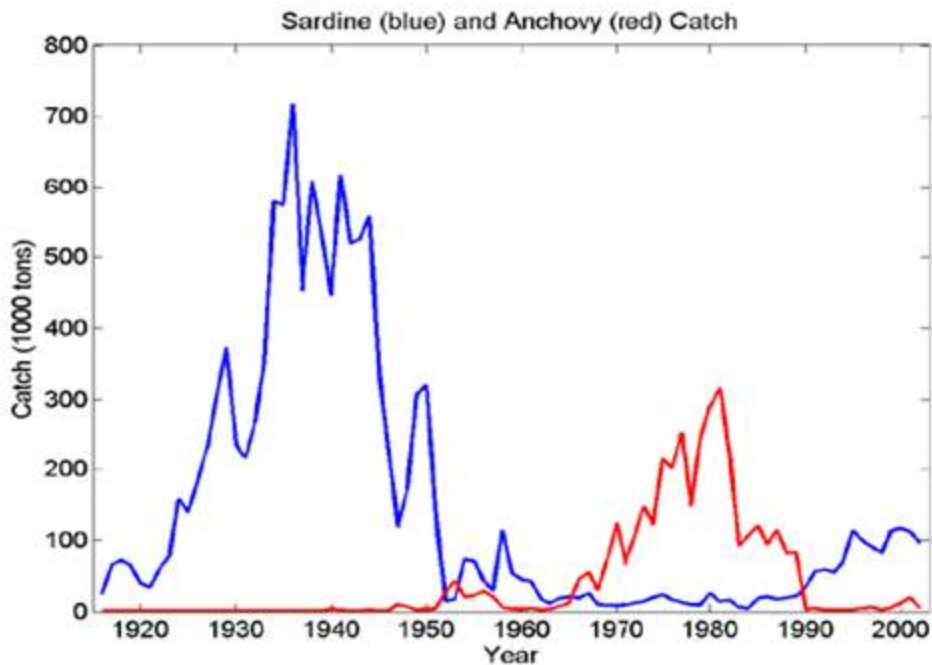
A FRACTION of the allowable sardine catch depends on recent ocean temperatures because of a previous found relationship between the sardine stock with warmer ocean conditions (Jacobson and MacCall, 1995).

An estimate of the relationship between Fraction Mean Stock Yield for sardine and ocean temperatures (T) is:

$$Fmsy = 0.24 T^2 - 8.19 T + 67.45$$

where T is the average three season sea surface temperature at Scripps Pier, California during the three preceding seasons. Under Option J (PFMC 1998), Fmsy varies between 5% and 15%. Fmsy will be equal to 15% under warm oceanic conditions.



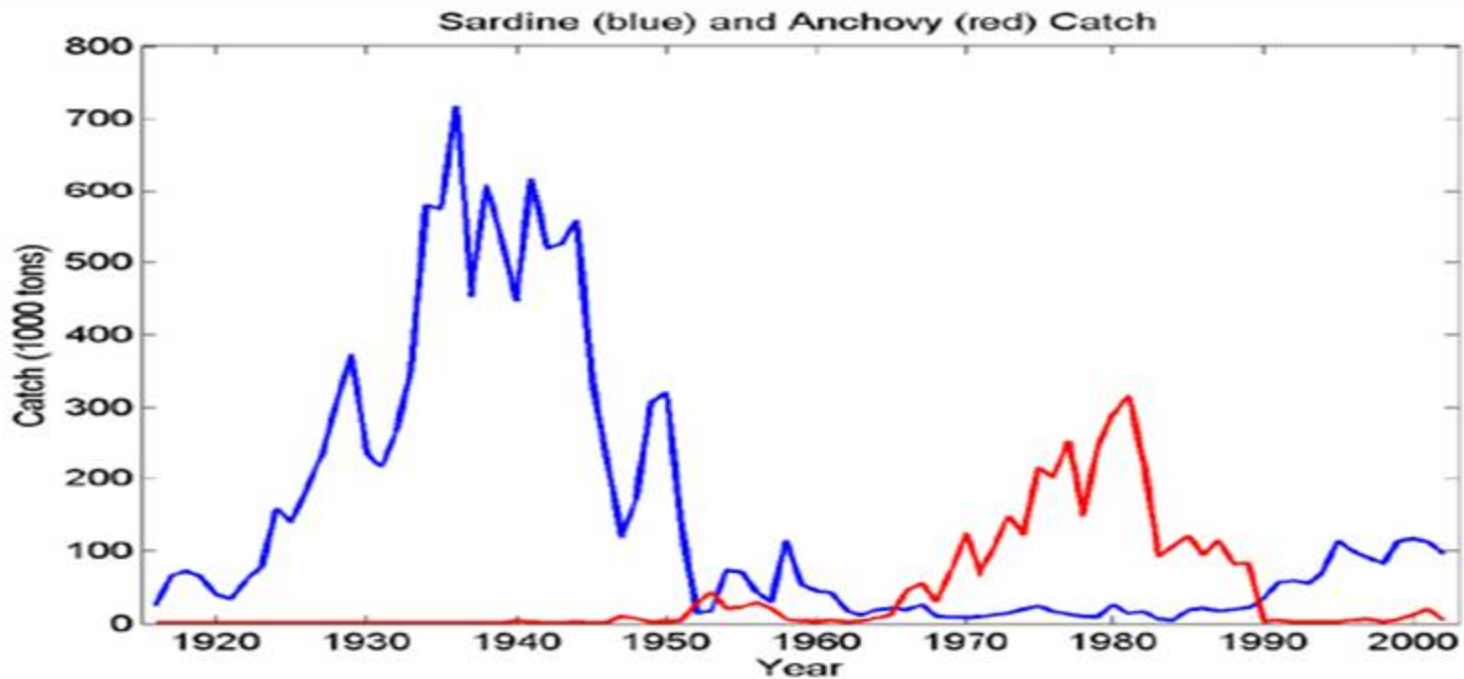


Paradigms based on 20th century observations

In the California Current, Sardines expand to Northern California, Oregon, Washington, Canada in periods of high abundance (warm periods?) and are limited to southern California and Baja California during periods of low abundance (cold periods?)

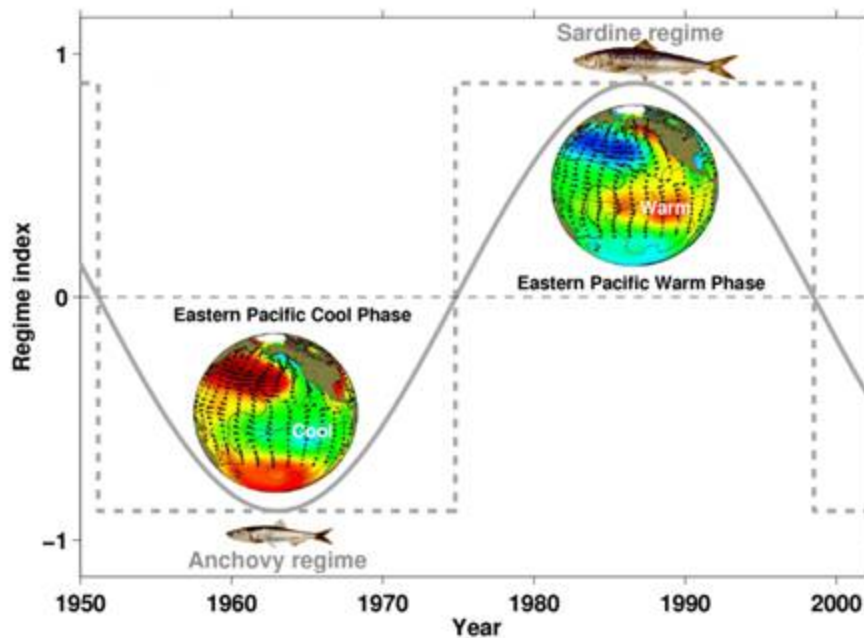
Higher SST could enable sardines to migrate north and take advantage of high fat resources, which would enhance egg production and viability

However, recruitment may merely be a covariable with SST in the 20th century

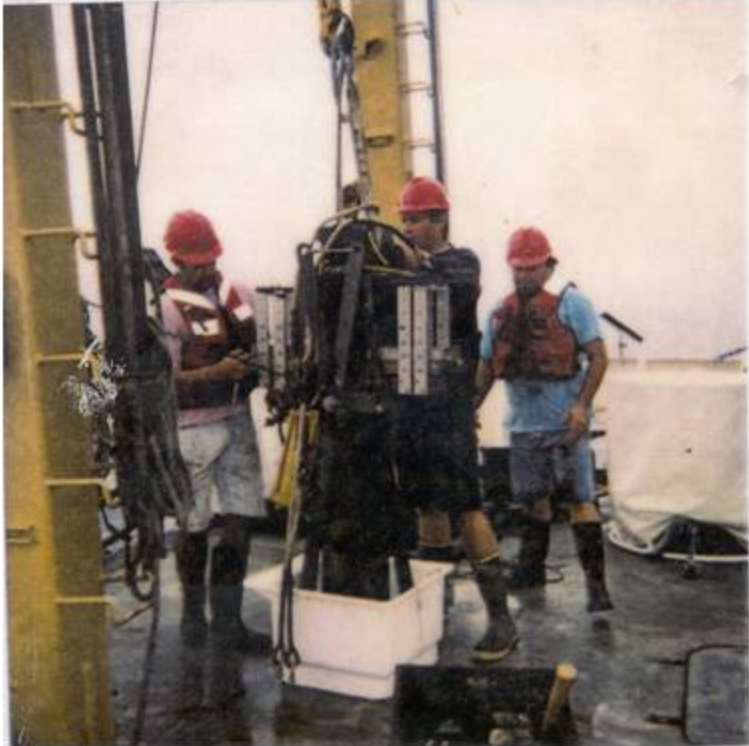


Patterns of sardine/anchovy capture during the latter 20th century in the California Current, Japan, and Peru lead to a general model of fluctuations in association with the PDO (Chavez et al., 2003)

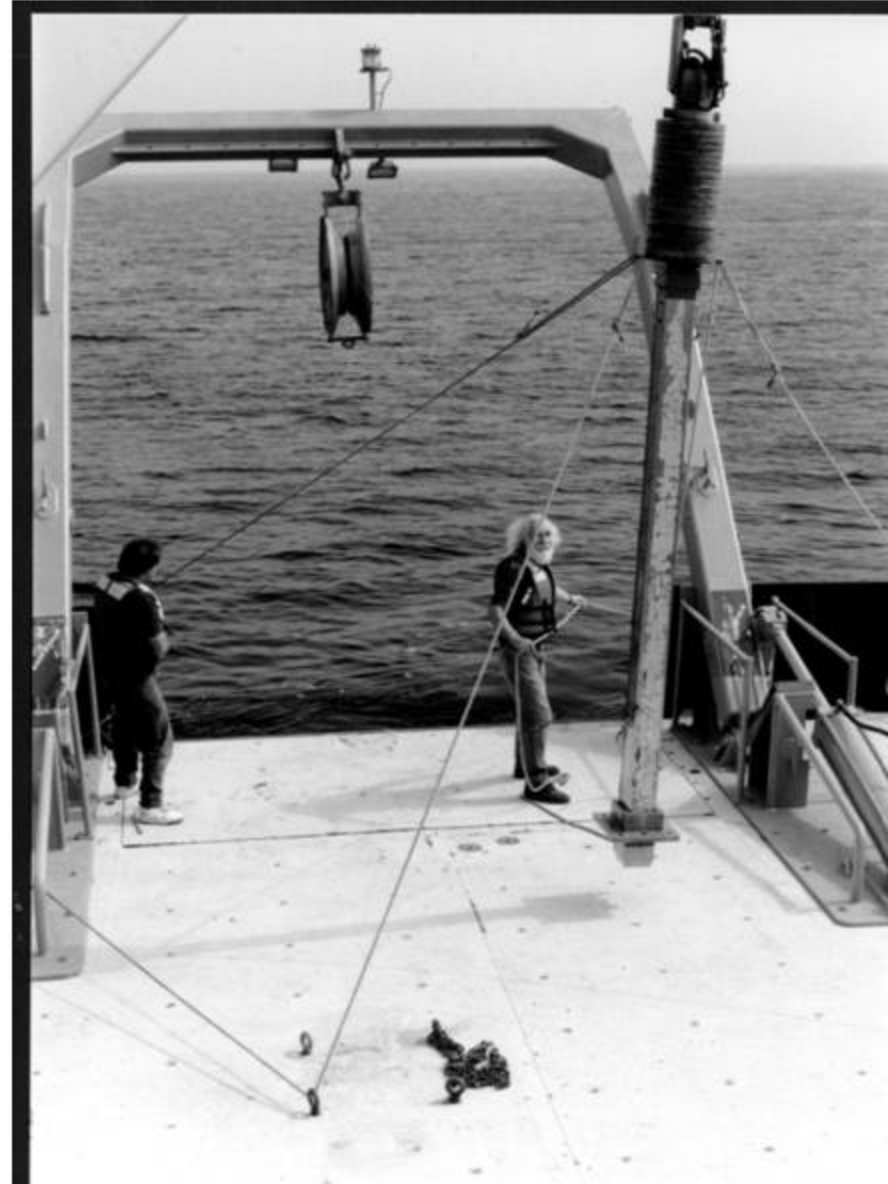
Does this pattern hold for longer timescales?



Sediment records of past changes

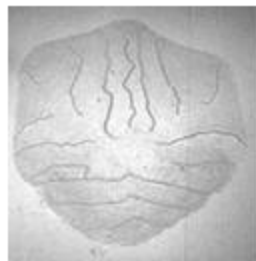
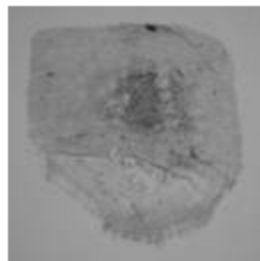
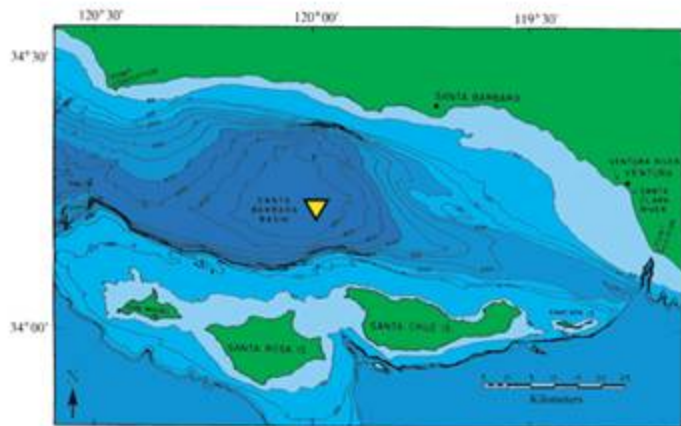


Soutar Box corer

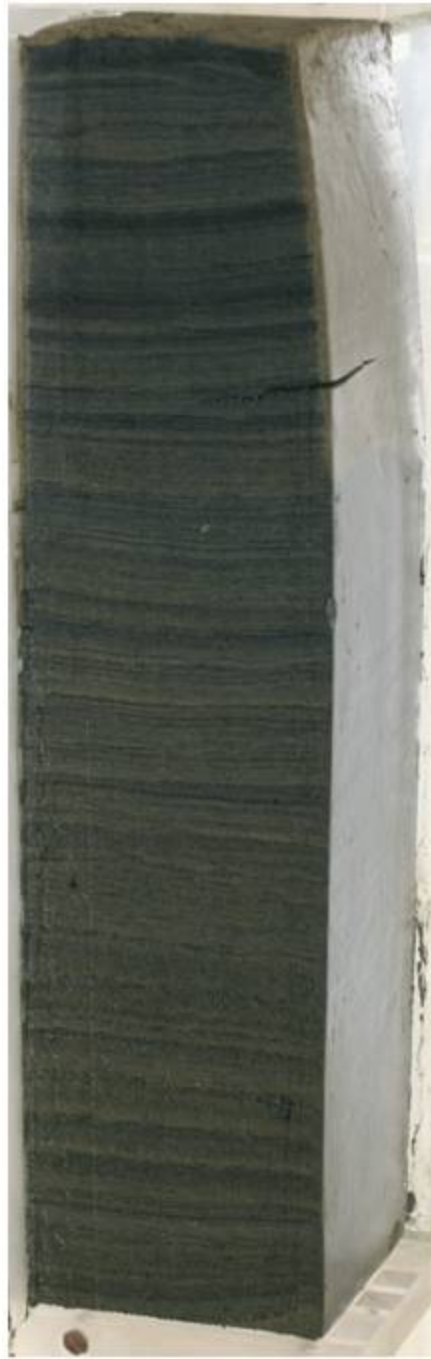


Santa Barbara Basin Sediments

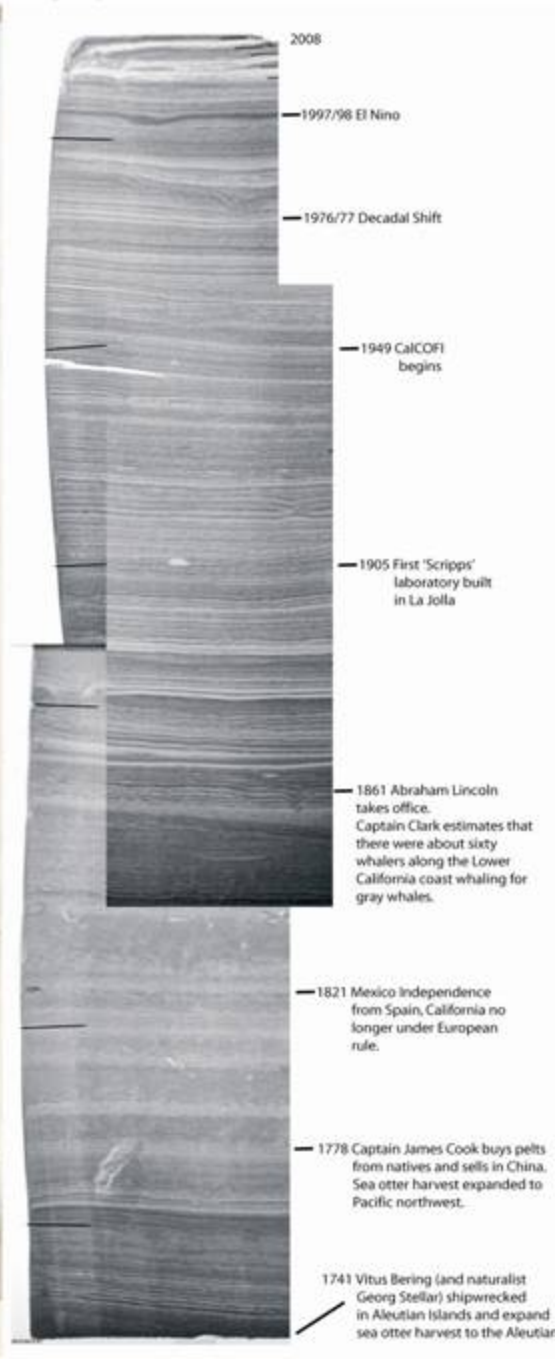
- Annual Laminae
- Continuous Deposition
- Preserve Fossil Remains

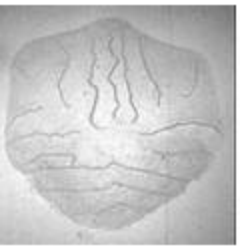


Photo



X-ray (positive)

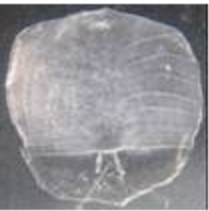




Anchovy



Hake



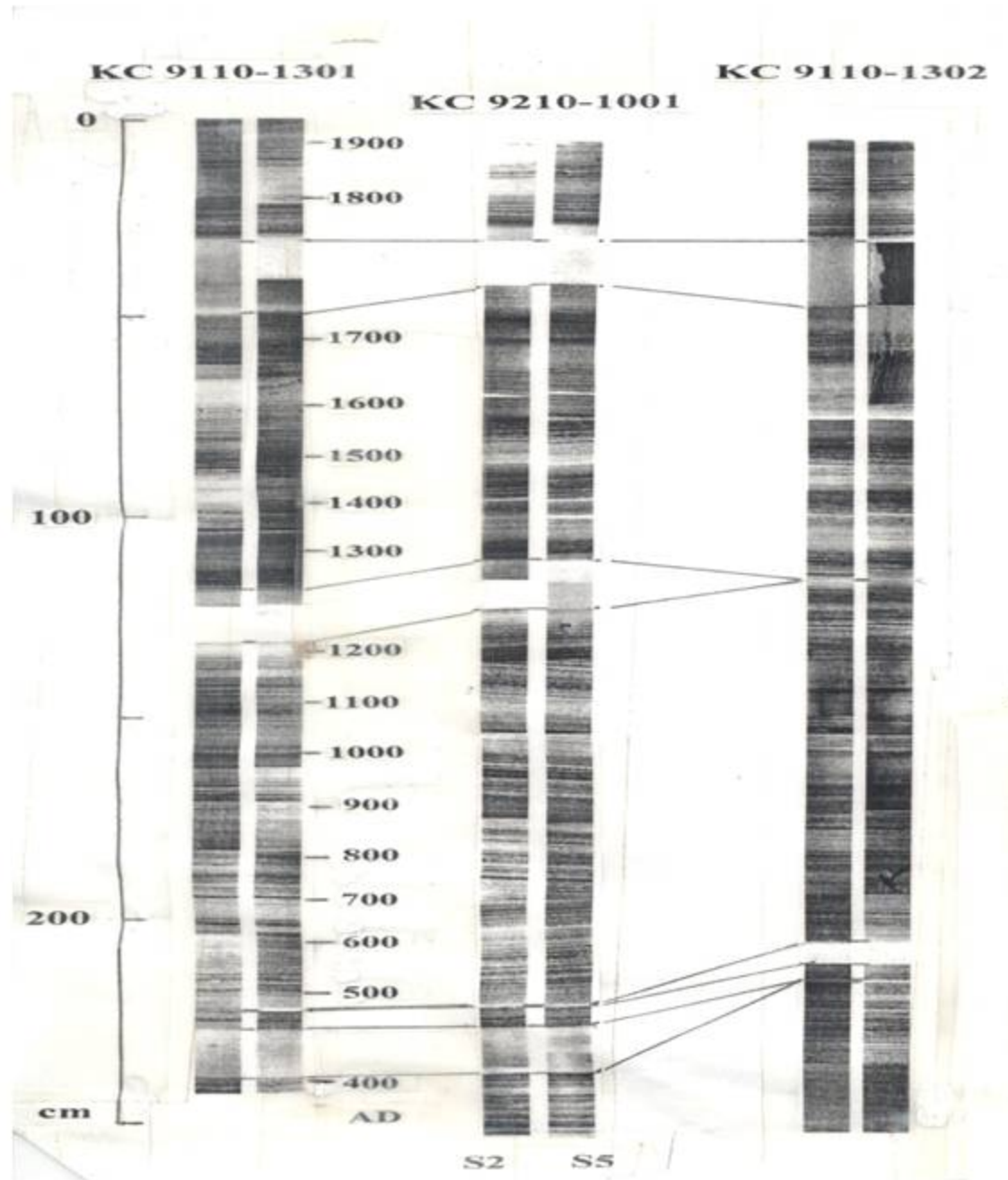
Sardine

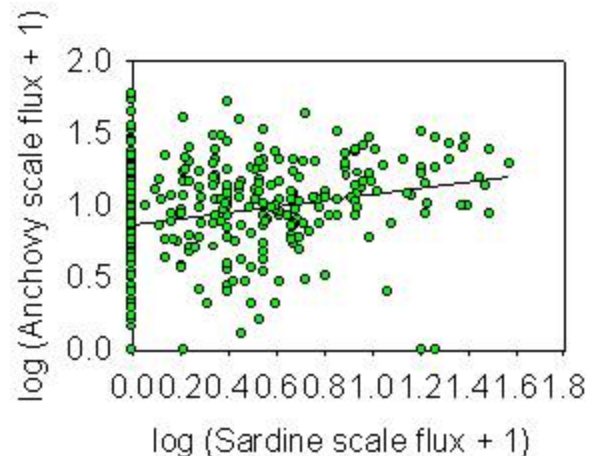
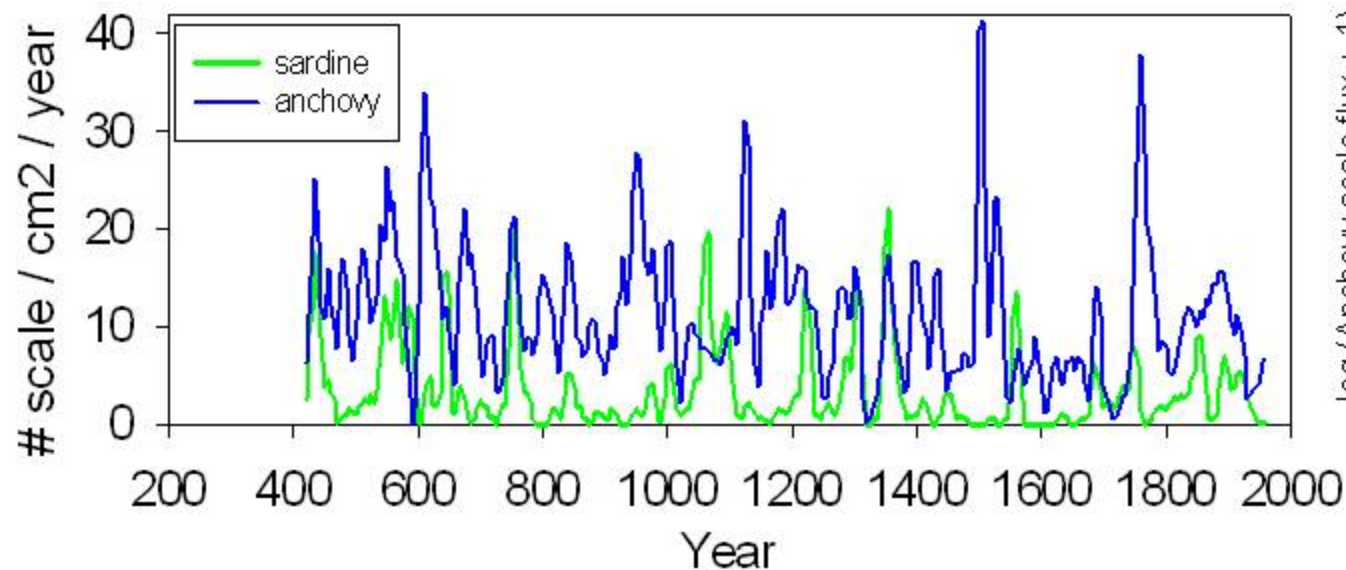


Jack Mackerel



Pacific Mackerel



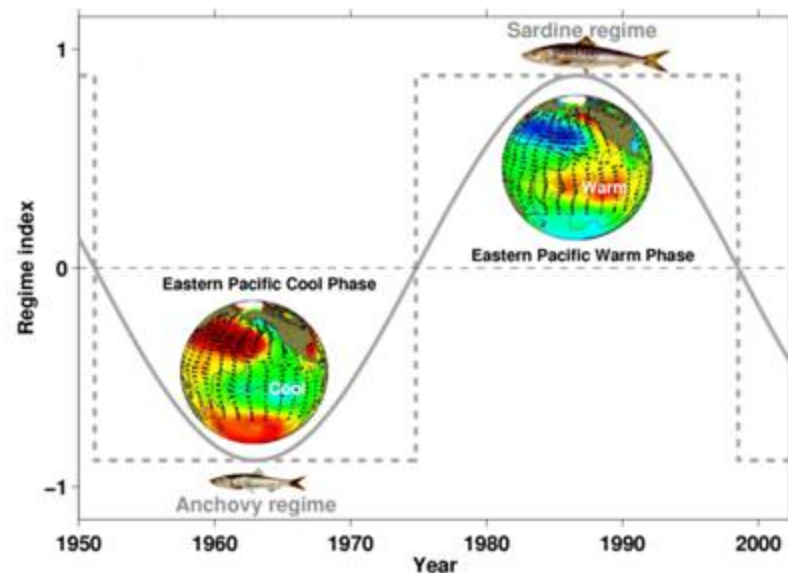


Historical records do not support the Paradigms

The record of anchovy and sardines in the Santa Barbara Basin sediments suggest past climate change much more complex than a simple 'cold/anchovy regime' and 'warm/sardine regime'

There is actually a very weak, but significant, positive relationship between the two species

Generally lower scale fluxes of both species during Little Ice Age (which some evidence indicates was a warm period in the California Current)

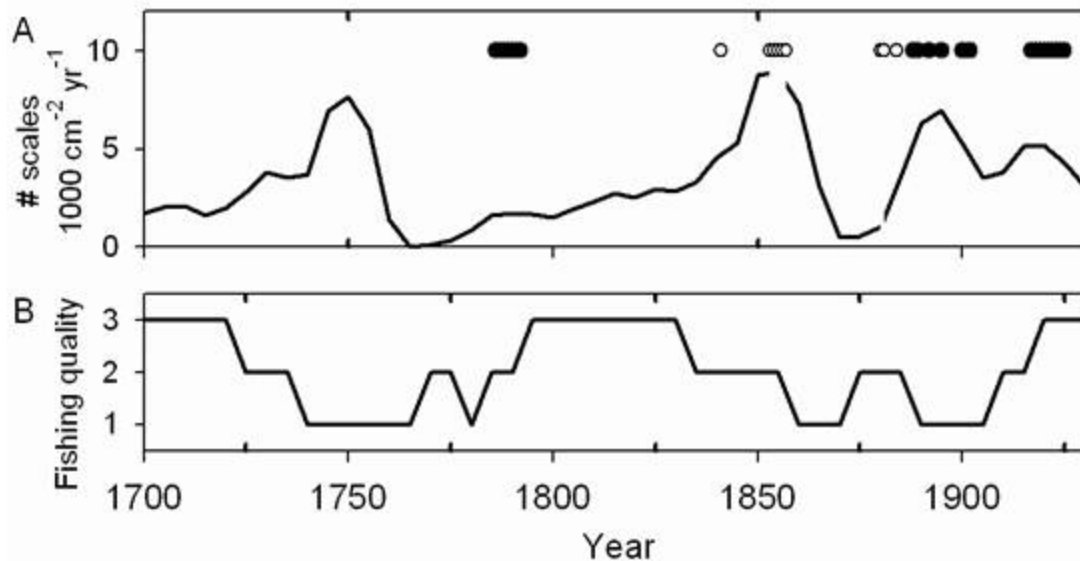


Baumgartner et al. (1992)

Historical records do not support the Paradigms

Historical records do not support the covariation of sardine abundance off California with those off Japan

Historical records do not support the occurrence of sardines in the Pacific northwest when there is inferred high abundance off California



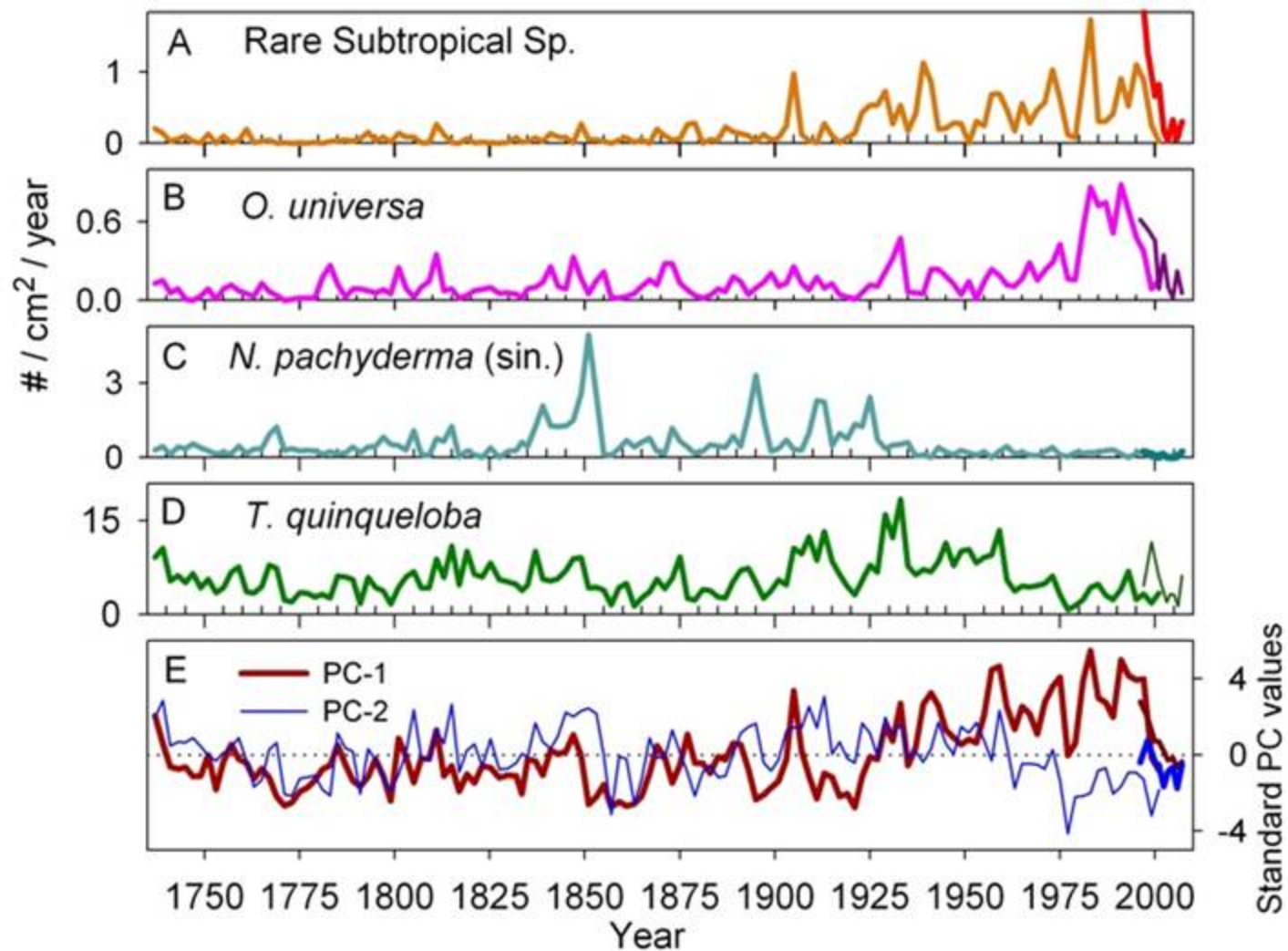
Historical records from Pacific Northwest

SBB scale deposition

Japanese historical records

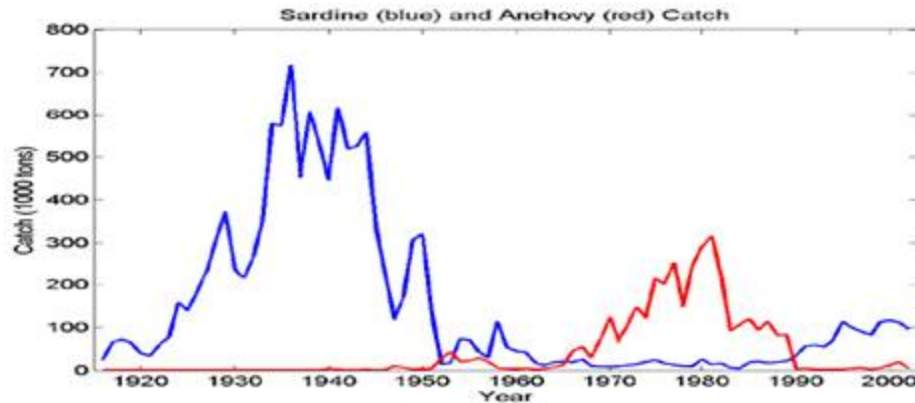
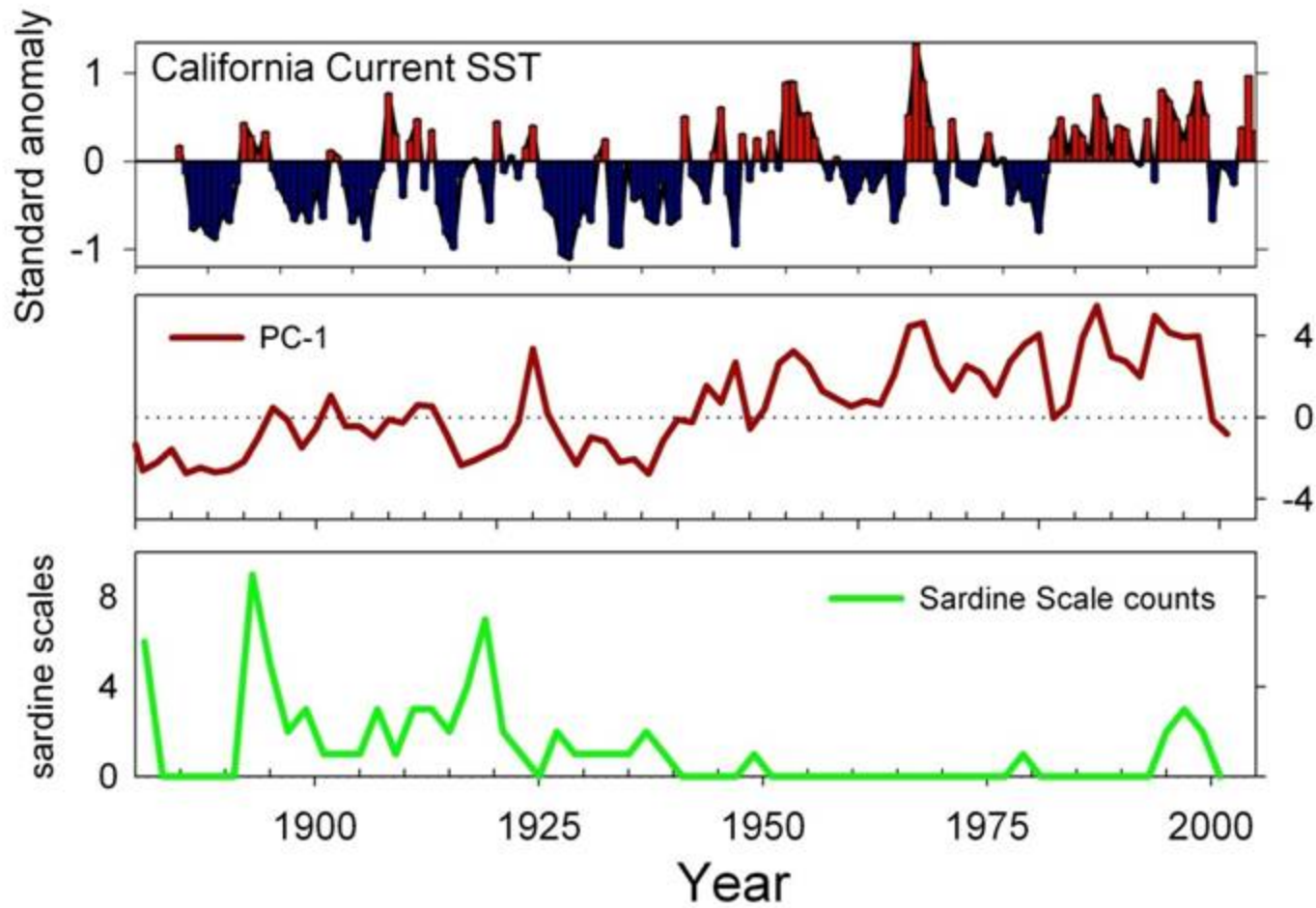
Field et al. (in press)

What about a better estimate of temperature variations from more recent periods?

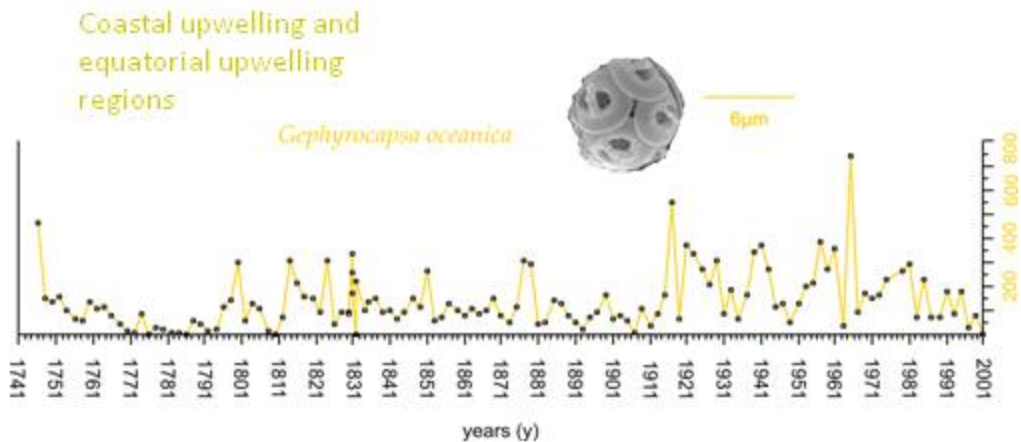
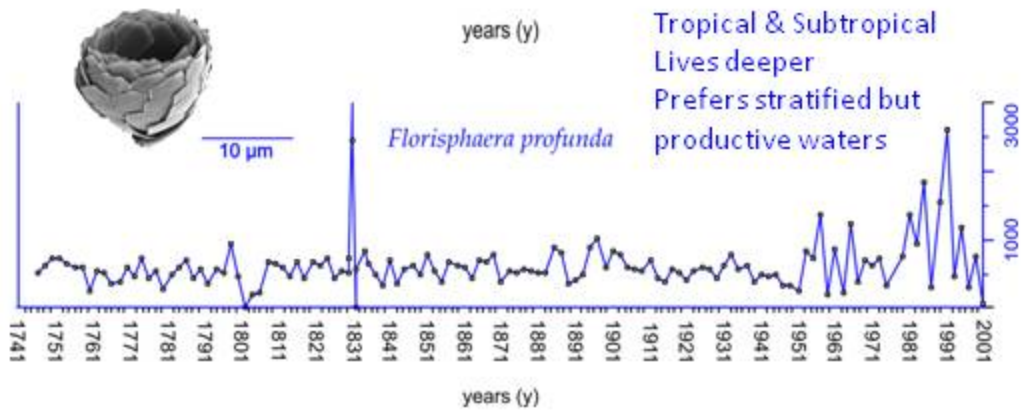
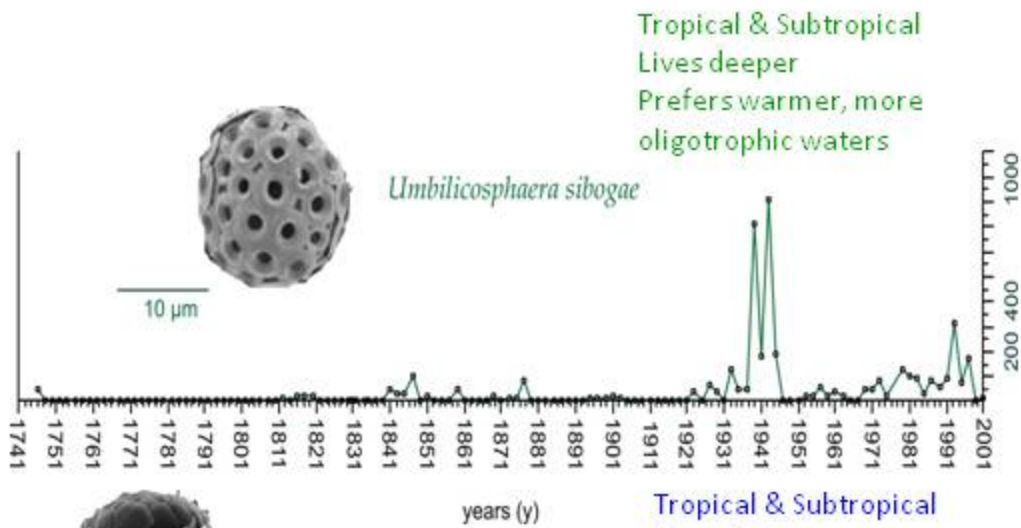


Field et al. (2006)

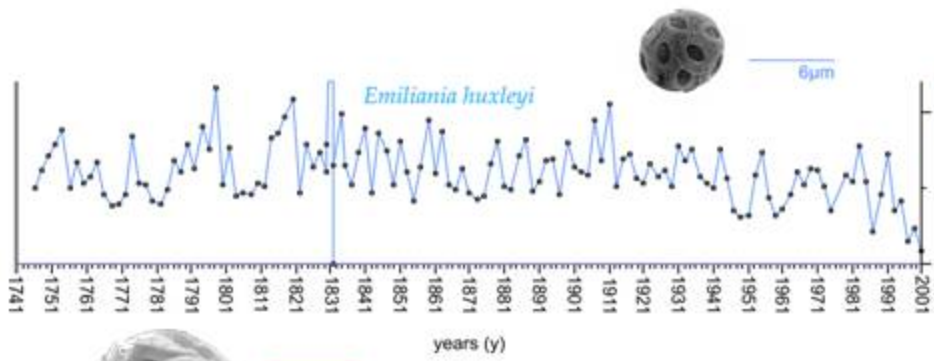




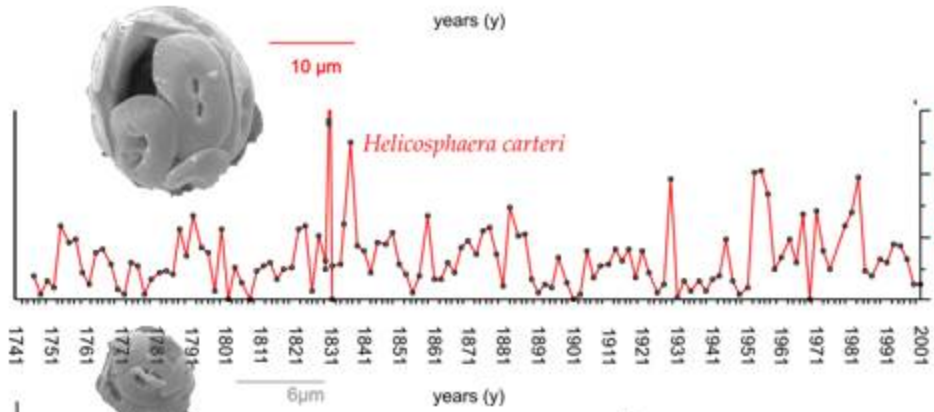
There is quite good evidence for very cool temperatures (from COADS and foraminifera) when fish scale deposition (and fish capture) is high during early 20th century (and late 19th century)



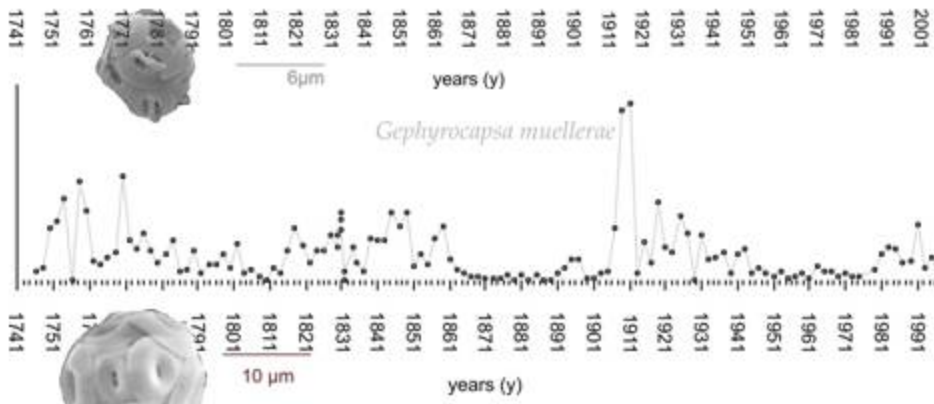
Courtesy De Bernardi



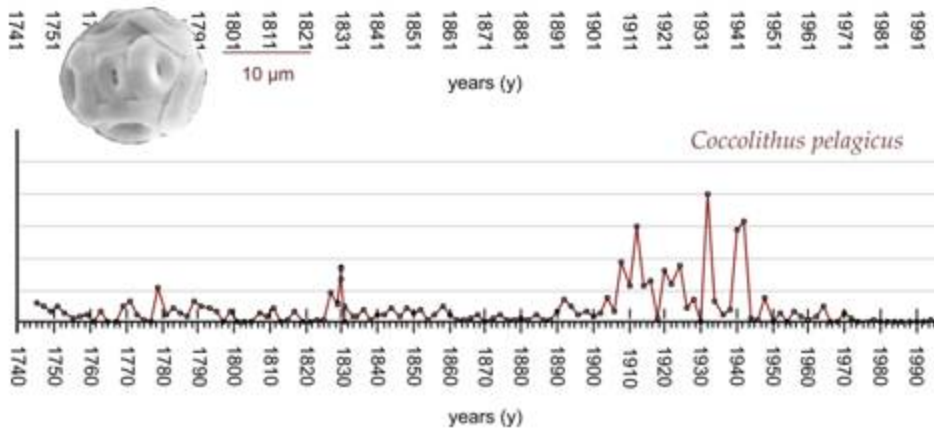
Ubiquitous, dominant species, particularly in temperate or higher productivity environments



Courtesy De Bernardi

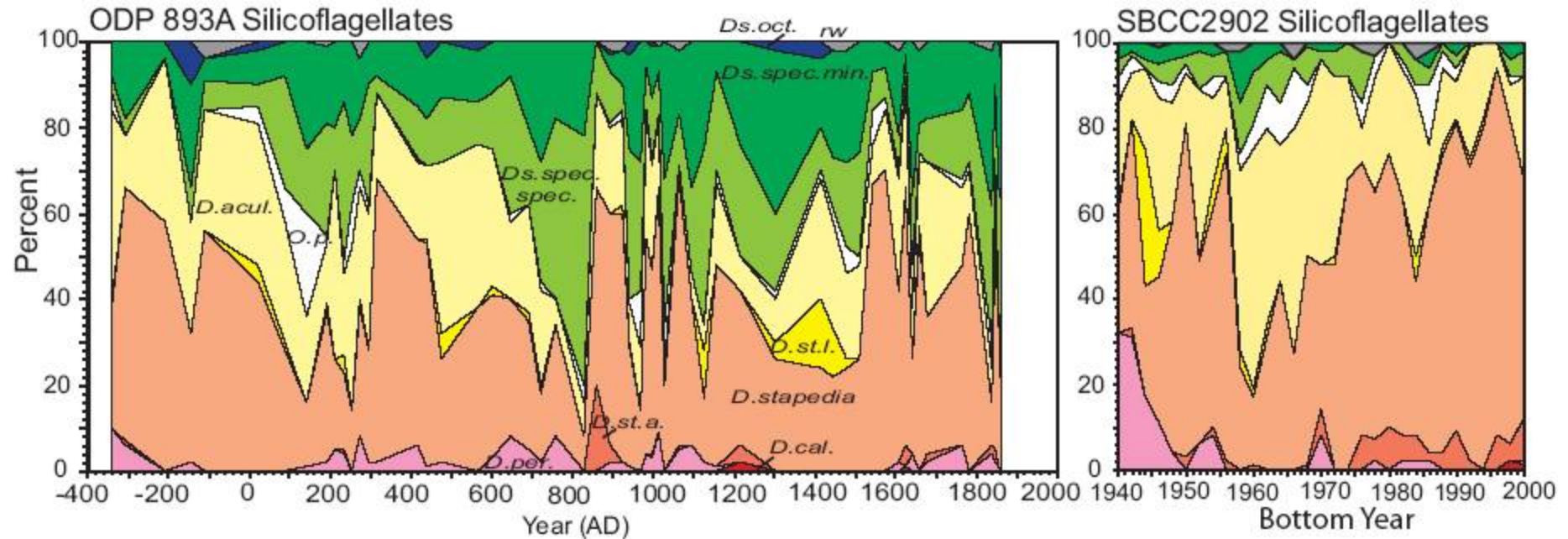
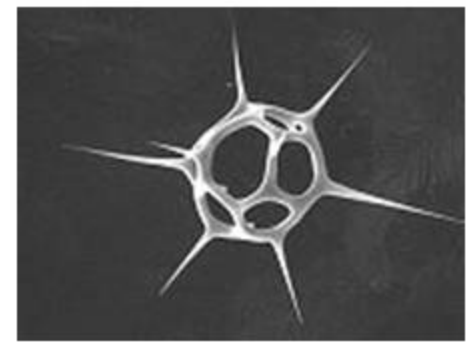


Temperate
Most abundant in near-surface with higher productivity



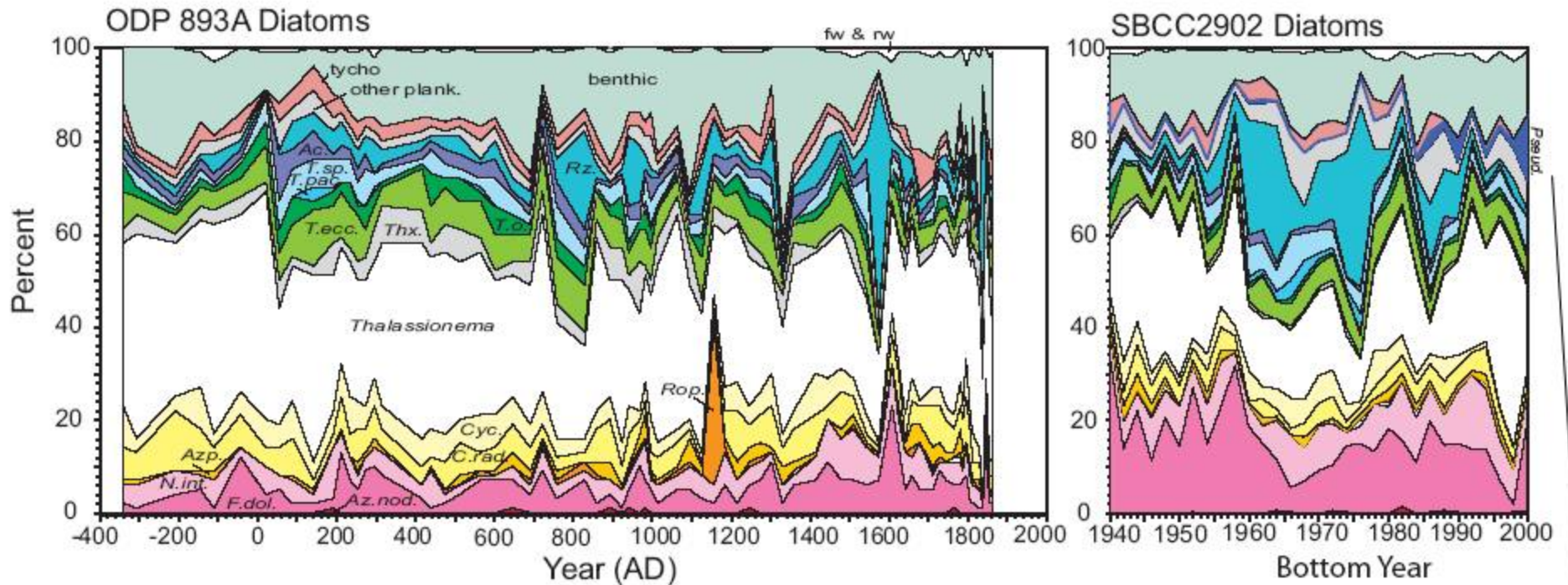
Subpolar species

Barron et al. (2009)

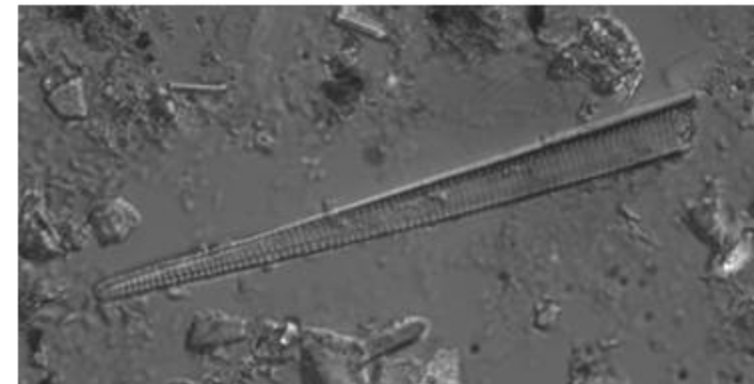


- Greater percent of tropical and subtropical species of silicoflagellates during 20th century (since 1940) than previous centuries

- Greater percent of tropical and subtropical species of diatoms during 20th century (since 1940) than previous centuries

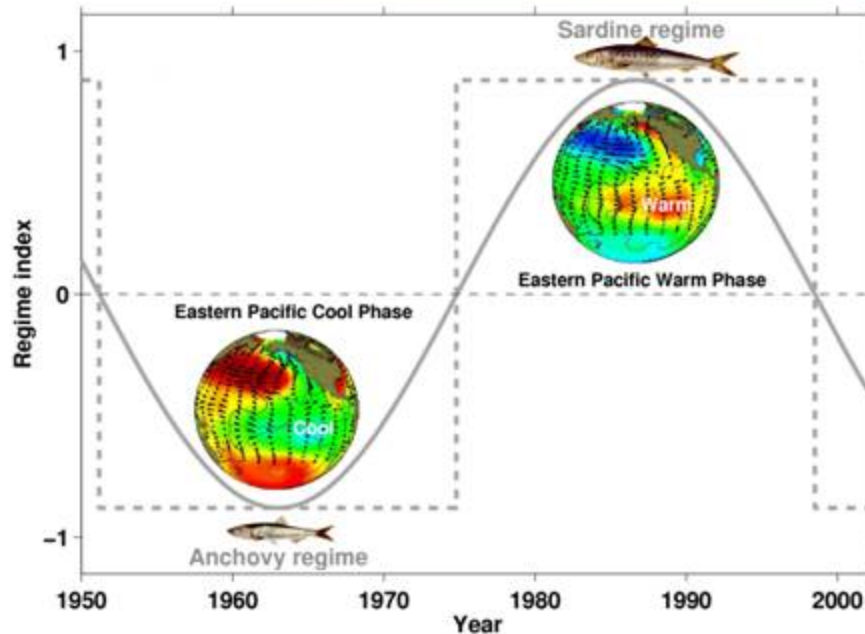


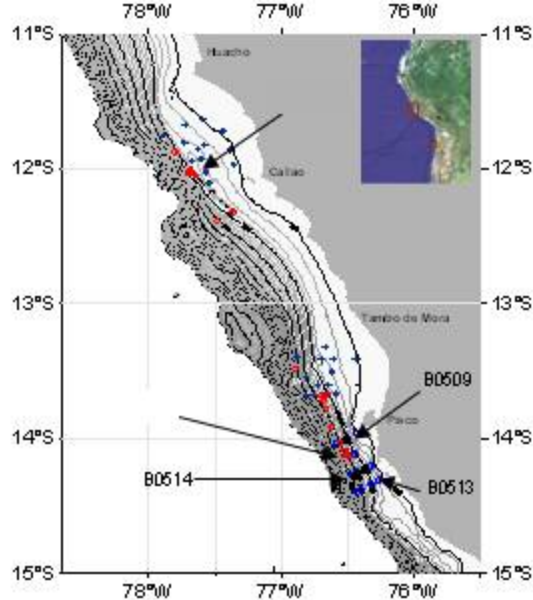
Appearance of *Pseudonitzschia* in 20th century, particularly in late 20th century



Barron et al. (2009)

PALEOPECES: What is the nature of decadal-scale variability in ocean climate and its effect on marine populations (Peruvian anchoveta) in the Humboldt Current?





Sediment cores located across a range of the distribution of anchoveta (off Peru).

Also a core off northern Chile (where anchovy are relatively more abundant during El Niño years)

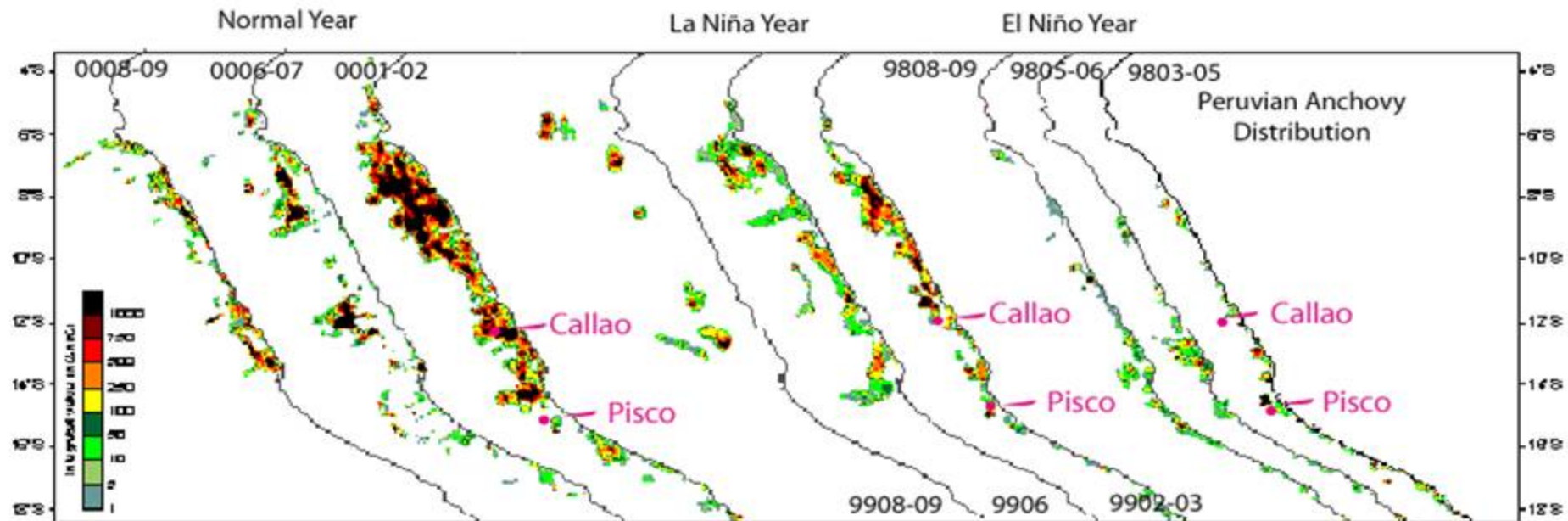
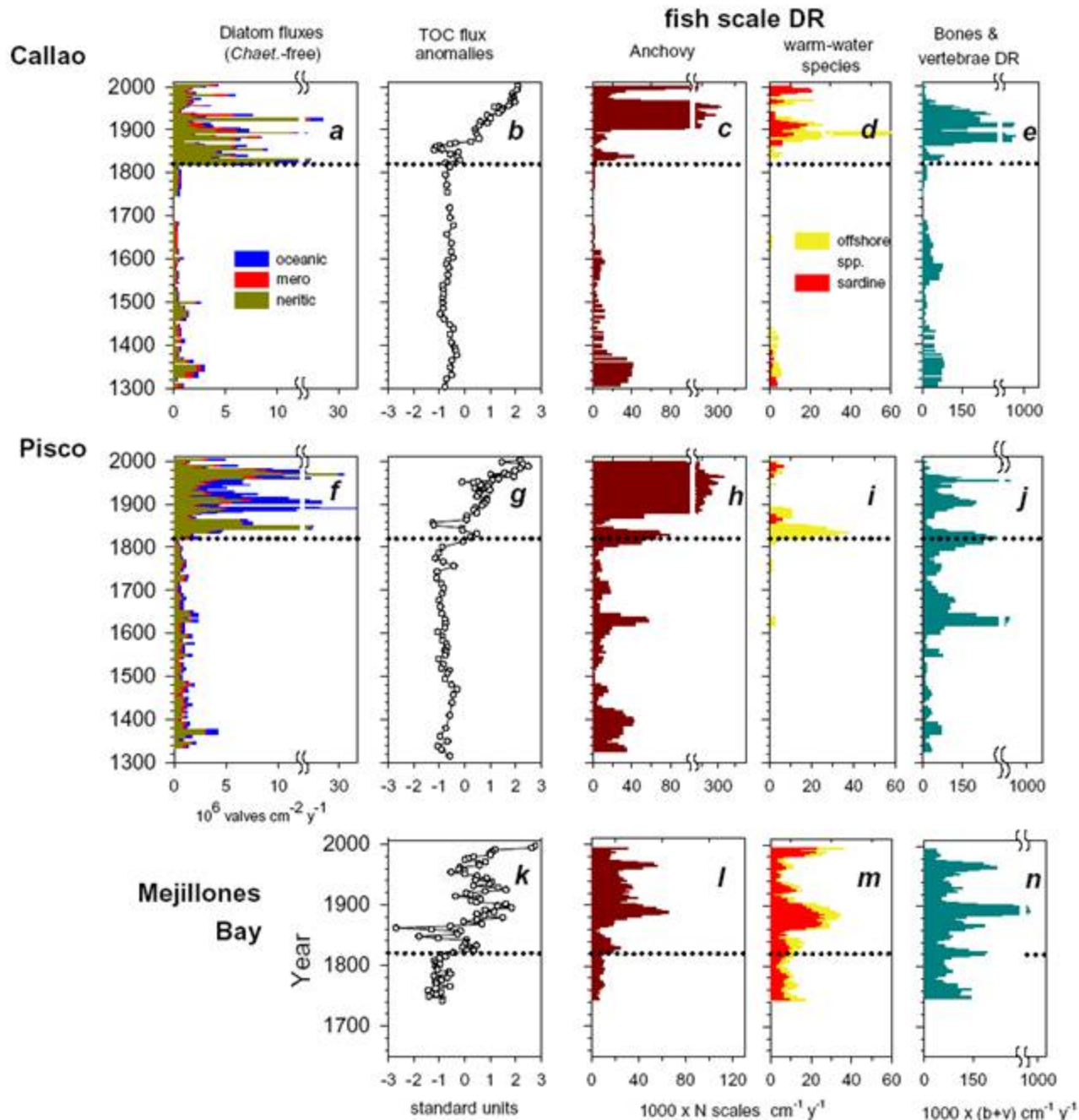


Figure 2. Distribution of anchovy biomass along the coast of Peru as inferred from acoustic surveys taken during different seasons (year and month) of three different years.



Like the Santa Barbara Basin, there is not clear evidence for strict alternations of sardine and anchovy

There is an extended period of low scale fluxes of both species corresponding to low productivity as inferred from fluxes of diatoms and organic matter

There is an increase in flux of Total organic carbon (TOC) at the same time as an increase in SST from COADS and decrease in coastal regions (not shown)

Gutierrez et al. (2009)

Conclusions

1. The relationships that exist in the 20th century of:
 - a) Alternations between sardines and anchovies in many different regions and
 - b) greater abundance of sardine in the California Current with higher SSTare not apparent in longer records
2. During the late 20th century there have been impacts of the warming trend (as well as anthropogenic activities) which will undoubtedly have increasing effects and modifications on ecosystems in the future
3. Many patterns or paradigms based on 20th century observations are unlikely to be maintained in the future. Increasing attention must be paid to the actual mechanisms of change, rather than covariables that are associated with changes for several years or decades.