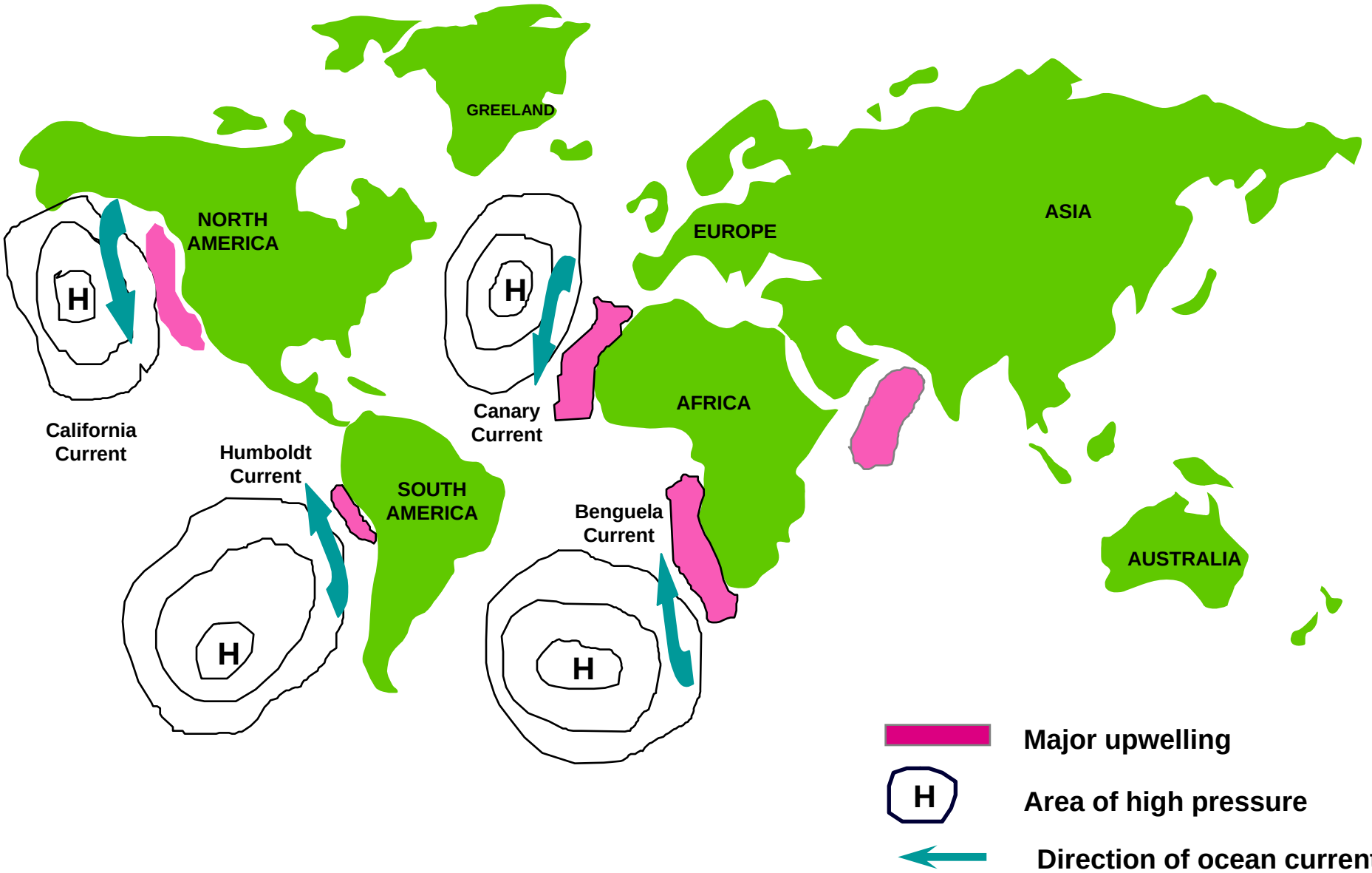
Long term changes in zooplankton size distribution in the Peruvian Humboldt Current System: Conditions favouring sardine or anchovy

Patricia Ayón[1], Gordon Swartzman[2]

Pepe Espinoza[1], Arnaud Bertrand[1,3]

[1] Instituto del Mar del Perú (IMARPE)
[2] University of Washington
[3] Institut de recherche pour le développement (IRD)

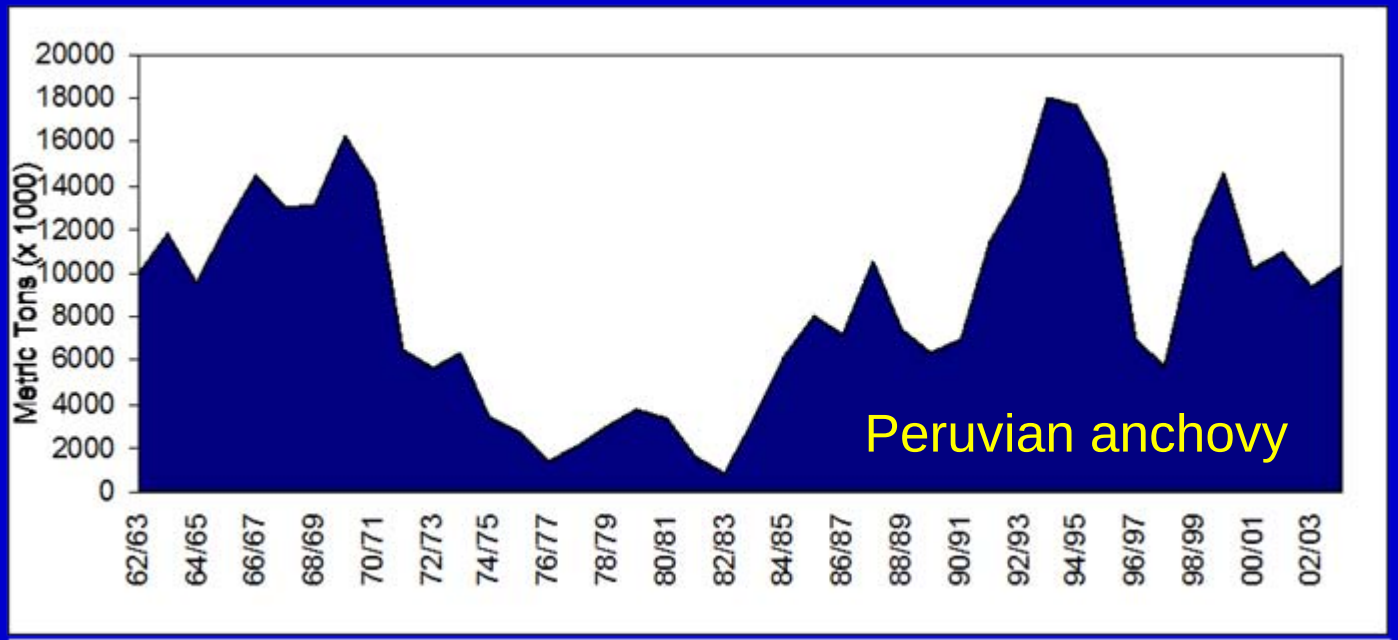
MAIN UPWELLING SYSTEMS

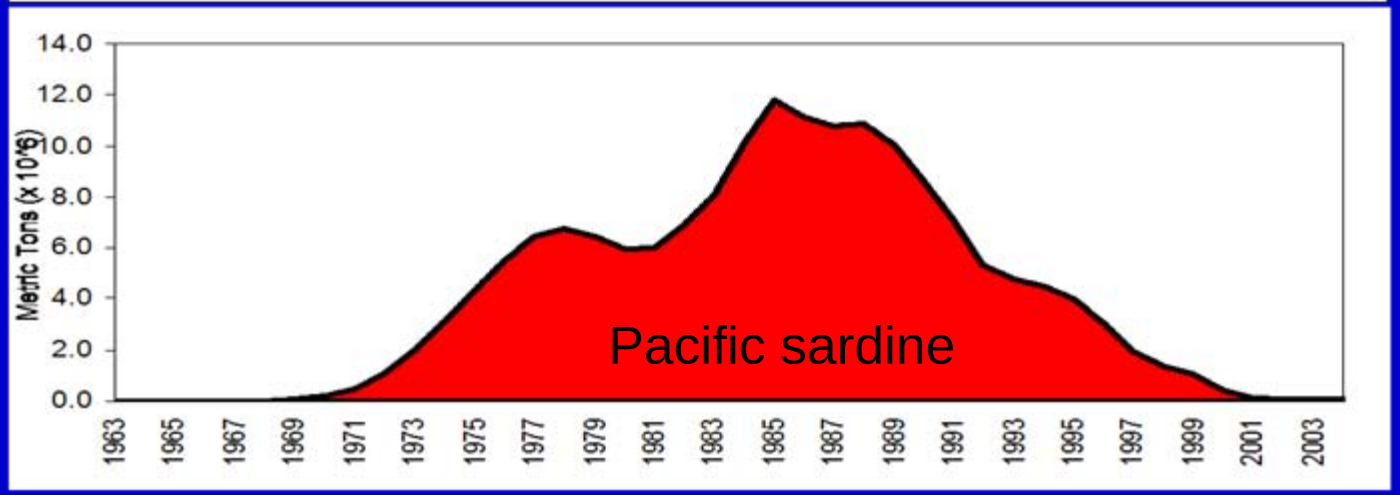


Pacific sardine
Sardinops sagax

Peruvian anchovy
Engraulis ringens

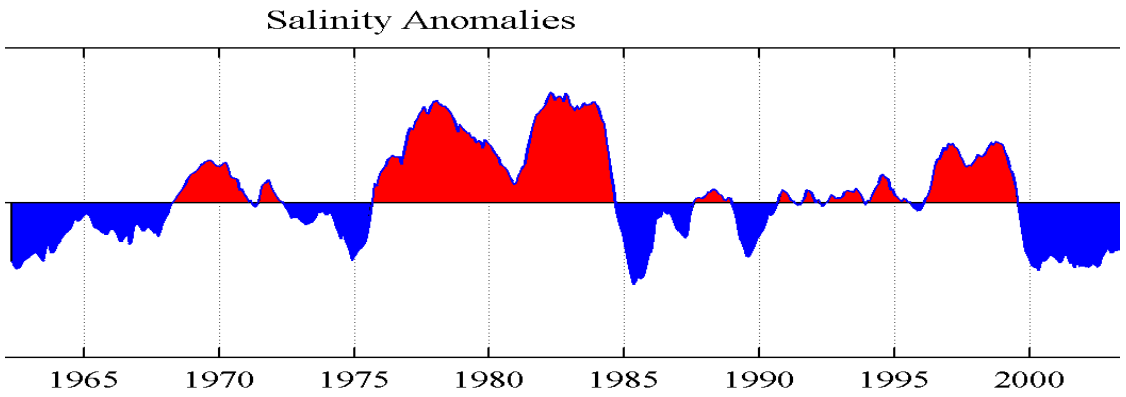
Trend of Mean Biomass of Peruvian ANCHOVY and SARDINE (Northern - Central stock)

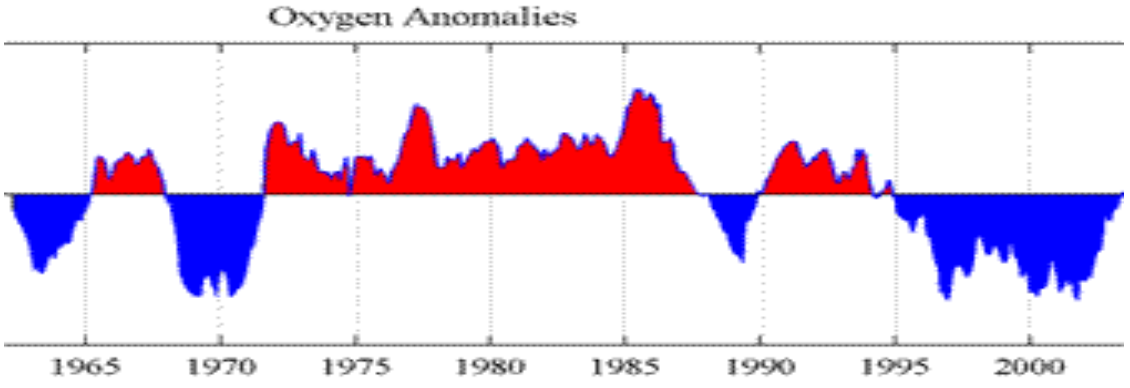




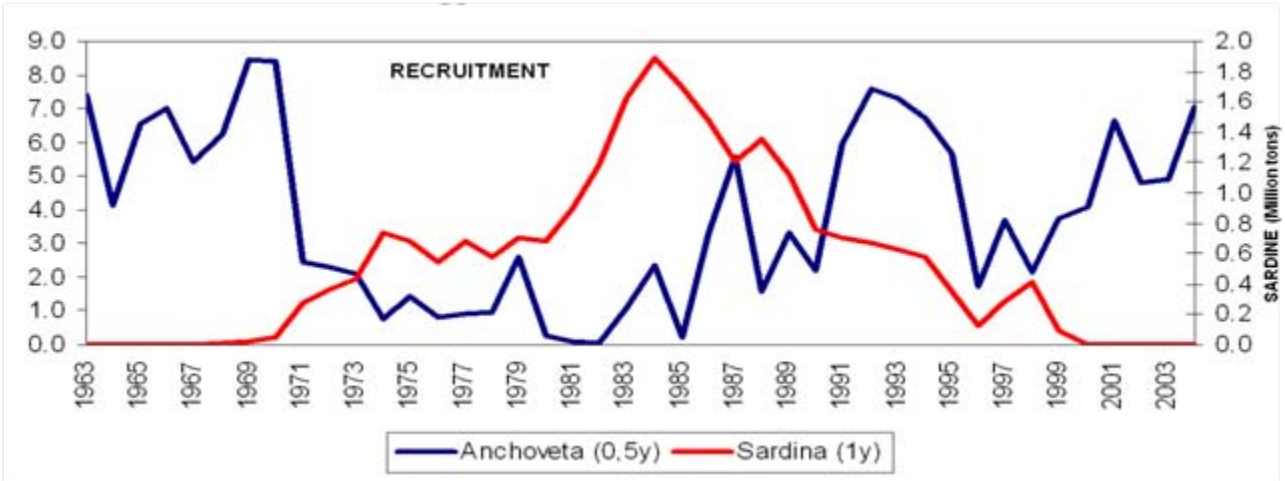
Source: Guevara-Carrasco

Hypotheses to explain alternation





Source F.Chavez



Source R. Guevara-Carrasco

Hypotheses to explain sardine-anchovy alternation

- Size-selective feeding hypothesis
- Optimal growth temperature
- Avoidance of low oxygen waters (upwelling) by sardine (habitat change)

A few relevant facts

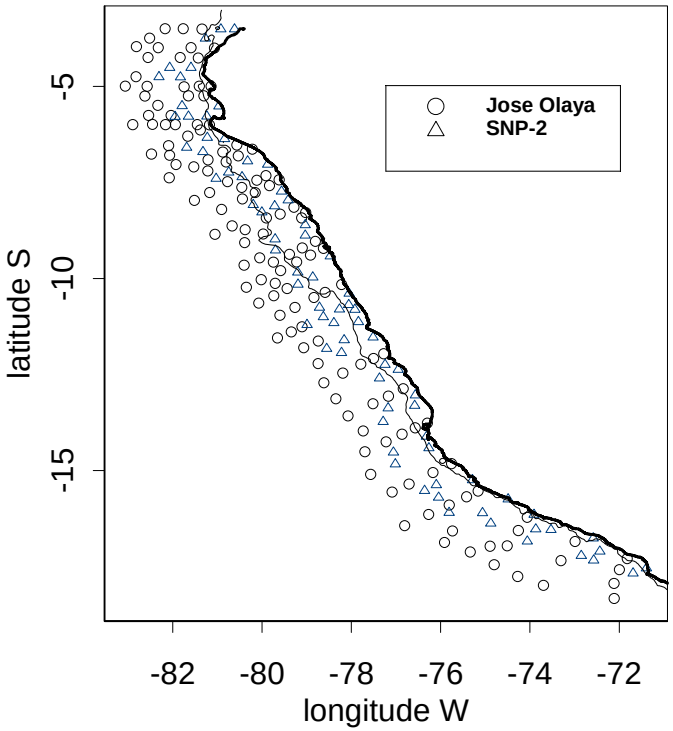
- Sardine distribution farther offshore than anchovy
- Sardine predominate during warmer periods (El Niño, El Viejo), anchovy during colder (higher upwelling) periods (La Niña, La Vieja)
- Anchovy are more associated with cold coastal waters, sardine with offshore oceanic waters

Size feeding hypothesis argument and support

- Both can filter feed, but sardine can filter feed energetically more efficiently and can take smaller organisms (up to 1 mm)
- Anchovy are mostly bite feeders and larger prey provide more nutrients
- More upwelling → more nutrients → larger phytoplankton → larger zooplankton → favor anchovy
- Less upwelling → scarce nutrients → smaller phytoplankton → smaller zooplankton → favor sardine

Examine size-feeding hypothesis

- Use zooplankton samples (formaldehyde stored) from 121 surveys 1963-2005 (> 15,000 samples)

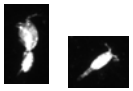


Zooplankton Sampling

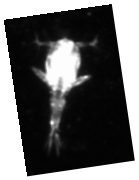
- Hensen nets, 300-um mesh
- 0-50 m vertical haul
- Remove gelatinous zooplankton and ichthyoplankton
- Zooplankton dominated by copepods and euphausiids
- Determined biovolume at time of sample

Qualitative sampling

- Classify organisms by size: small, medium, large zooplankton, euphausiids
- In each sample classify dominance of each size groups by integer between 0 and 3 (0=absent)
- Dominance is independent of biovolume (supposedly!)



small



medium

large

euphausiids

Zooplankton analysis
1. Validation

Comparison with two data sets:

- A) Species enumerations for 2 surveys in 1996 and 1998 (species composition-abundance)
- B) Size distribution from Zooscan on 2 surveys in 1965 and 1967 (32 samples)

small <1.3mm medium 1.3-2.9mm

large > 2.9mm euphausiids 10-25mm

Zooplankton analysis
1. Validation- correlation (r)

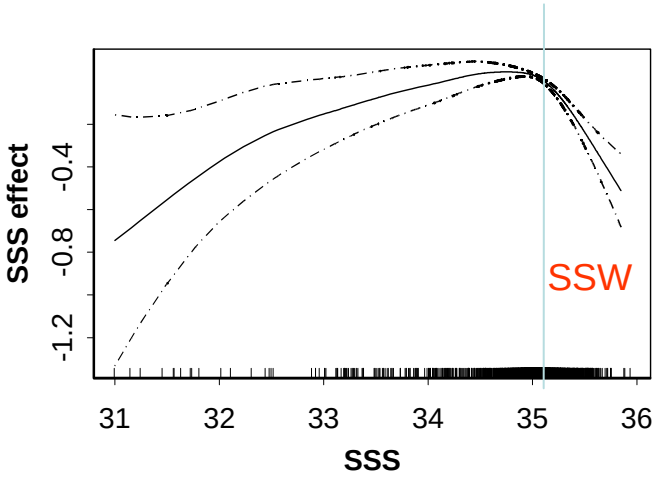
Data	Small zooplankton (< 1.3 mm)	Medium zooplankton (1.3-2.9 mm)	Large zooplankton (>2.9 mm)*	Euphausiids (10-25 mm)*
1996,1998 species composition A	0.22 (p =0.027)	0.33 (p=0.0014)	0.24 (p=0.016)	0.519 ($p=5x10^{-7}$)
1965, 1967 Zooscan size composition B	0.433 (p=0.013)	0.526 (P=0.0019)	0.407 (0.0205)	0.761 ($4.3 x10^{-7}$)

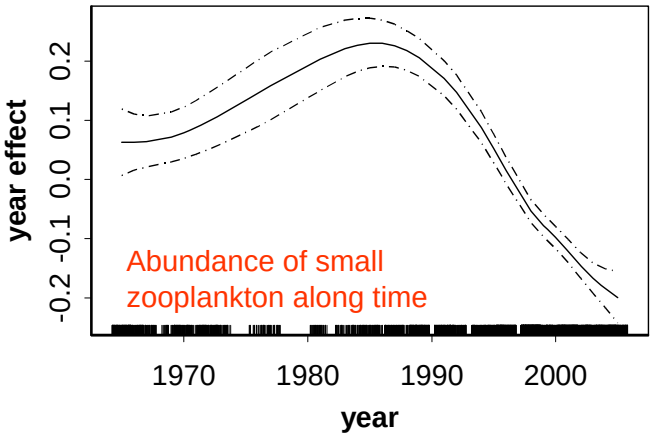
Zooplankton analysis - GAM

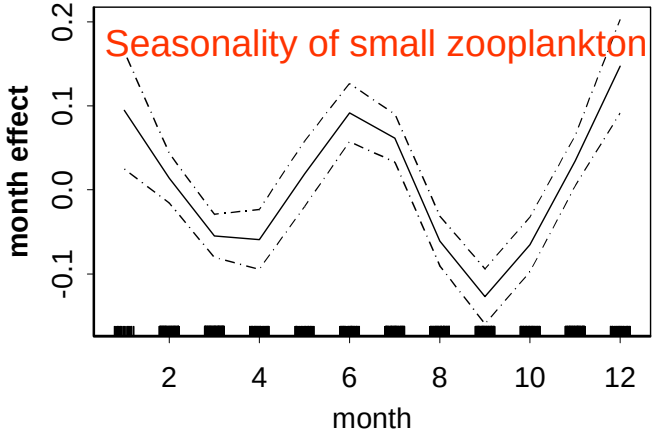
- Generalized Additive Models Nonparametric regression – uses smooths instead of least square fits (not linear)
- Effect of covariates – Sea surface temperature (SST), surface salinity (SSS), latitude (lat), year, month (mo), time of day (time) and distance from 200-m isobath (dist200; determines on-off shelf location)

Zooplankton analysis

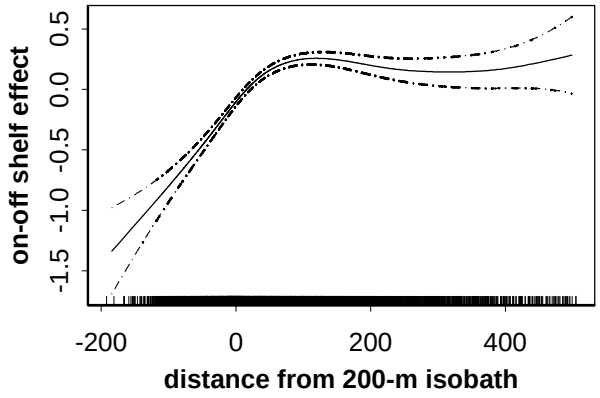
GAM- small zooplankton significant covariates

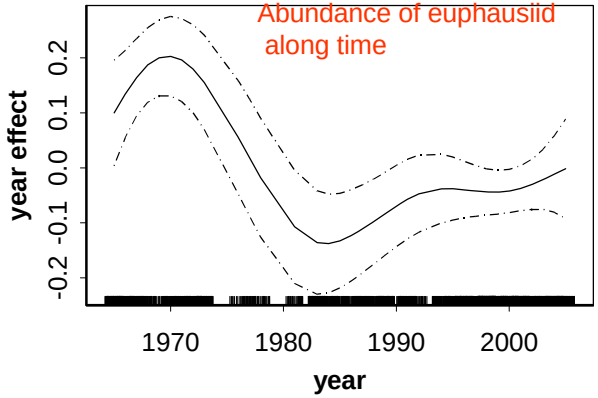


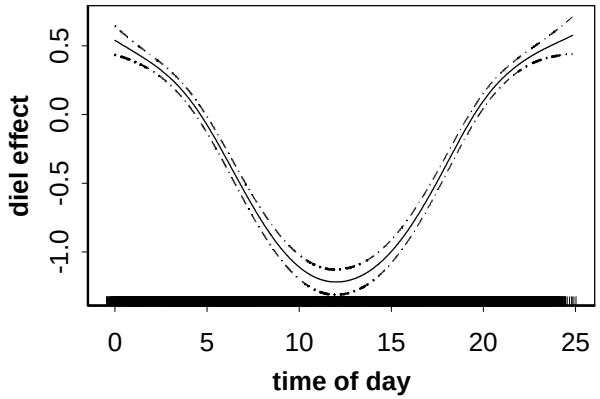




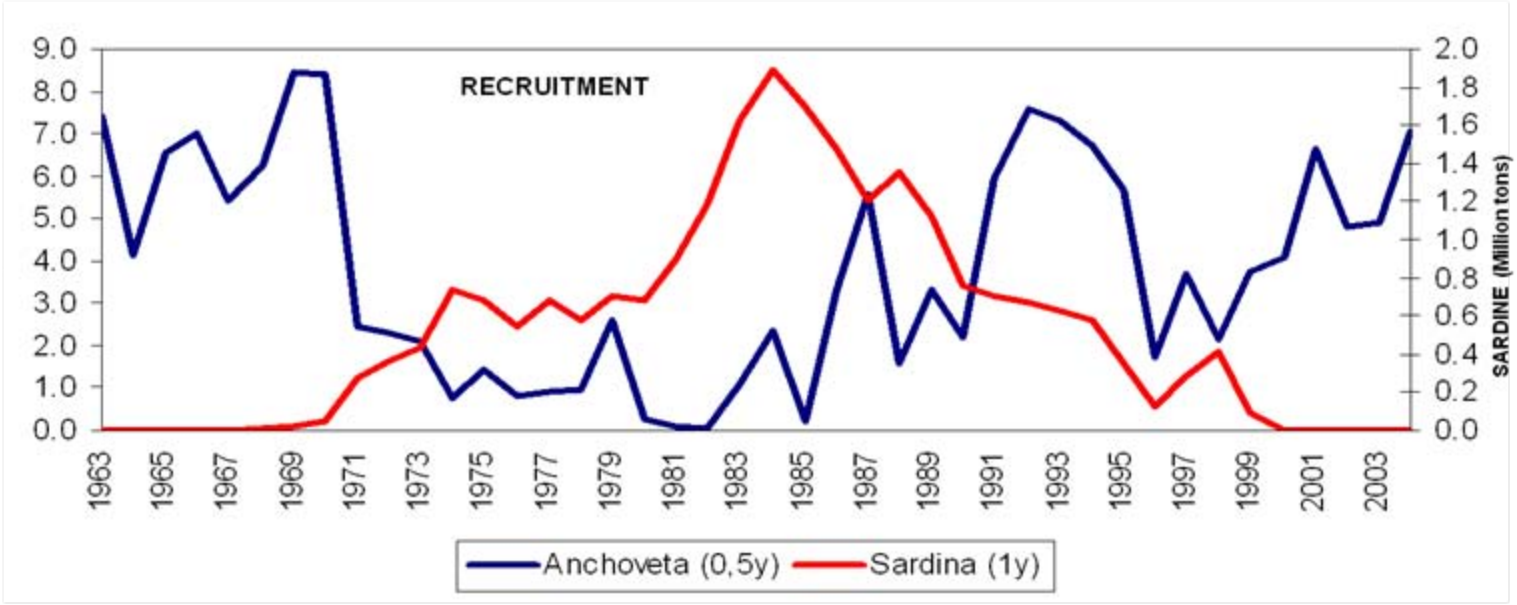
Zooplankton analysis – GAM euphausiids

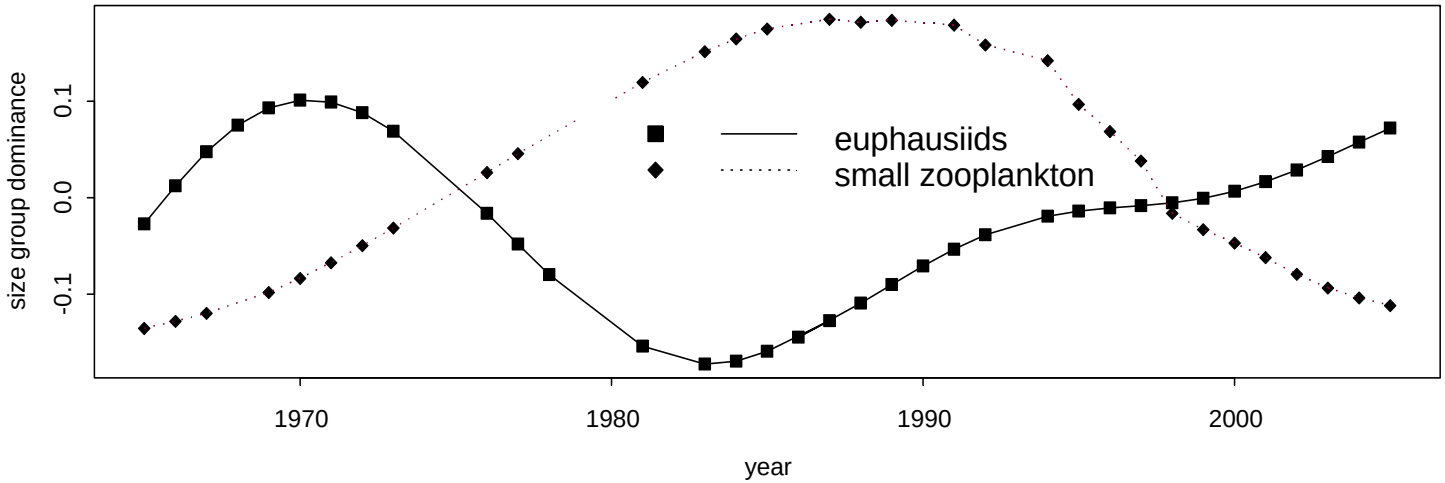






Zooplankton analysis – relationship to anchovy and sardine abundance





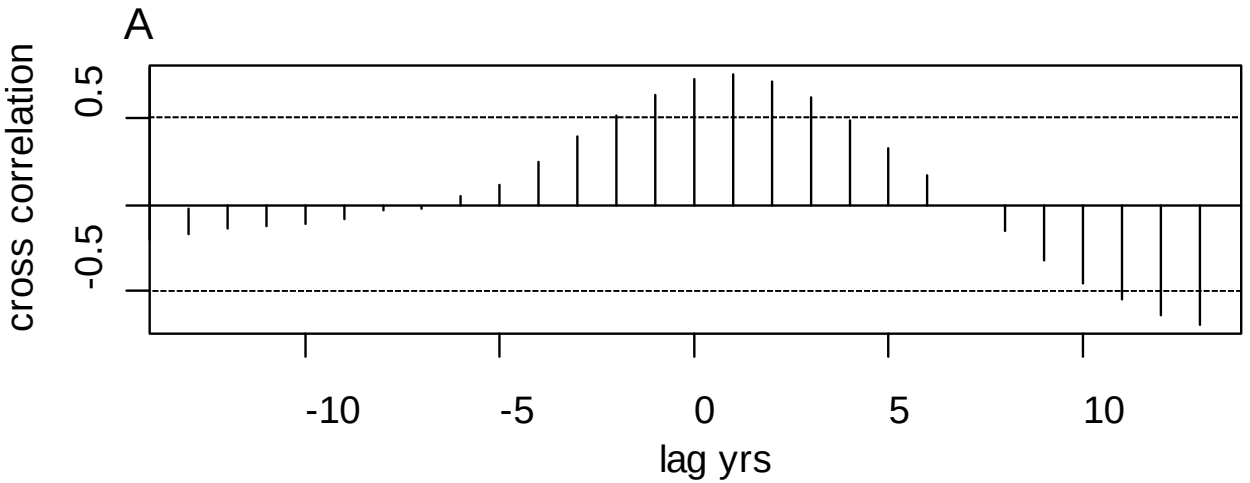
Zooplankton size – fish time series

Examine temporal pattern of size classes of zooplankton in relation to sardine and anchovy biomass time series:

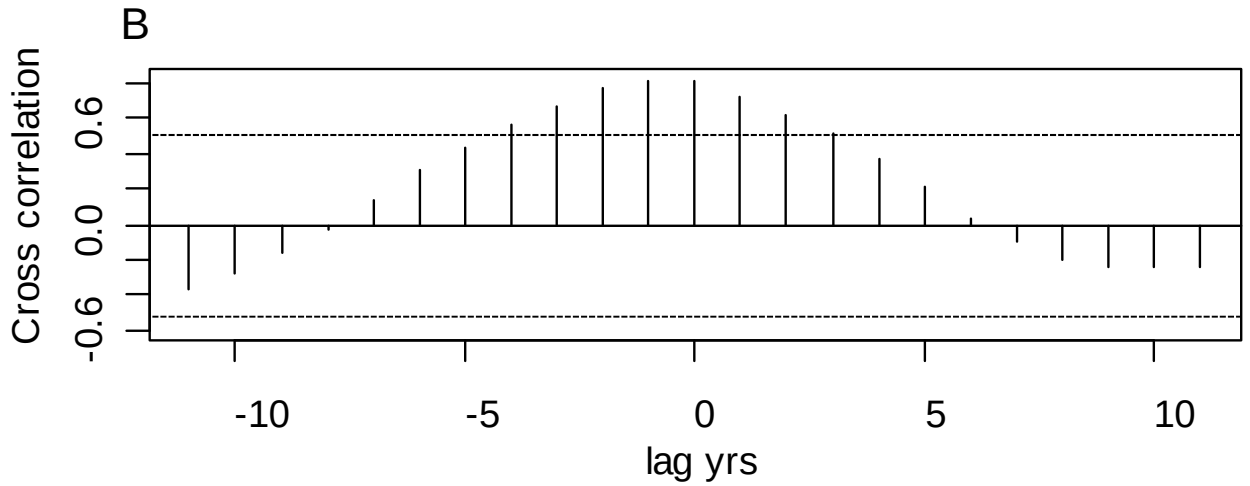
→ Cross correlation analysis at different time lags (i.e. years)

Zooplankton size – fish time series – cross correlation analysis

A – anchovy-euphausiids



B – sardine-small zooplankton



Cross correlation interpretation

- Anchovy in phase with euphausiids

- Sardine in phase with small zooplankton

- Other size groups not in phase with either

- This supports the size-feeding hypothesis for both anchovy and sardine