Zooplankton time series from Eastern Boundary Upwelling Systems: within- and between-system comparisons

Jenny Huggett, Todd O'Brien, Hans Verheye, Patricia Ayon, Antonio Bode, Ruben Escribano, Anja Kreiner, Angel Lopez-Urrutia, Dave Mackas, Mark Ohman, Bill Peterson & Chris Reason

Eastern Boundary Upwelling Ecosystems Symposium – Las Palmas 2008:

SCOR WG125: A comparison of zooplankton time series from four eastern boundary upwelling systems

(WG125 group photo –Nov 2005)

+ our Global Data Partners for this comparison 'Partners'

David Mackas , Hans Verheye , Patricia Ayón, Luis Valdés, Mark Ohman, Todd OBrien & Hal Batchelder
(SCOR WG125 members)

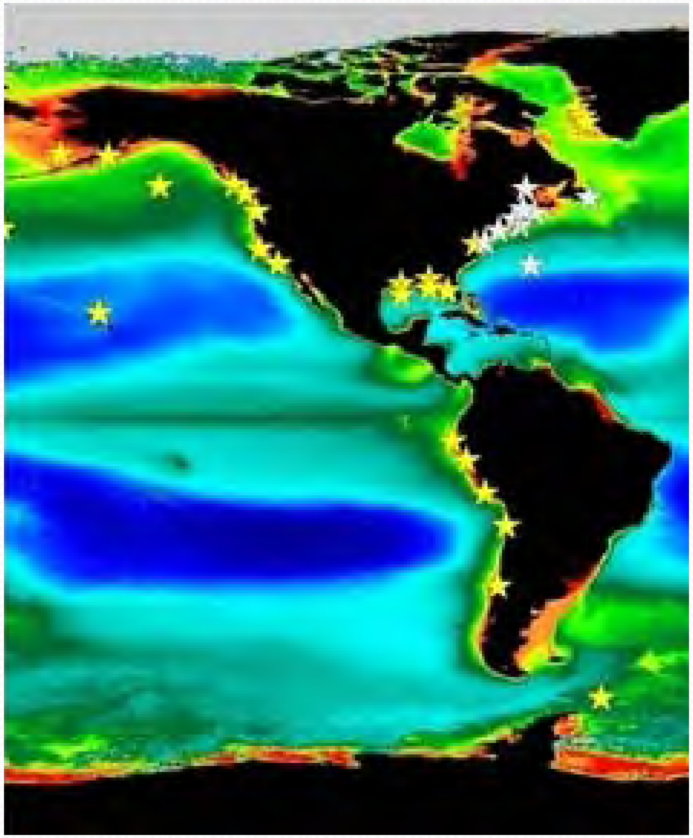
W. Peterson, B. Lavaniegos, A. Miranda, M.T. Alvarez Ossorio , K. Aronés , M. Galbraith, M. Trudel

Datasets & acknowledgements 1

PACIFIC OCEAN

- California Current
  - Vancouver (Dave Mackas)
  - Oregon (Bill Peterson)
  - CalCOFI (Mark Ohman)

- Humboldt Current
  - Peru (Patricia Ayon)
  - Chile (Ruben Escribano)



Datasets & acknowledgements 2

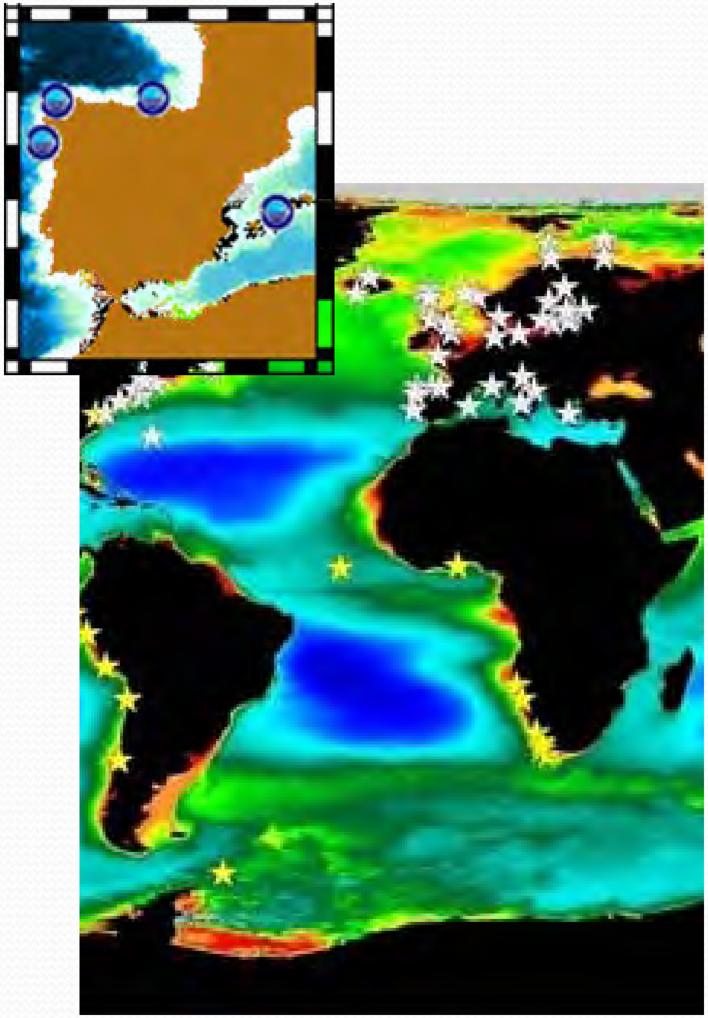
ATLANTIC OCEAN

- Iberian Peninsula

  Project RADIALES - Antonio Bode

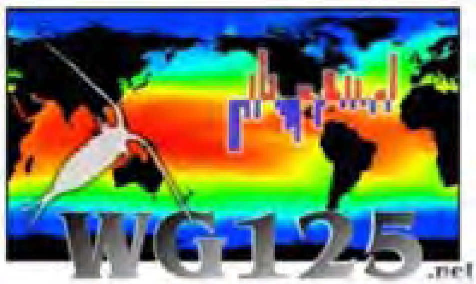
  - A Coruna – Maite Alvarez-Ossorio
  - Gijon – Angel Lopez-Urrutia
  - Vigo – Ana Miranda

- Benguela Current
  - Namibia – Anja Kreiner & Rudi Cloete; Fabienne Cazassus, Sakhile Tsotsobe, Hans Verheye
  - South Africa - Hans Verheye, Jenny Huggett

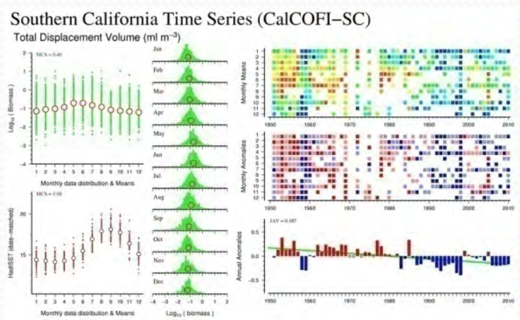


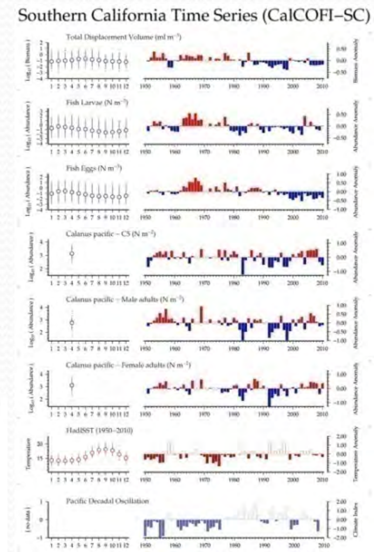
The tools for the job

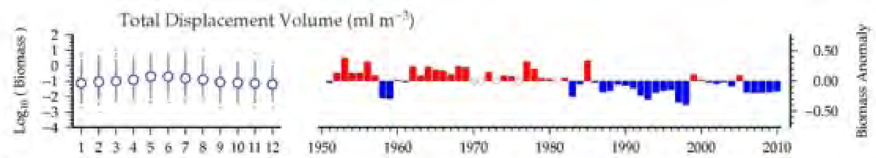
- Toolkit – Todd O'Brien



2.4 Gb; 46,719 files

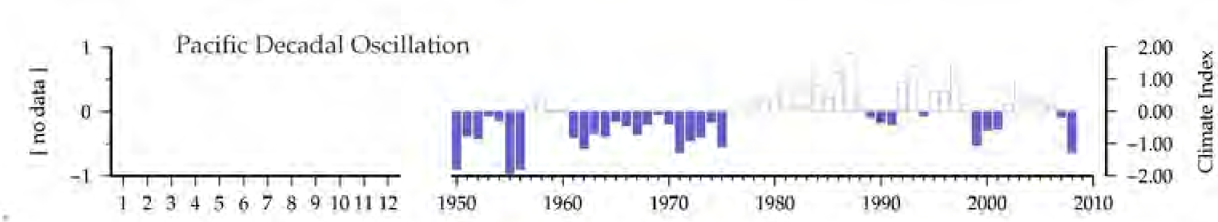


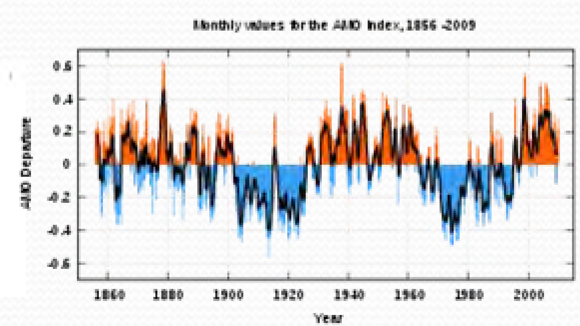




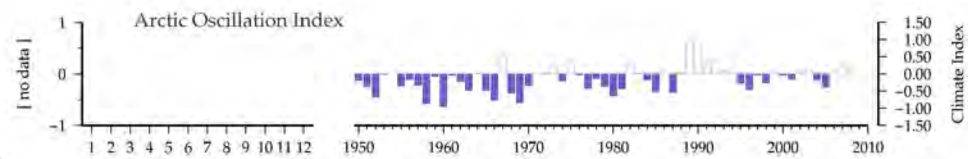
Standard zooplankton time series analyses and graphical visualizations were developed in support of and in collaboration with the SCOR Global Comparisons of Zooplankton Time Series Working Group (WG125), adapted from **O'Brien *et al.* 2008**

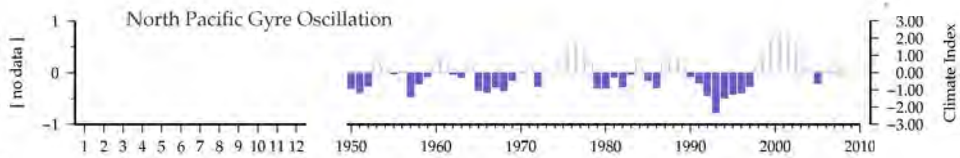
- Climate index advice – Chris Reason

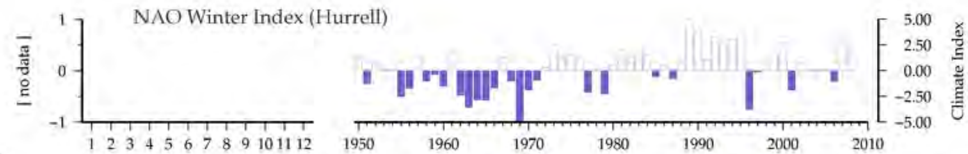


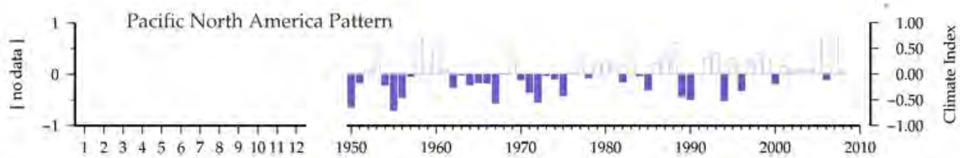


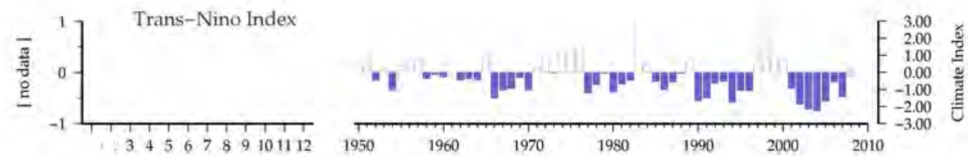
Climate Indices considered

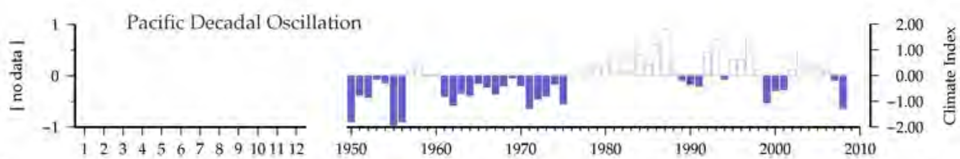


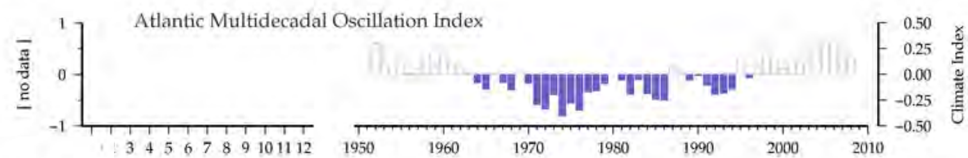


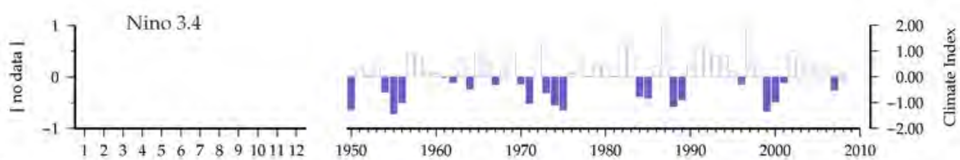








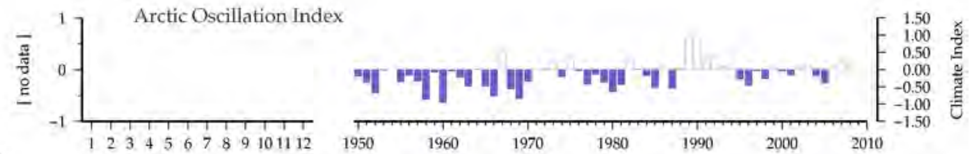


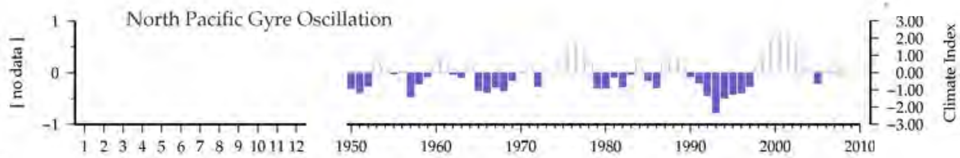


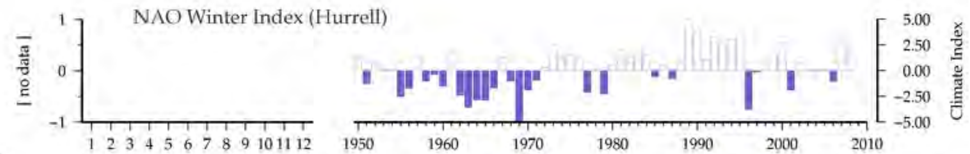
Southern Annular Mode? (SAM)

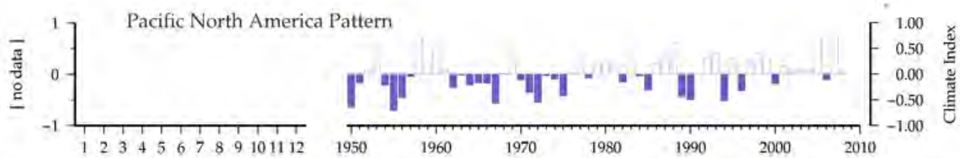
Climate Indices considered

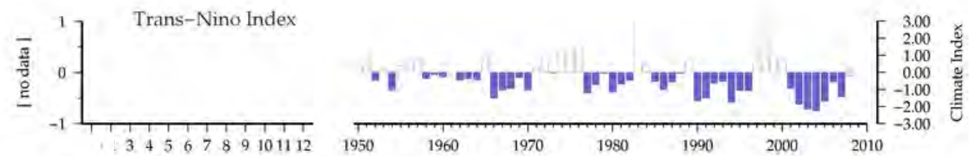
PDO & AMO show most promise
(low frequency climate variability)

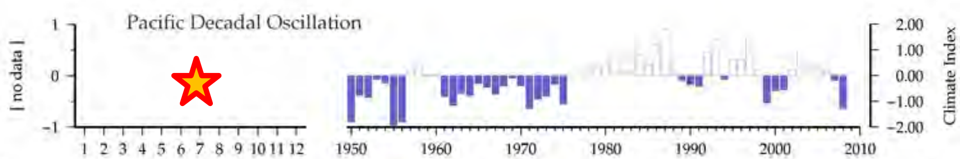


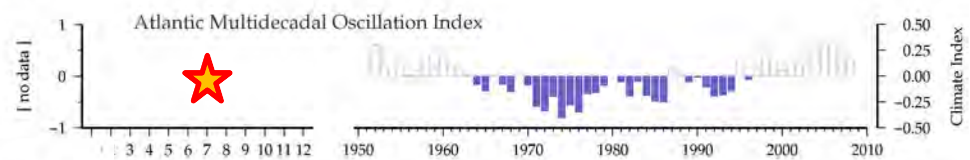


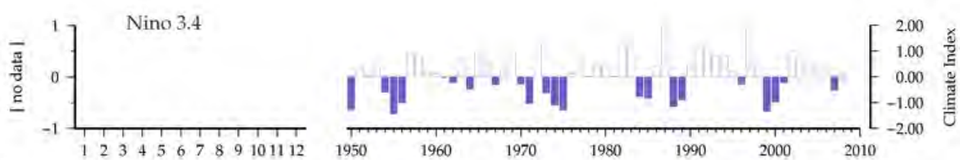






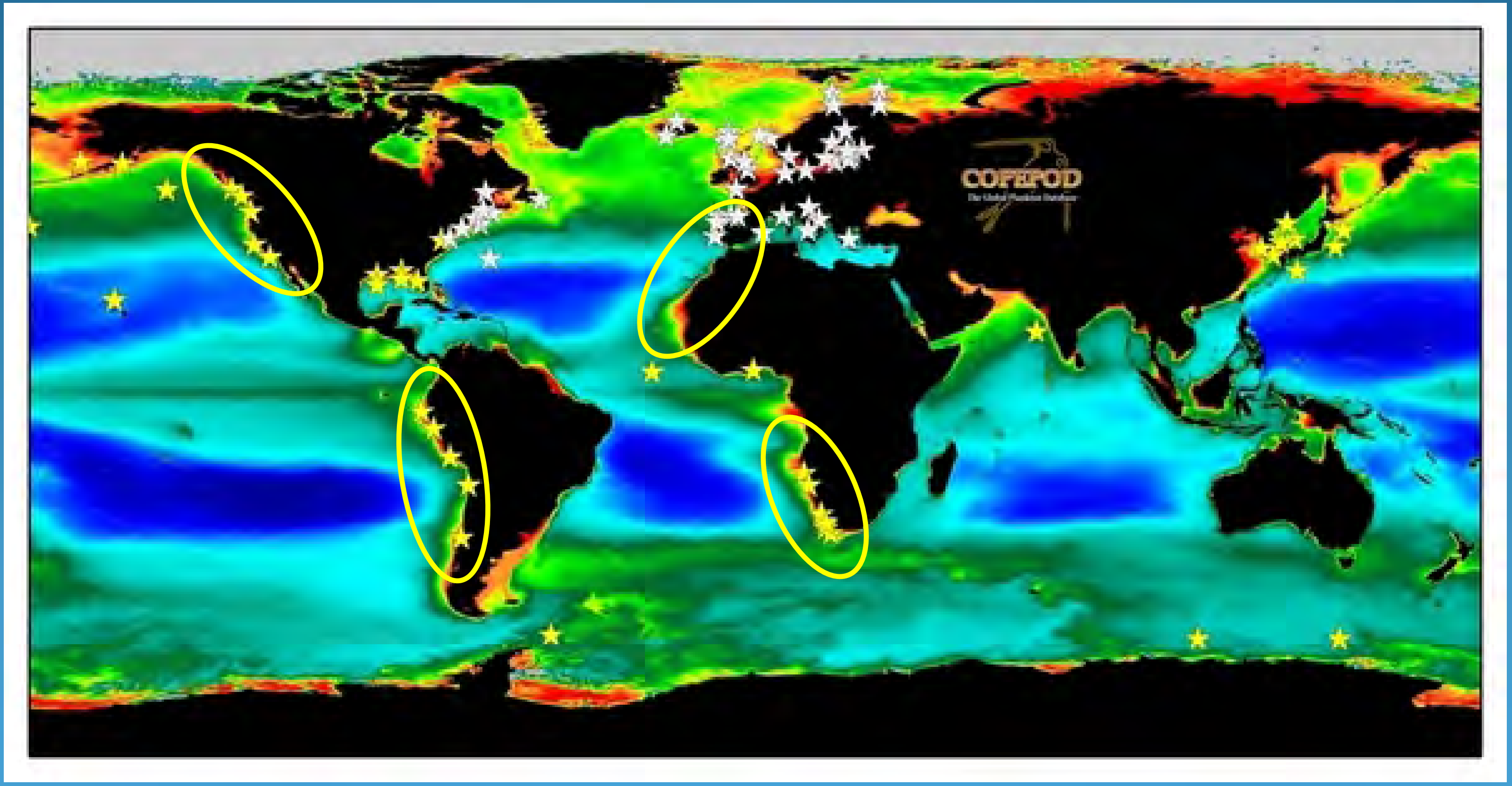






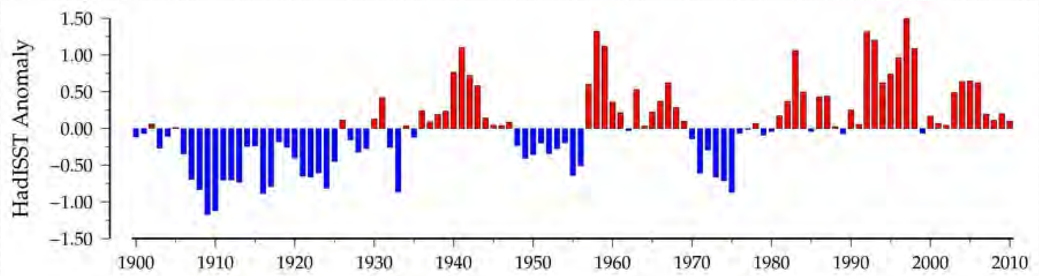
Southern Annular Mode? (SAM)

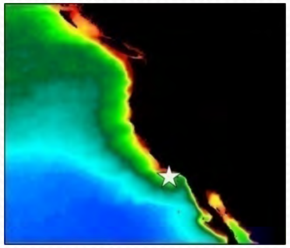
Between-system comparison



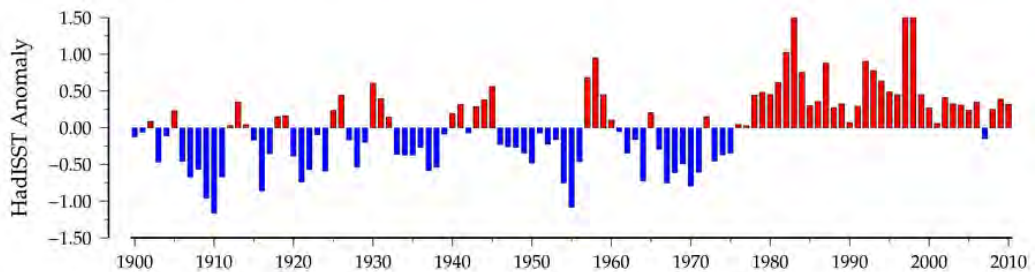
Long term SST – all regions

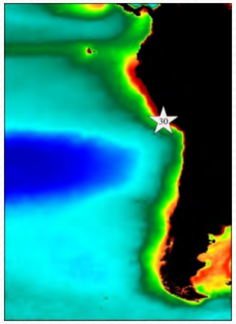
Southern California



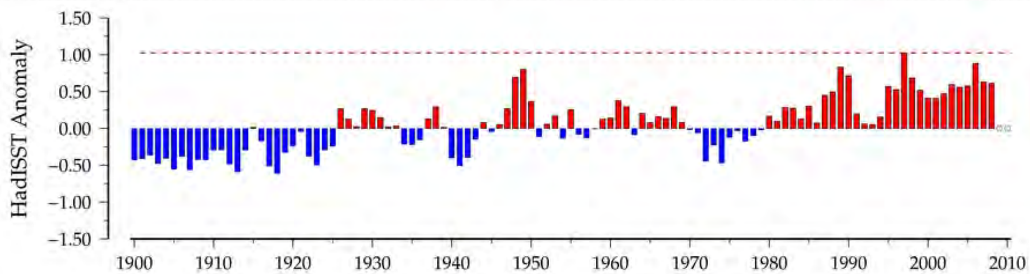


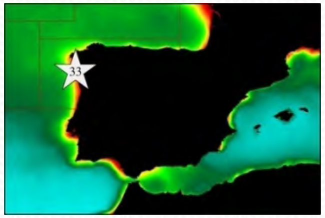
Humboldt – Peru C (14-18.5°S)



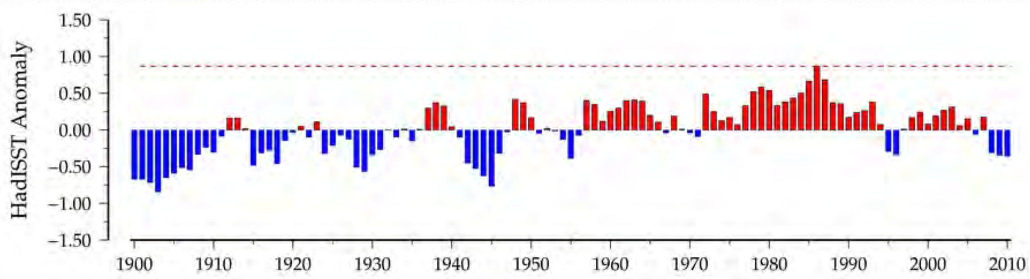


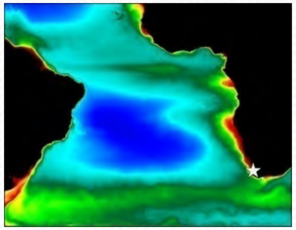
Canary (Iberia) Vigo



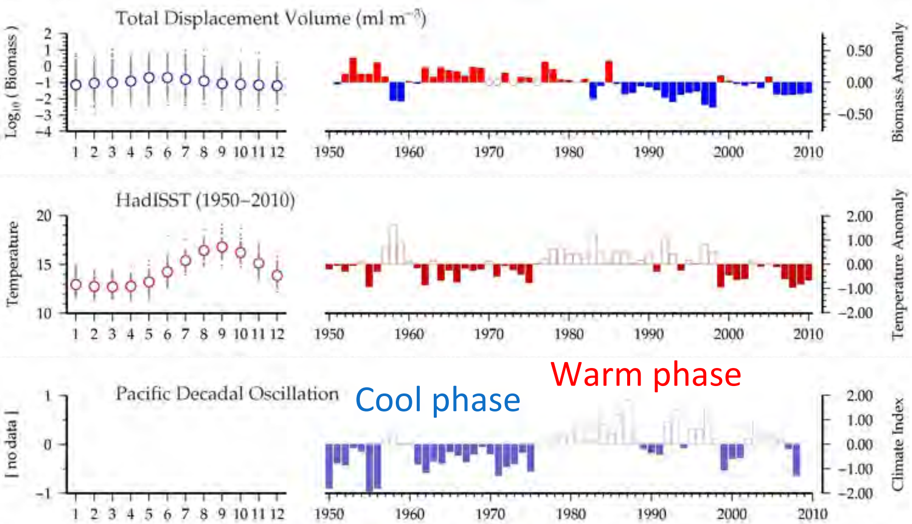


Southern Benguela (St Helena Bay)

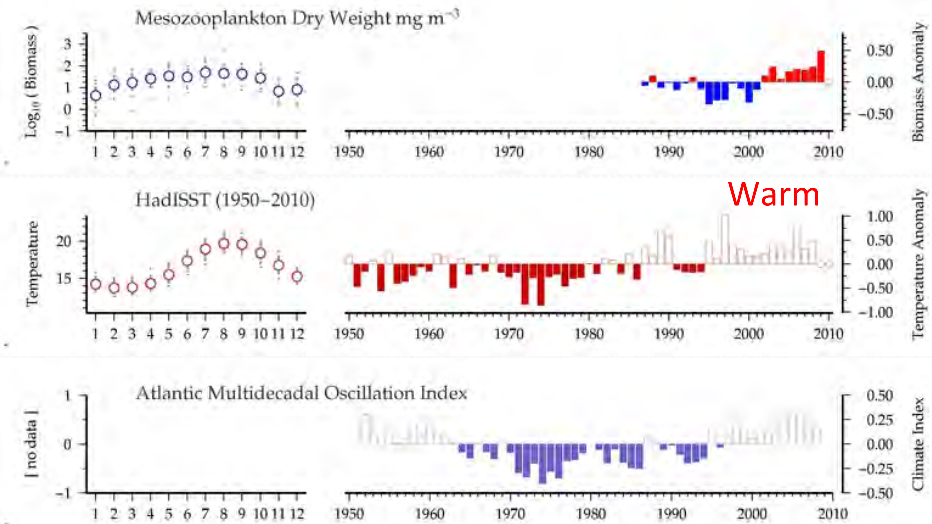




North Pacific – Southern California (CalCOFI)



North Atlantic – Vigo (Iberian Peninsula)

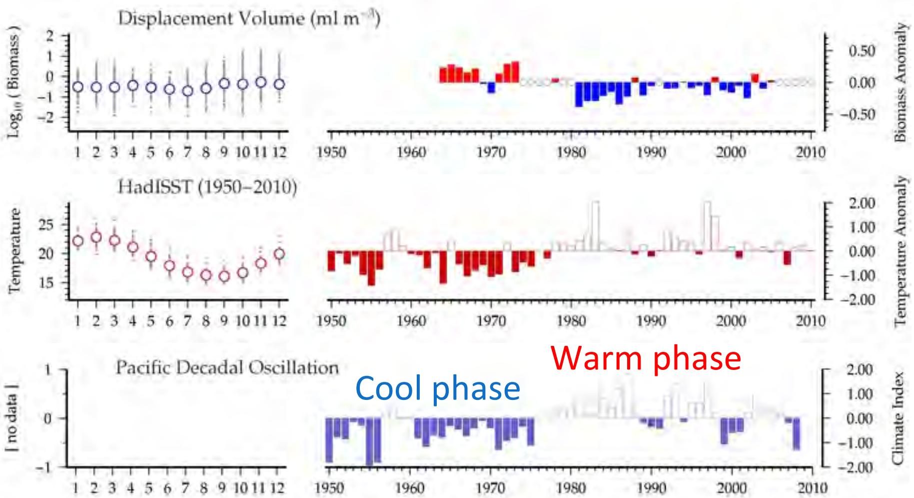


- Long-term warming trend in all areas (1900-2010) but not always clear for 1950s+ (recent cool phase except for Iberia)

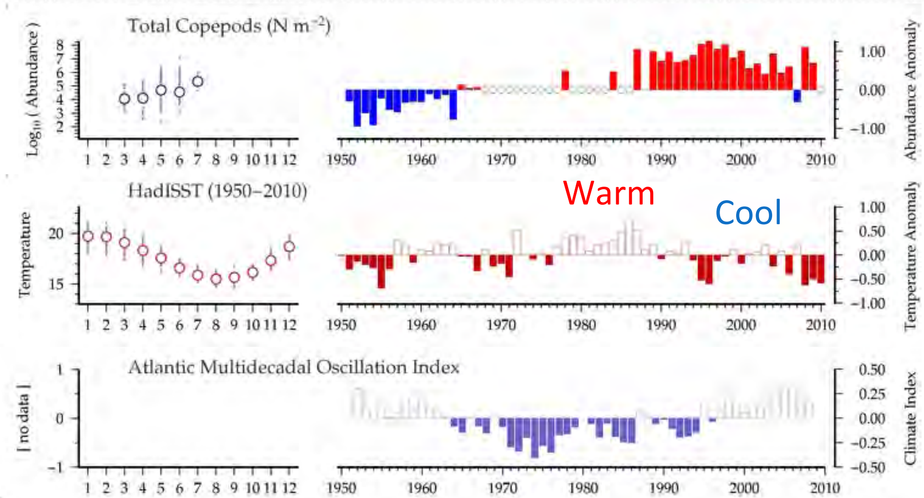
- North Pacific: long-term decline in zooplankton (salps)
- South Pacific zooplankton: Shift from +ve to -ve phase
- broadly similar patterns between N & S; PDO linkage

- North Atlantic: recent increase in zooplankton biomass
- South Atlantic: long-term increase, but recent decline
- recent trends in SST and zooplankton are opposite; AMO?

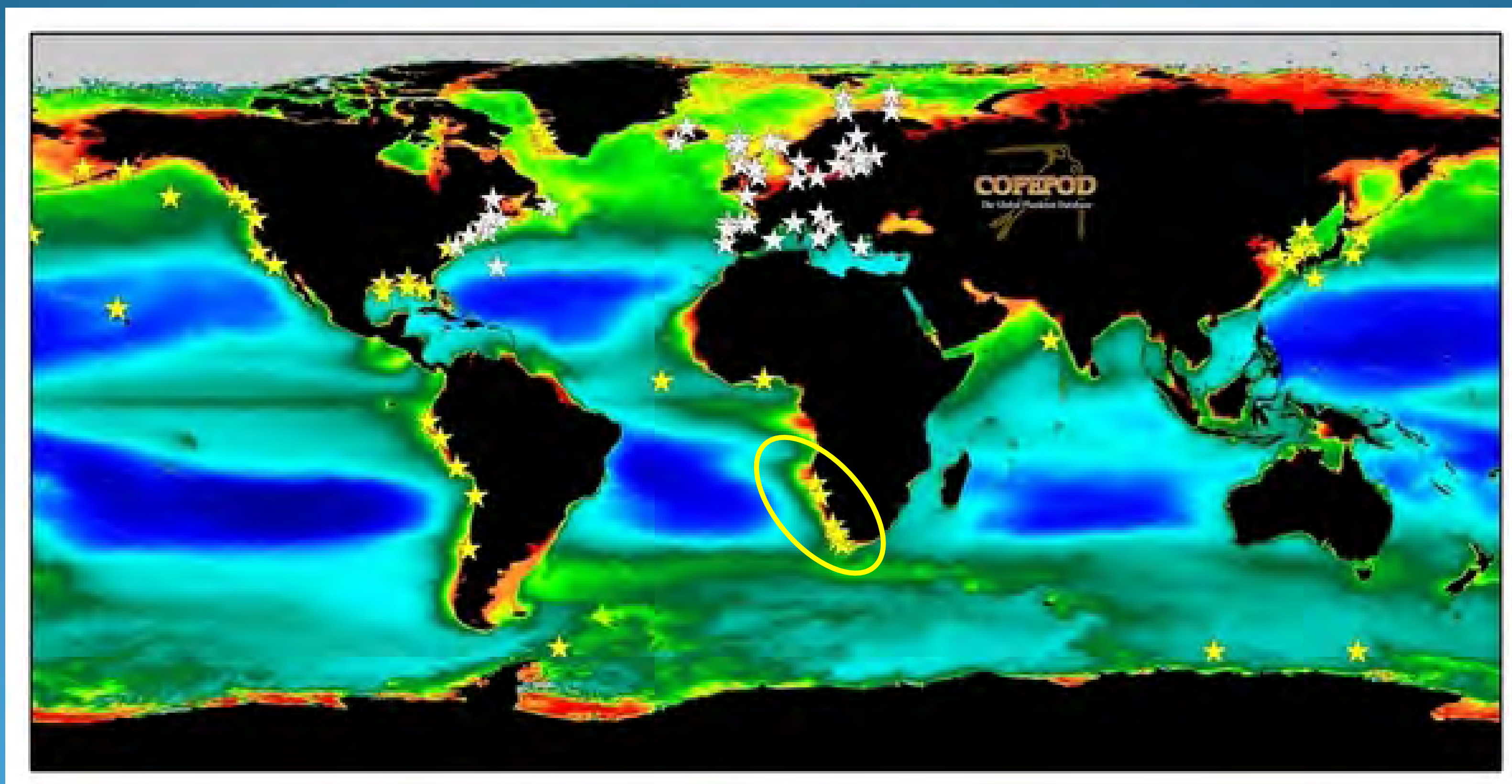
South Pacific – Peru Area C



South Atlantic – St Helena Bay (S Benguela)

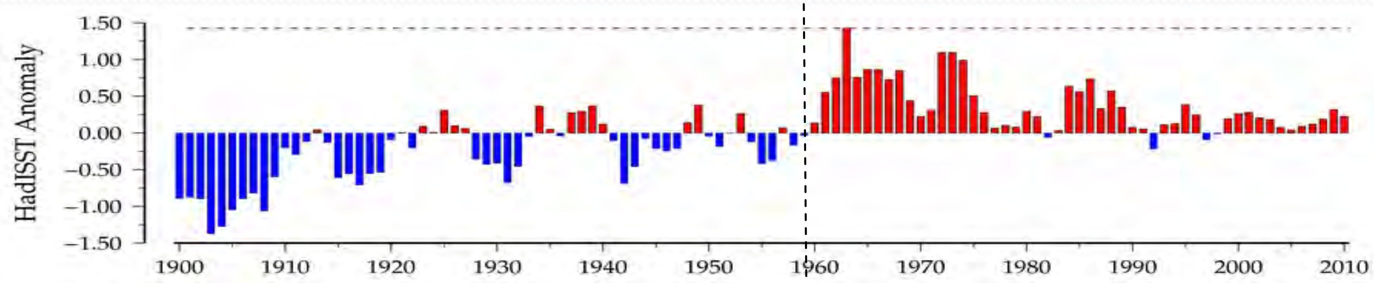


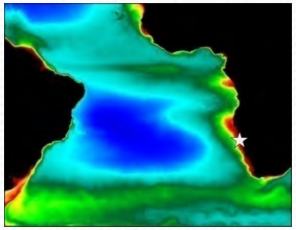
Benguela Current



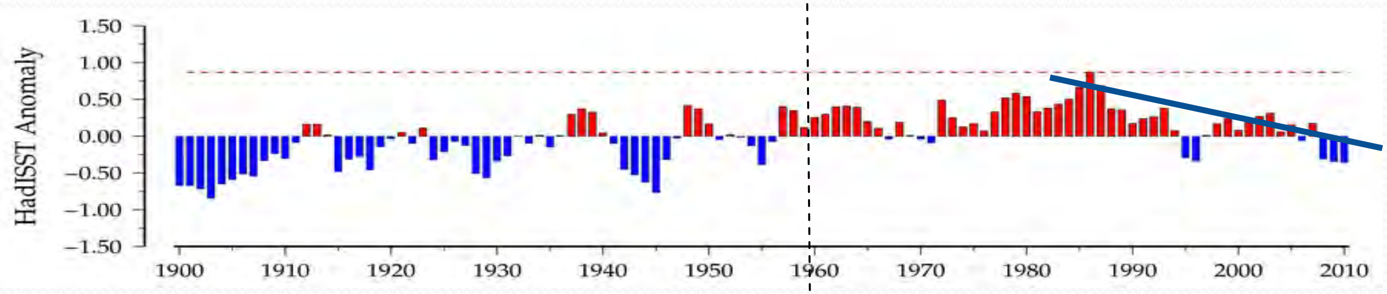
Benguela long term SST: North vs South

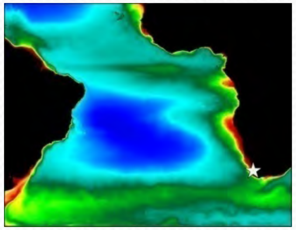
Northern Benguela: Walvis Bay (23°S)





Southern Benguela: St Helena Bay (32.5°S)

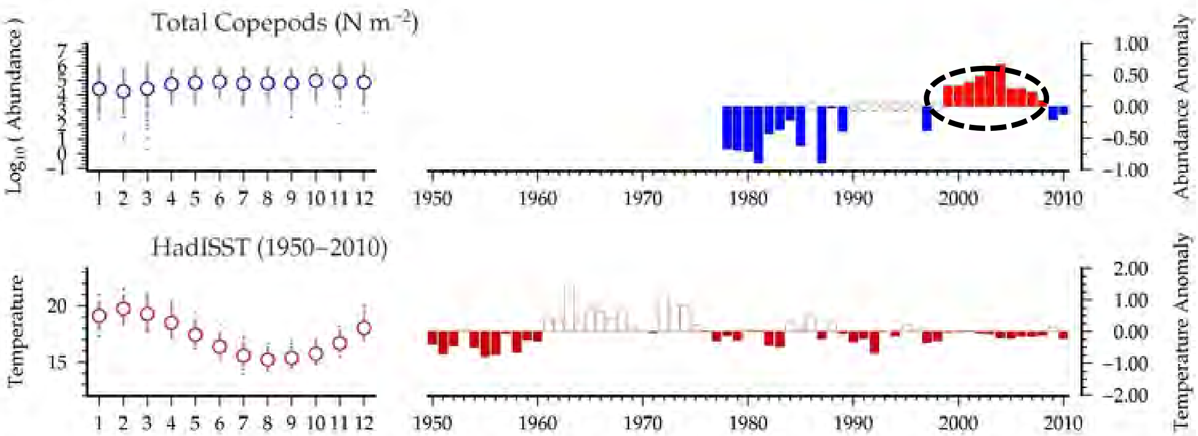




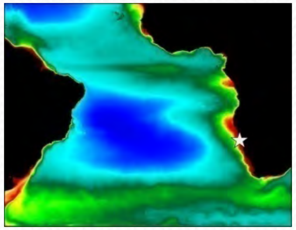
- Similar pattern of cold anomalies in both systems up to 1950s
- Shift to warmer phase in late 1950s, slightly later in N Benguela
- More intense warm anomalies in N Benguela in 1950s & 1960s
- Cooling trend in S Benguela from 1980s, up to 0.5°C per decade (Roualt et al. 2010) due to an increase in upwelling-favourable south-easterly winds
- Appears to be similar cooling trend in N Benguela

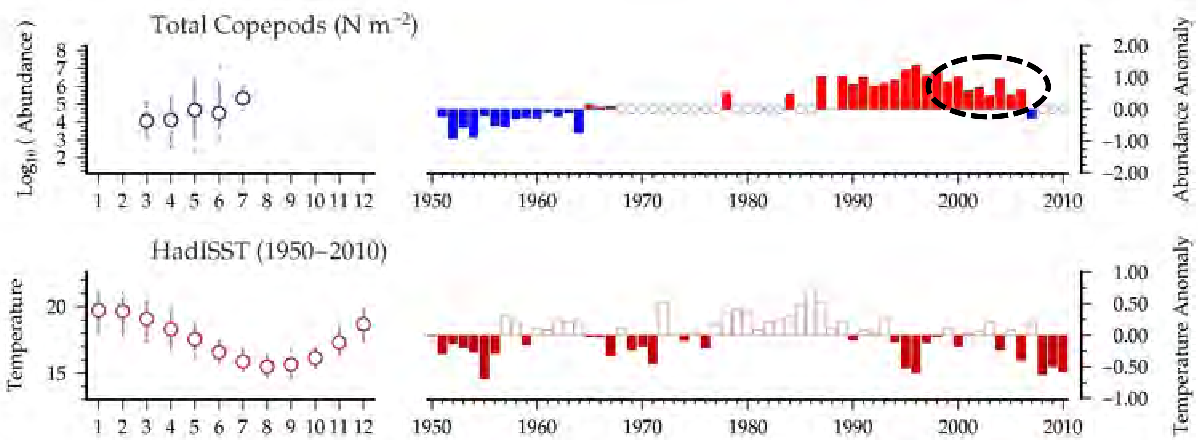
Roualt, Penven, Pohl 2010: Coastal oceanic climate change and variability from 1982 to 2009 around South Africa. African Journal of Marine Science 32(2): 237–246

Benguela copepods: North vs South

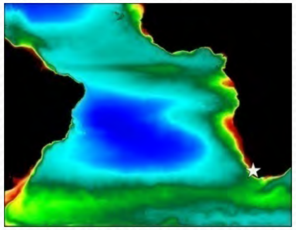


Northern Benguela:
Walvis Bay (23°S)





Southern Benguela:
St Helena Bay (32.5°S)

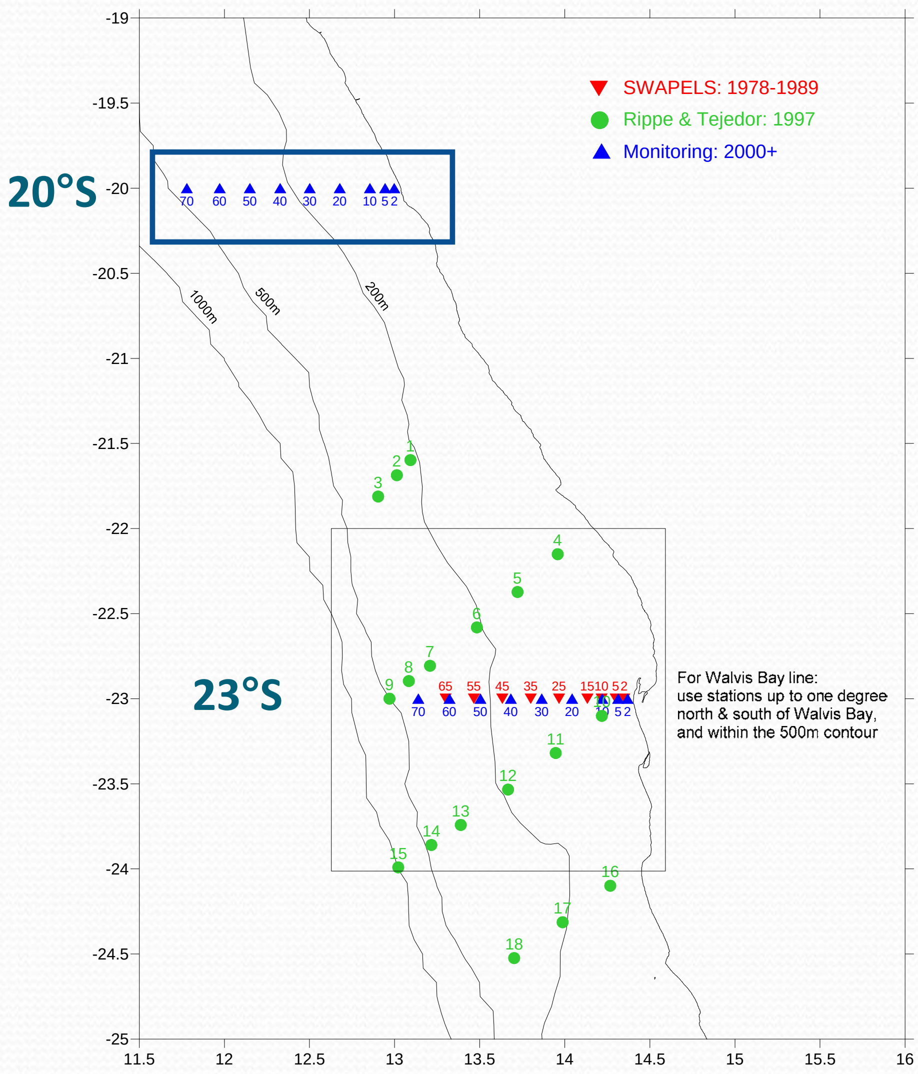


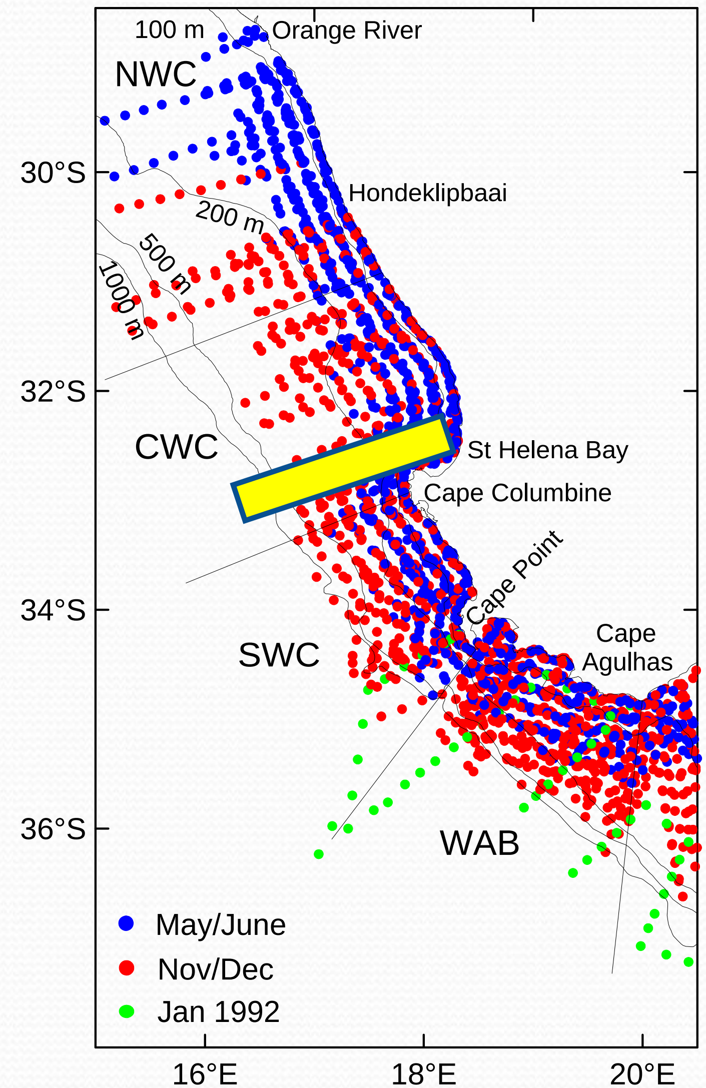
- long-term increase in abundance for both regions, but no clear synchronicity -
- complicated by gaps in both abundance data sets, plus different sampling periods
- but both show positive abundance anomalies for late 90s-mid 2000s (cooling phase?)

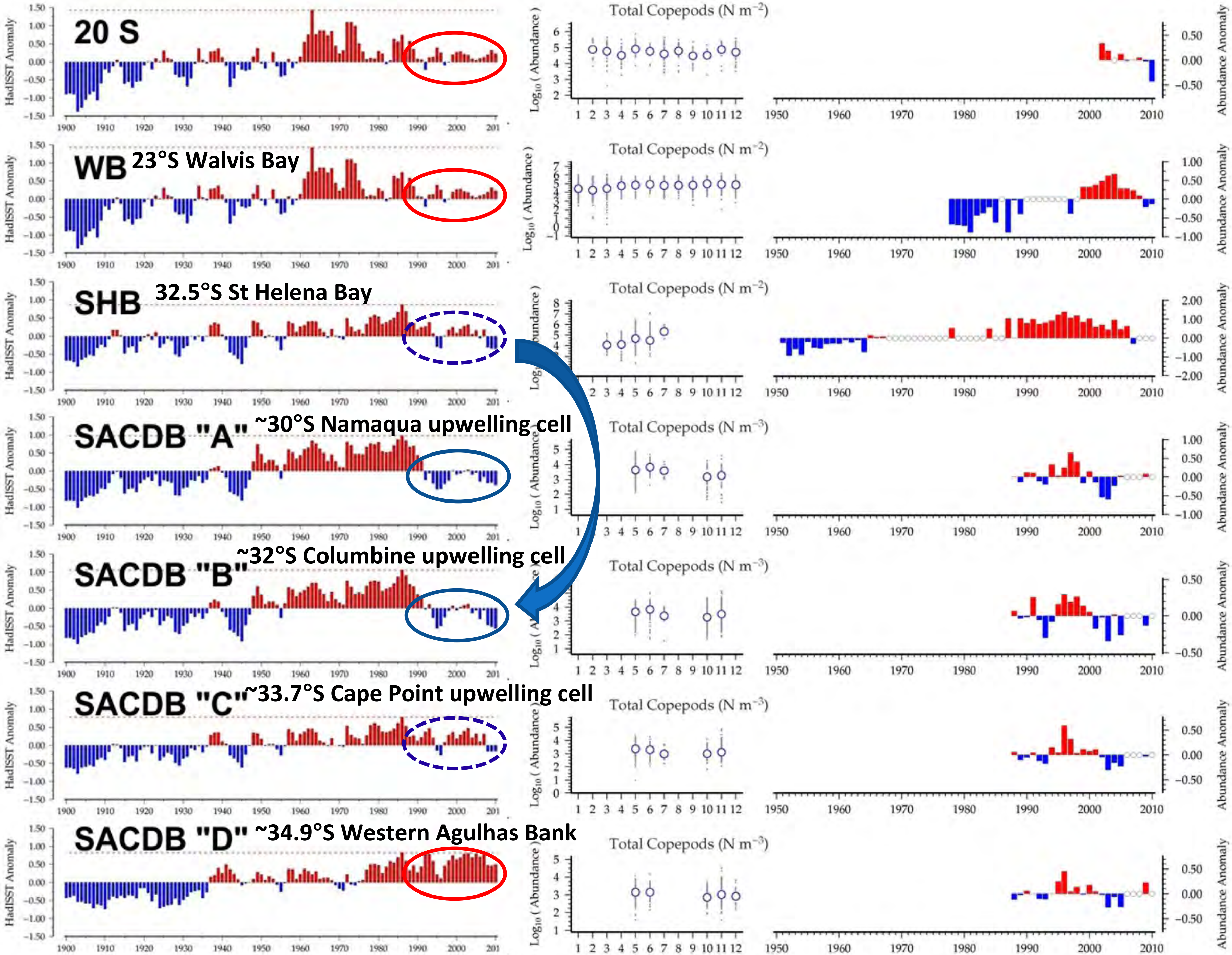
Benguela – expanding the latitudinal comparison

N Benguela – new line off 20°S (Dec 2002+)

S Benguela – biannual sampling in 4 areas from 1988+





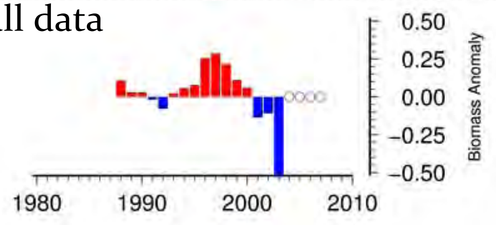


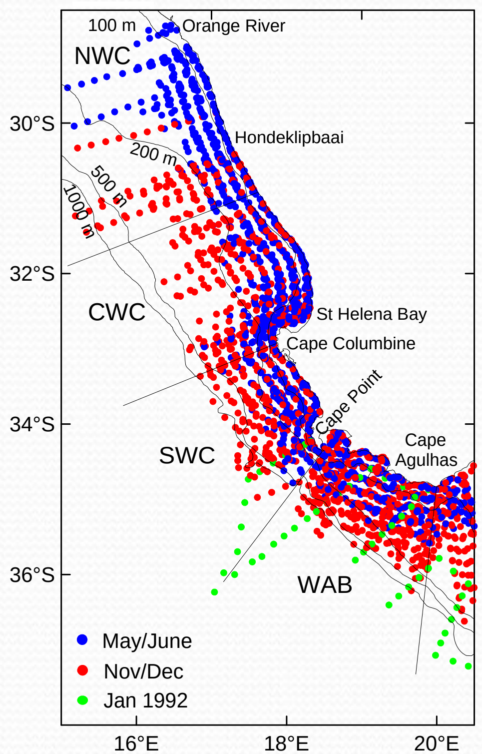
20 S
WB 23°S Walvis Bay
SHB 32.5°S St Helena Bay
SACDB "A" ~30°S Namaqua upwelling cell
SACDB "B" ~32°S Columbine upwelling cell
SACDB "C" ~33.7°S Cape Point upwelling cell
SACDB "D" ~34.9°S Western Agulhas Bank
HadISST Anomaly
Total Copepods (N m⁻²)
Total Copepods (N m⁻³)
Log10 (Abundance)
Abundance Anomaly

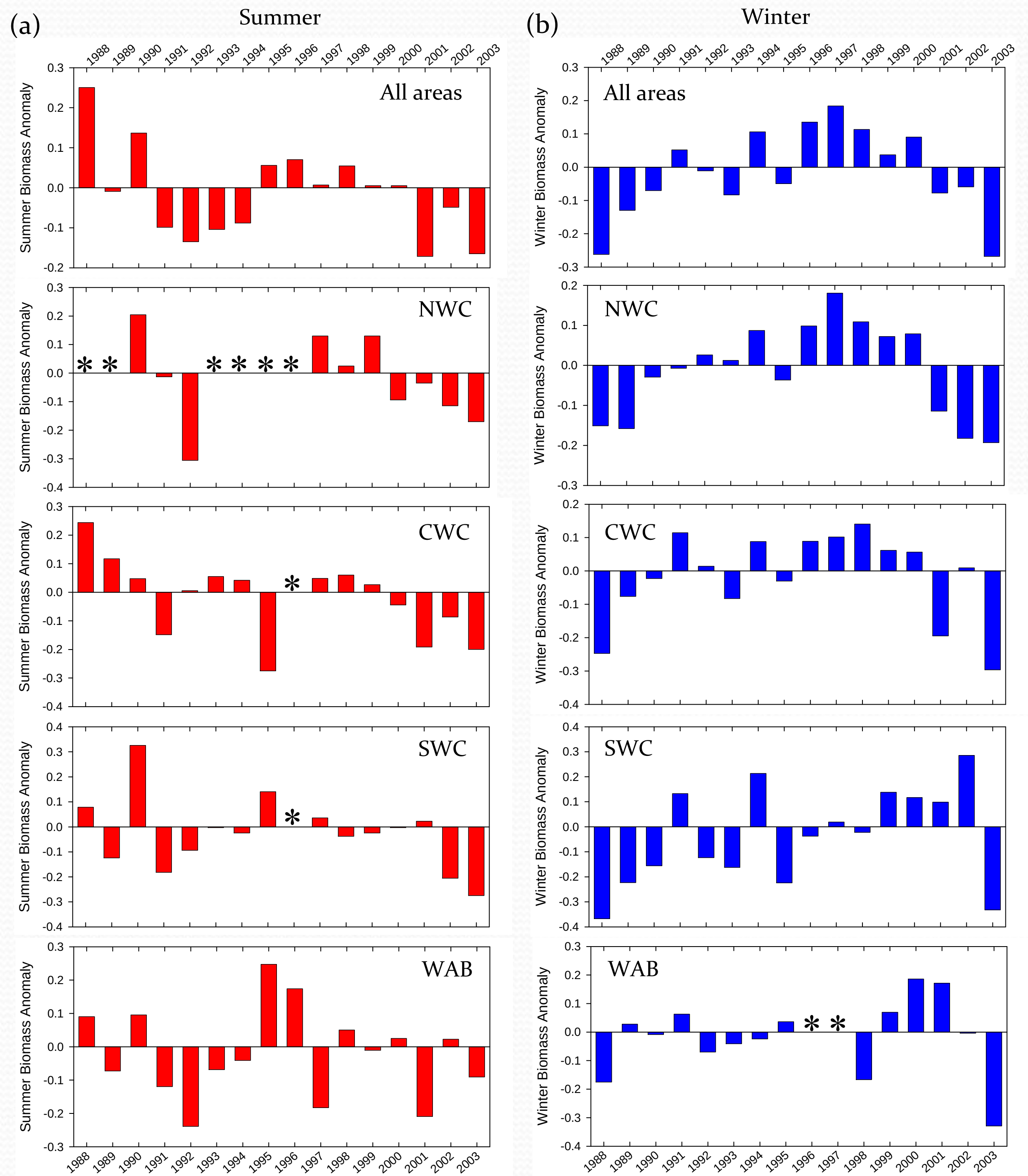
Southern Benguela

Seasonal & within-region (latitudinal) comparison of biomass time-series

all data

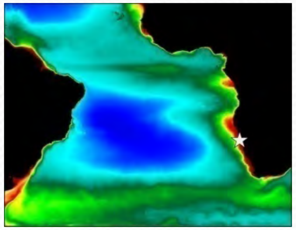




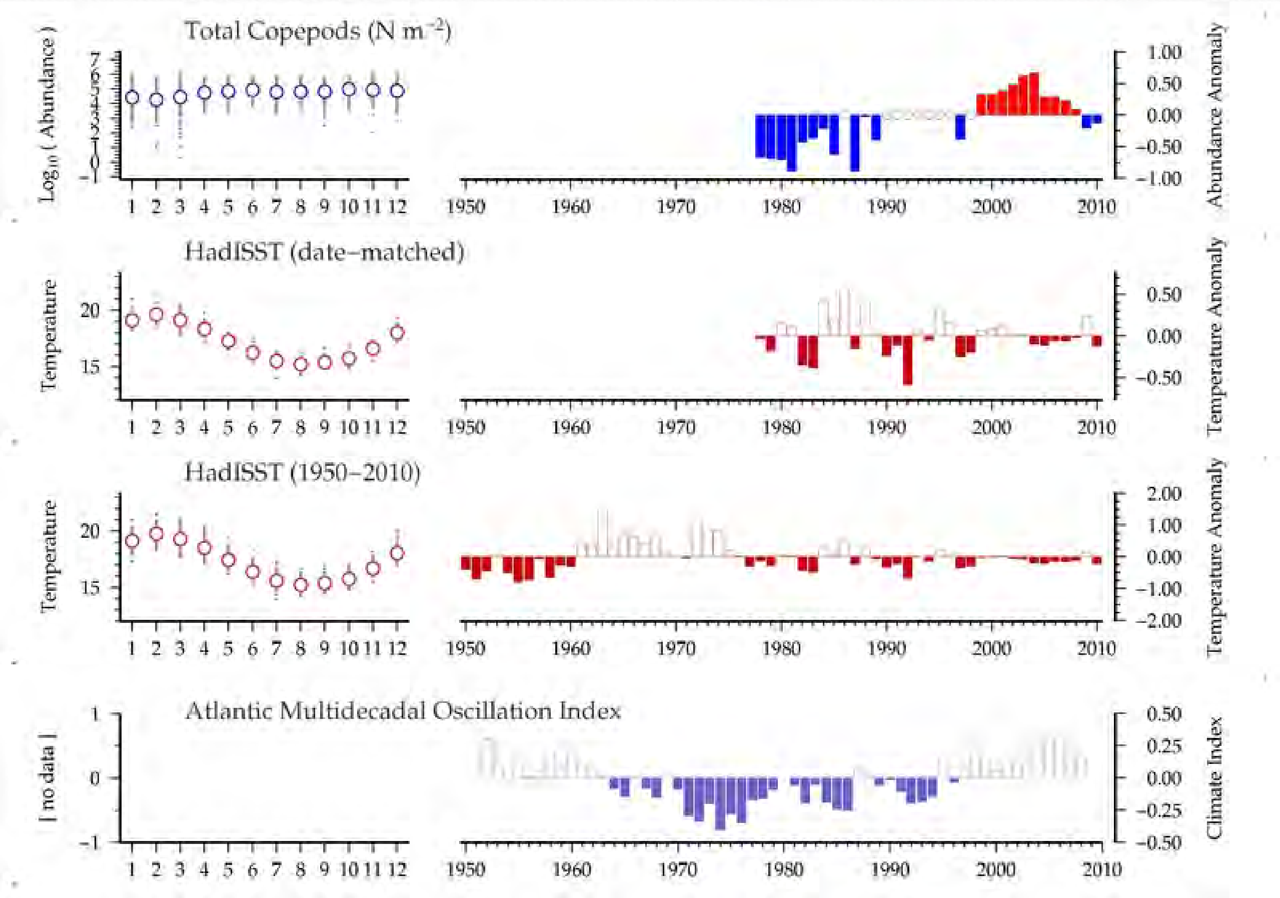


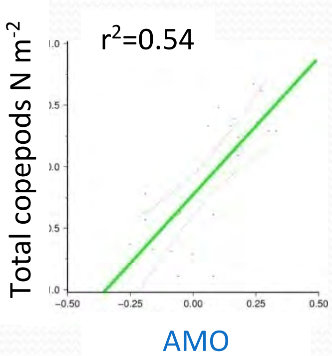
Huggett et al. 2009 – P in O

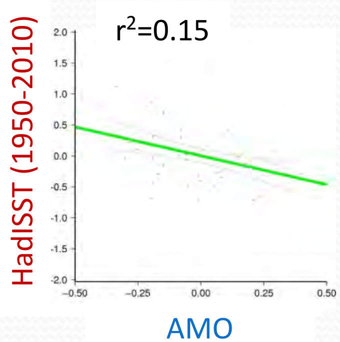
Northern Benguela: Walvis Bay



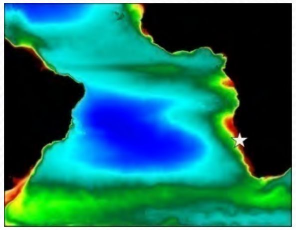
Variability in Copepod abundance vs variability in SST, Climate indices?



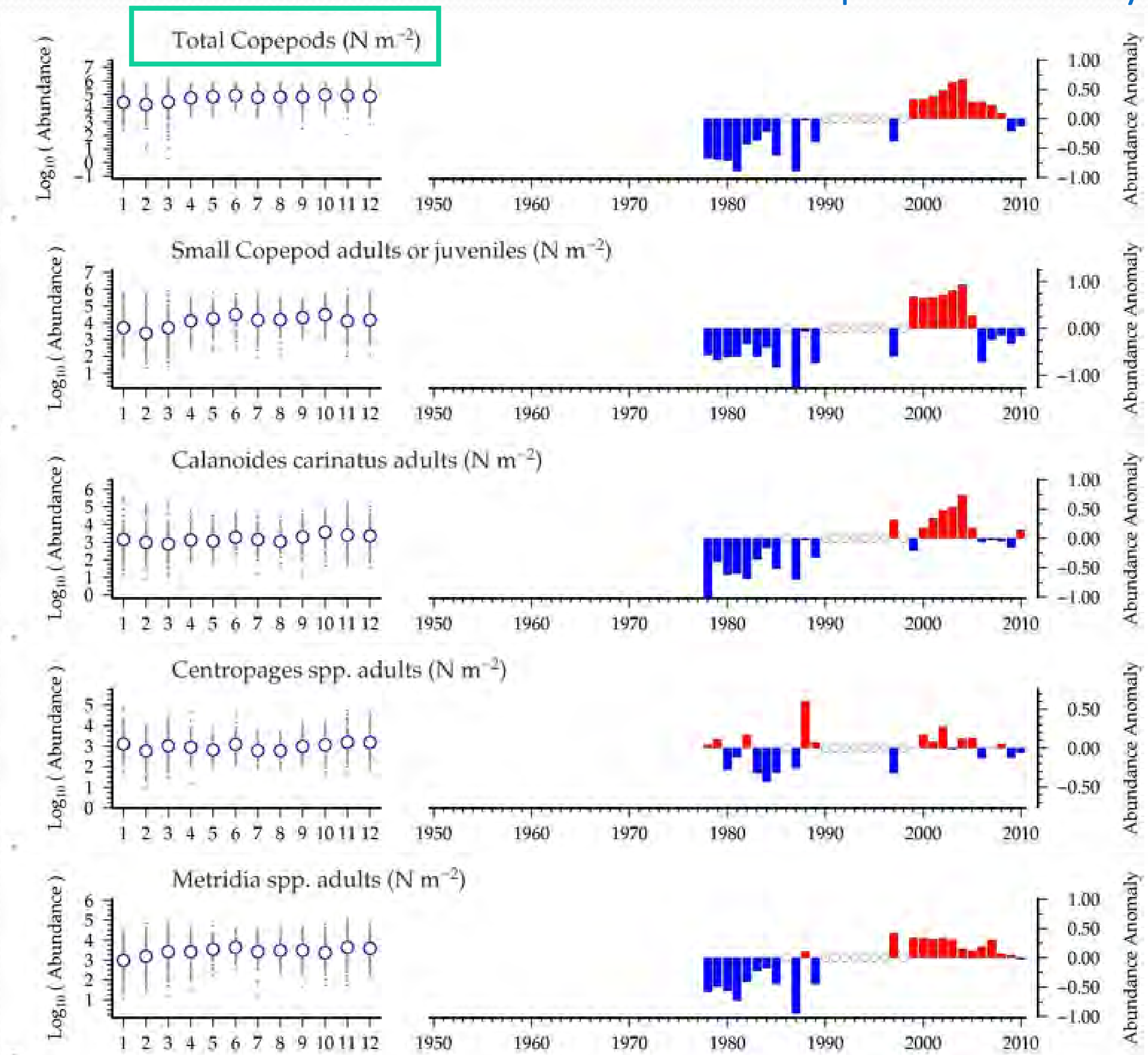


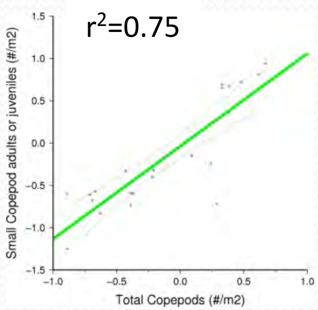


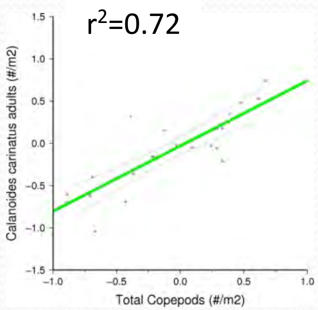
Northern Benguela: Walvis Bay

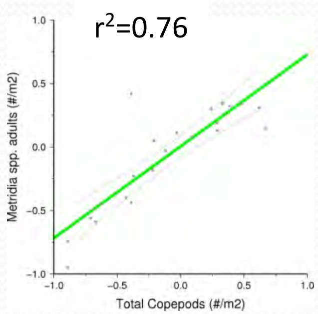


Total abundance & species variability



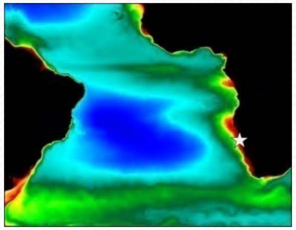




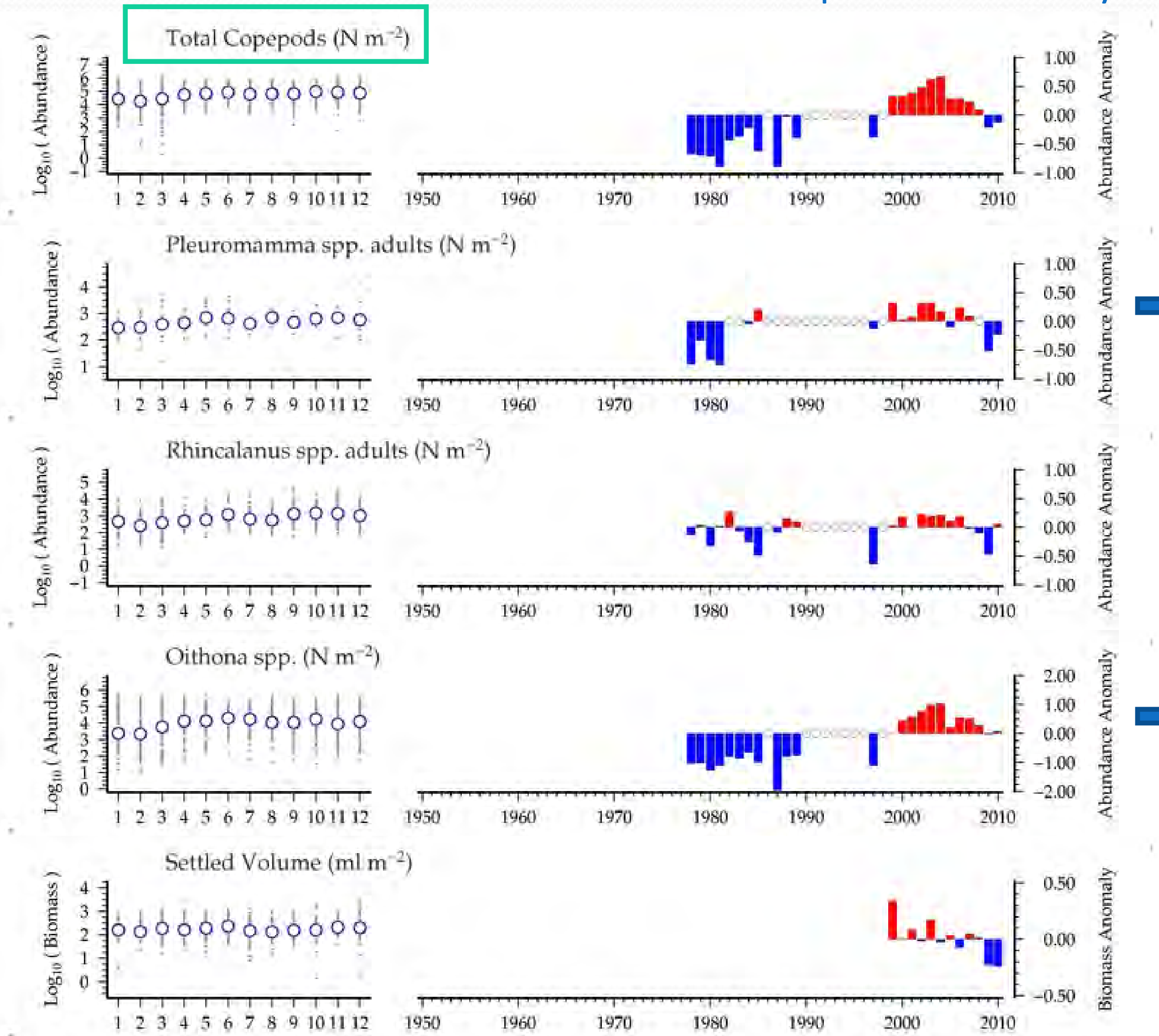


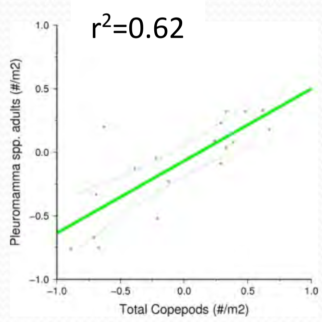
+ve correlation: *C. carinatus* (N m^{-2}) vs AMO; r^2 = 0.47

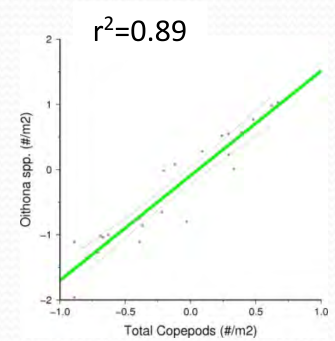
Northern Benguela: Walvis Bay



Total abundance & species variability

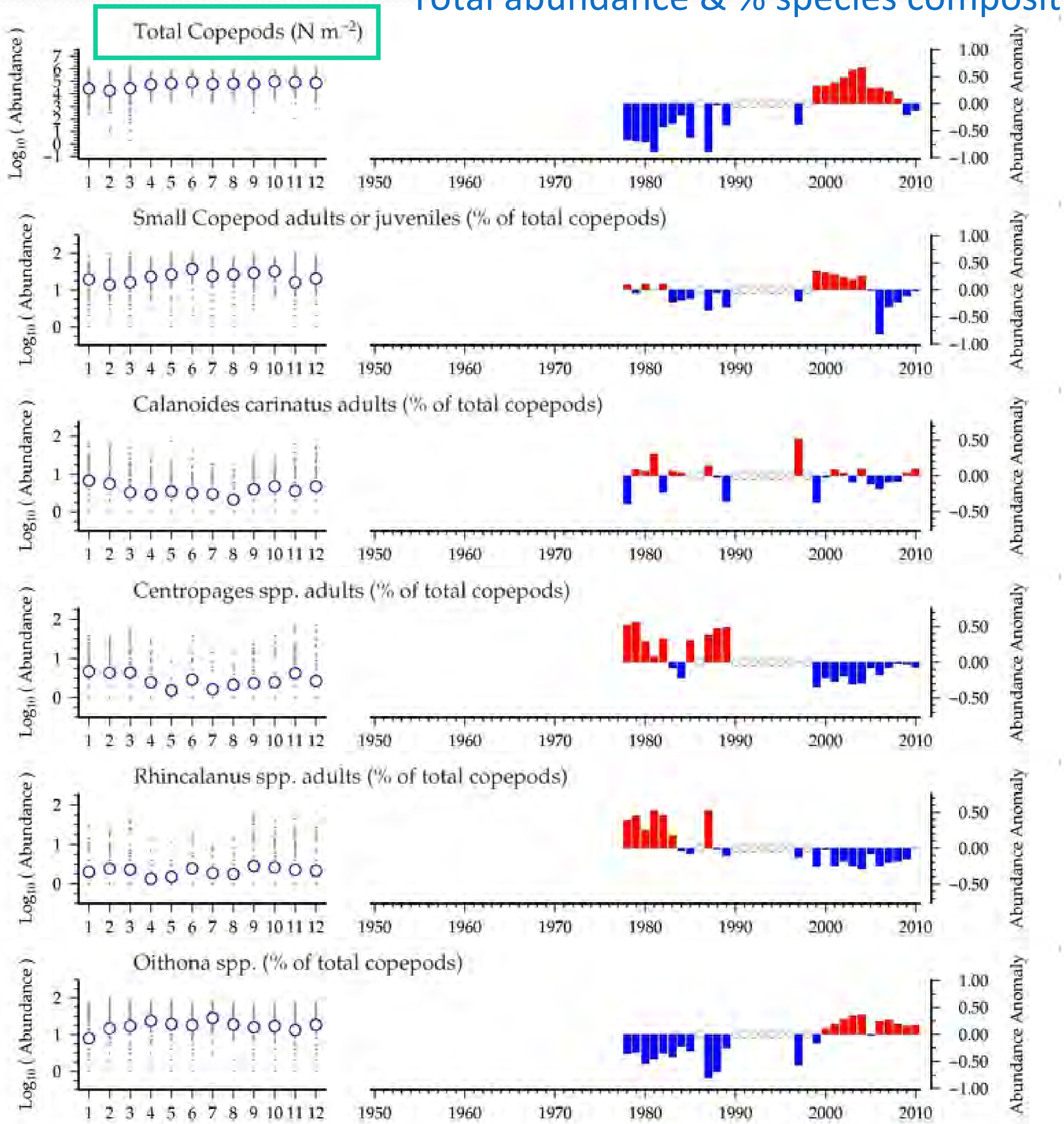


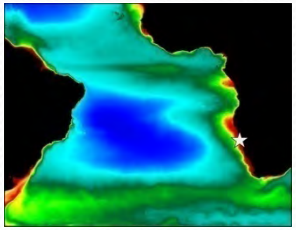


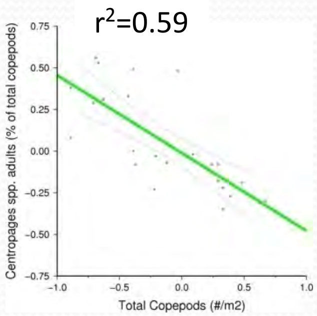


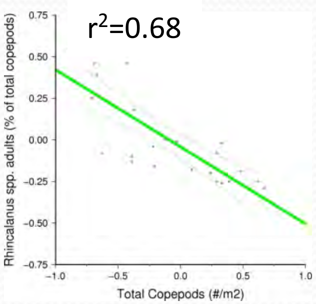
+ve correlation: *Oithona* spp (N m^{-2}) vs AMO; $r^2 = 0.48$

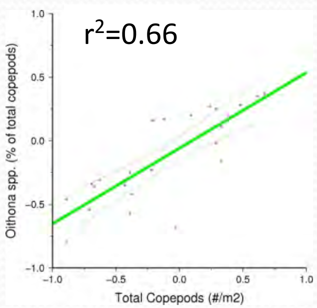
Total abundance & % species composition







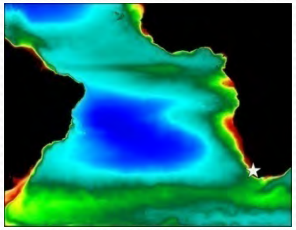


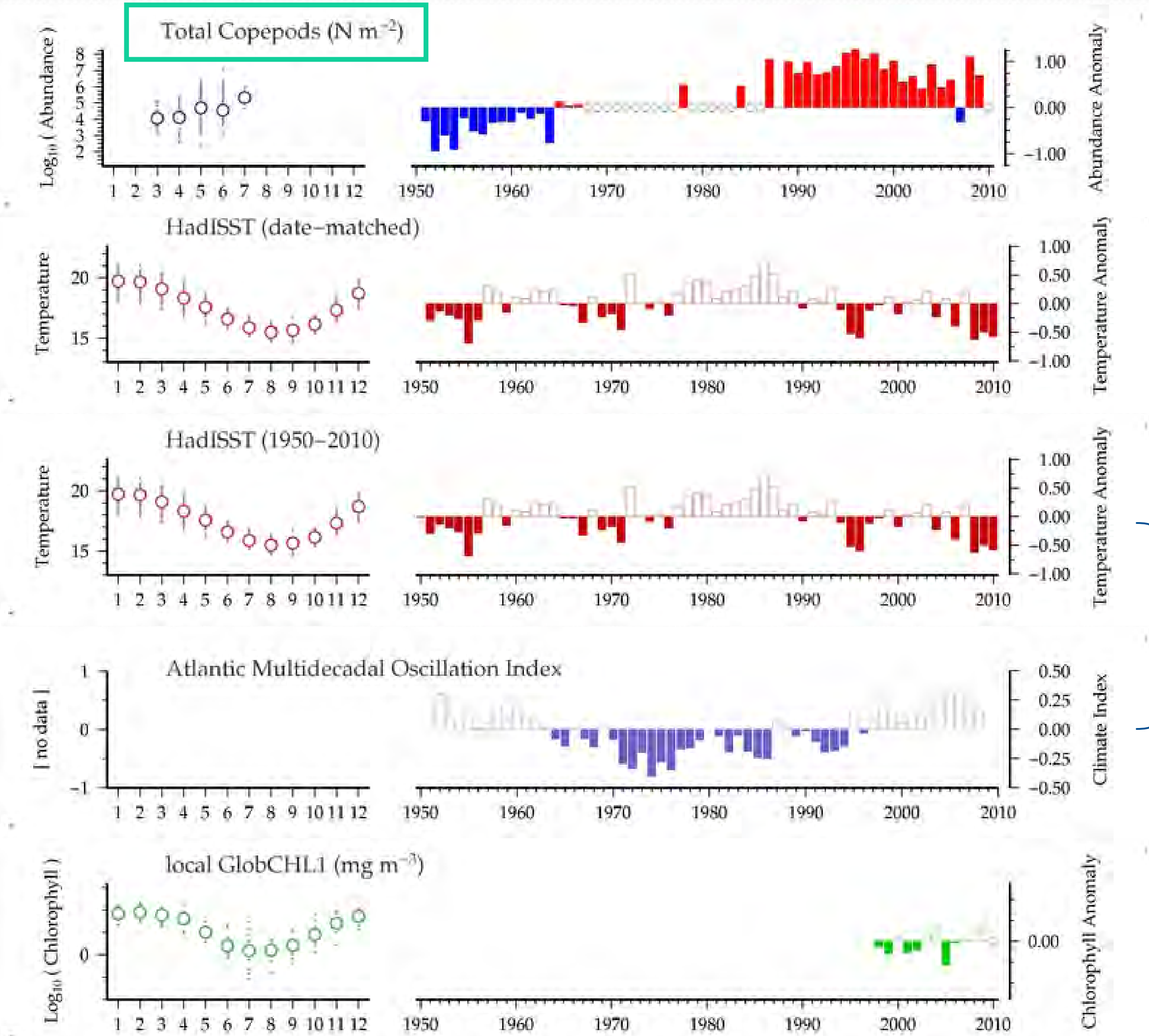


-ve correlation: % *Centropages* & *Rhincalanus* vs AMO; r^2 = 0.36

Southern Benguela: St Helena Bay

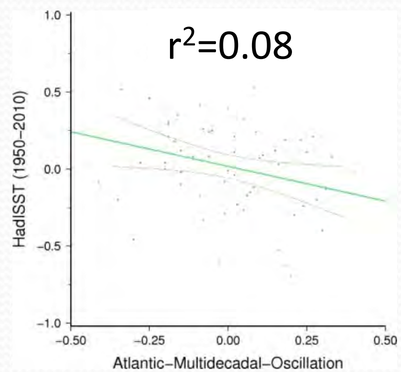
Variability in Copepod abundance vs variability in SST, Climate indices?





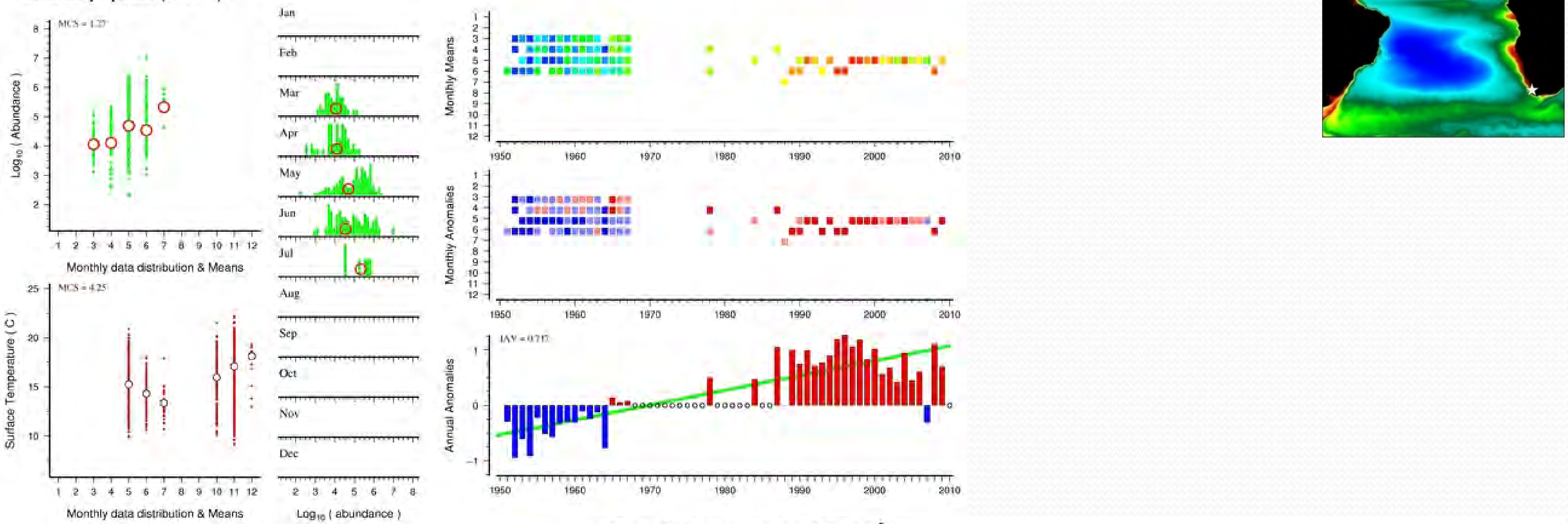
“No patterns in the Southern Benguela – just variability!”

inverse relationship?



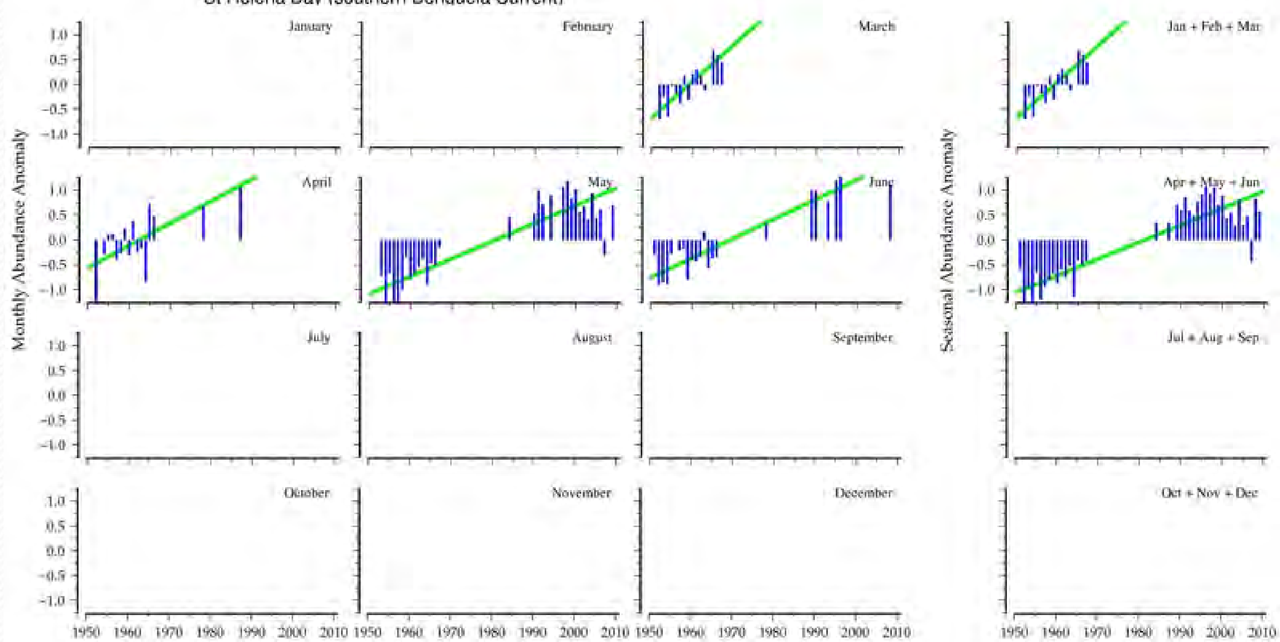
St Helena Bay (southern Benguela Current)

Total Copepods (N m^{-2})

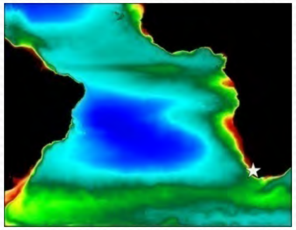


Total Copepods (N m^{-2})

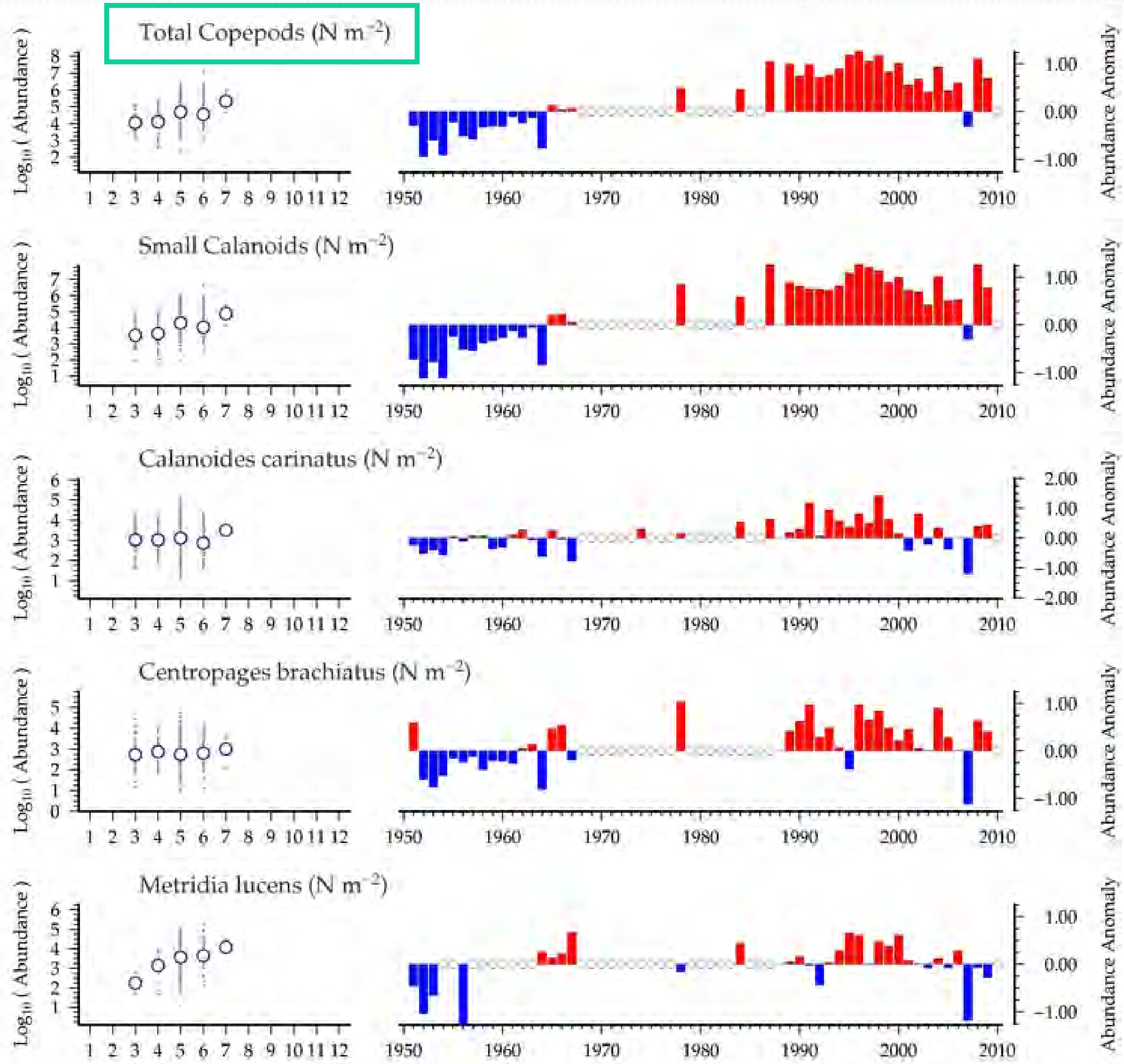
St Helena Bay (southern Benguela Current)



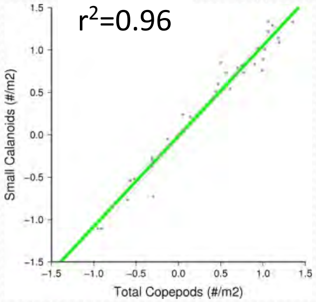
Southern Benguela: St Helena Bay

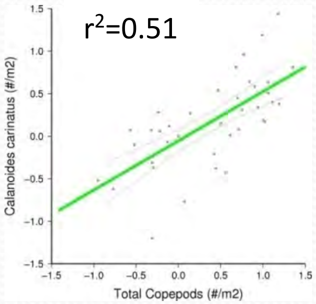


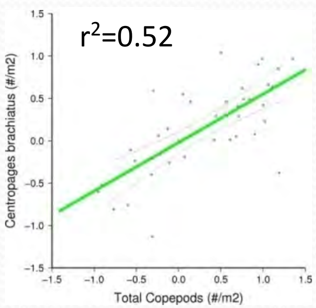
Total abundance & species variability



Largely driven by small calanoids...



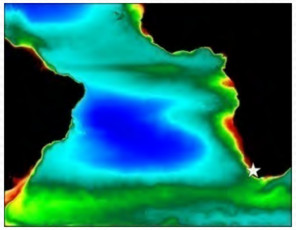


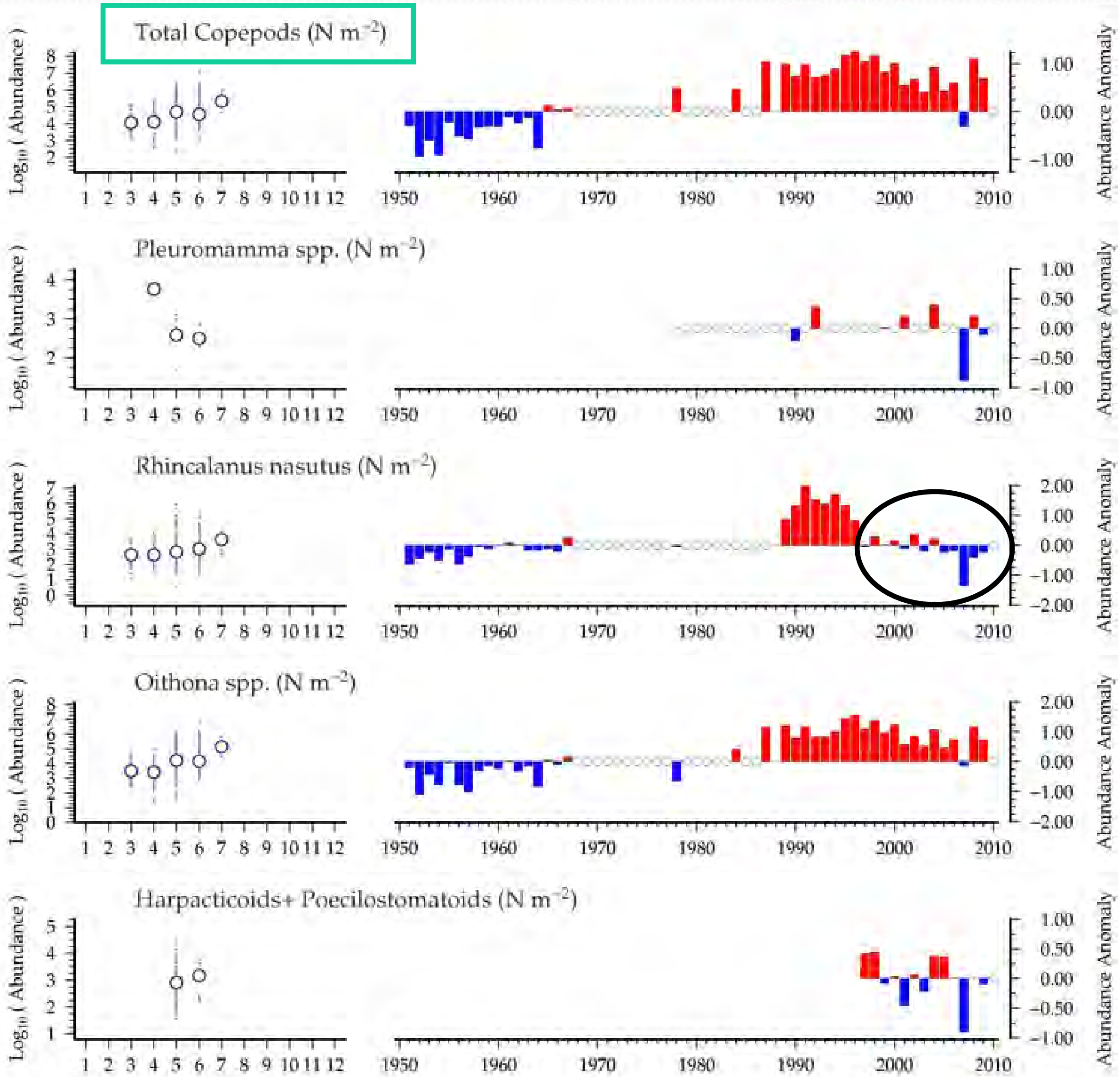


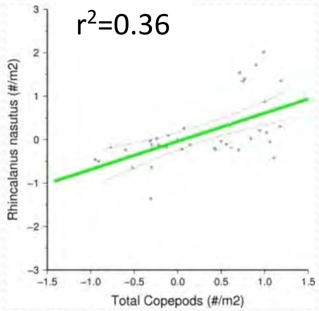
2007?
El Nino

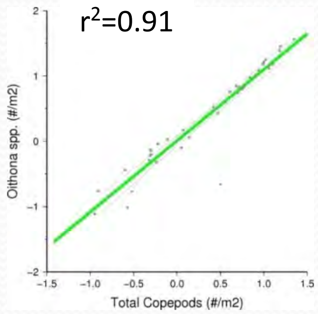
Southern Benguela: St Helena Bay

Total abundance & species variability



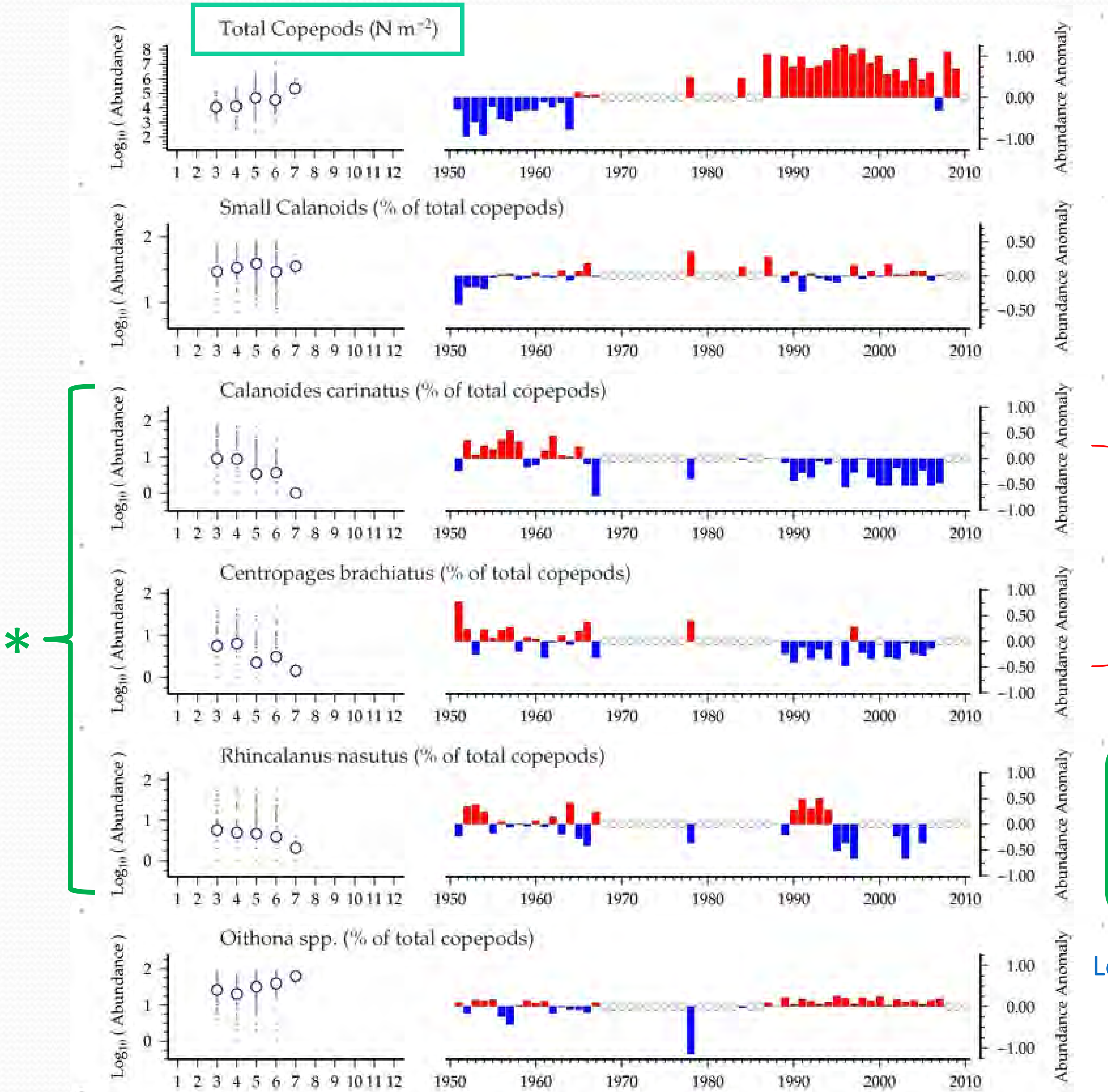


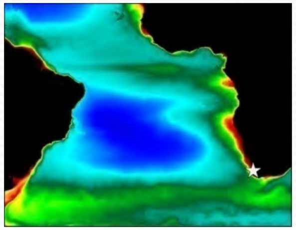




...and *Oithona* spp.

St Helena Bay   Total abundance & % species composition





[No updates for % abundance]

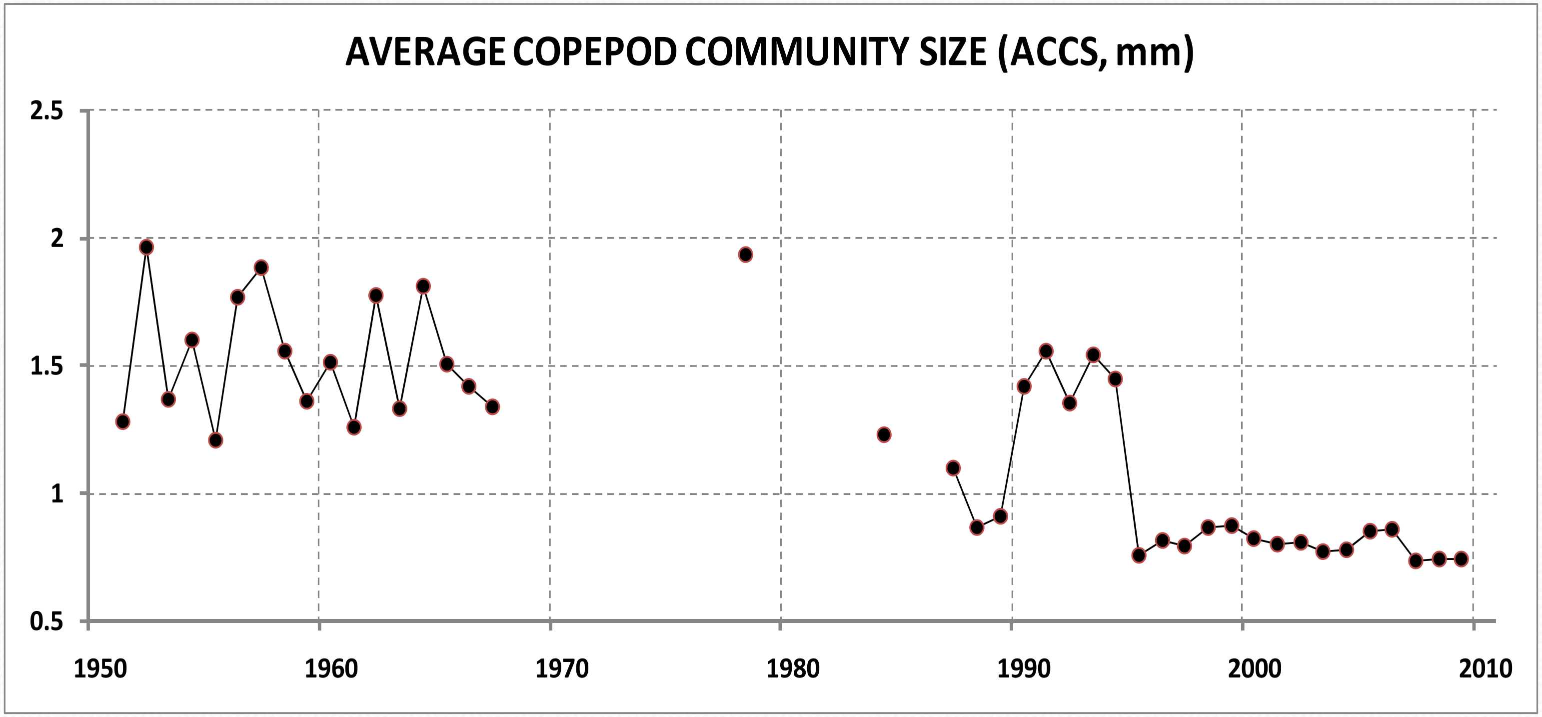
Low variability - fairly consistent proportion of total abundance

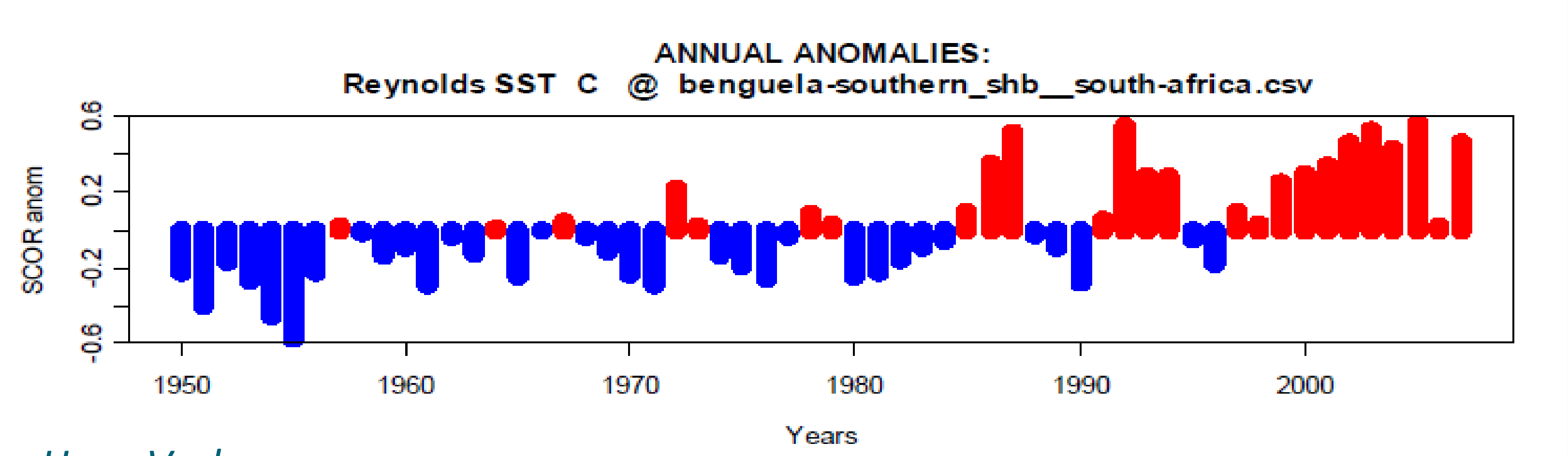
General decline in % TC abundance over time-series = opposite trend to total abundance

* Possible decline in prop. med/large copepods through autumn as pelagic fish recruit?

Low variability apart from strong +ve anomaly in 1978; slight increase over last 2 decades

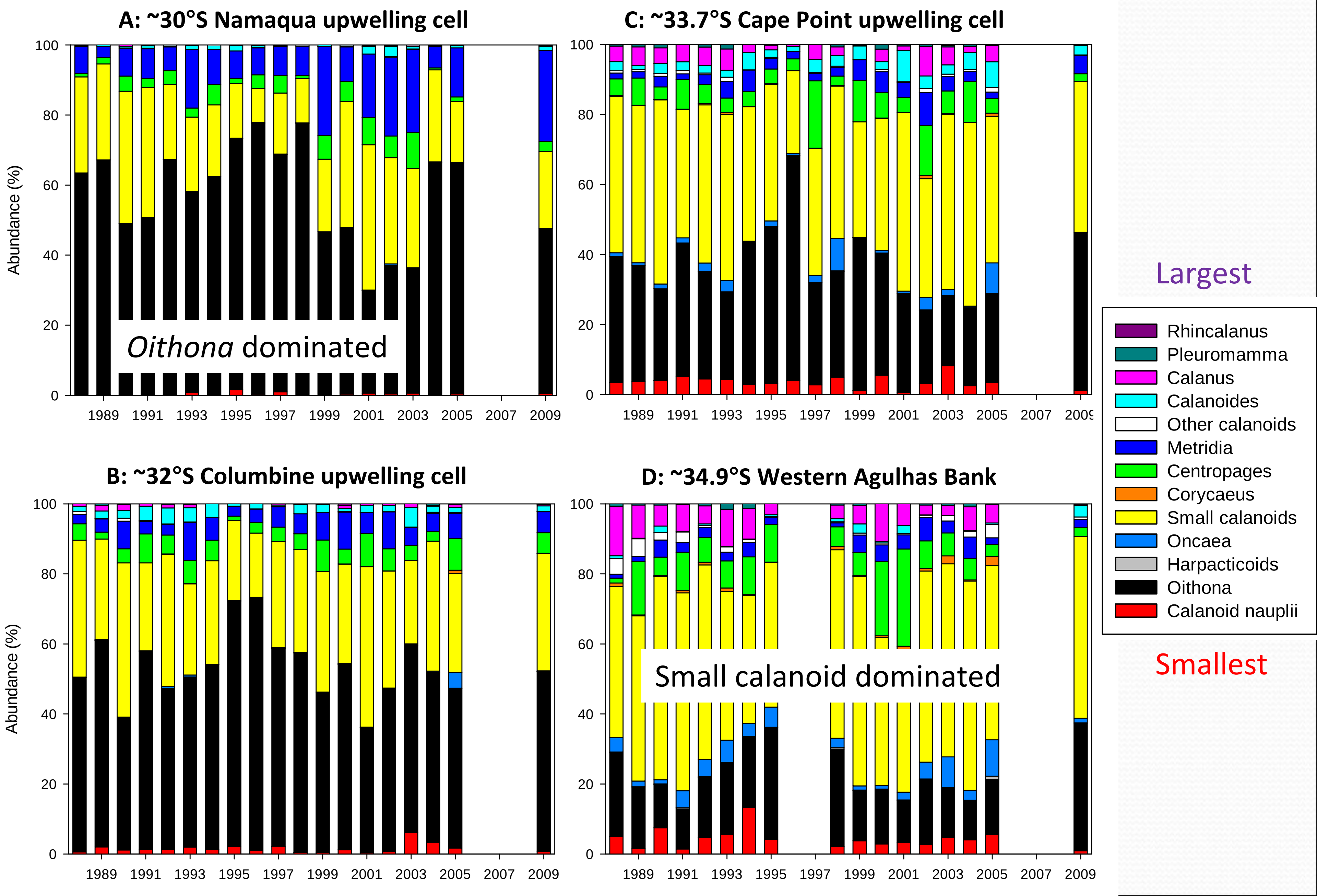
St Helena Bay – Long term change in mean copepod community size



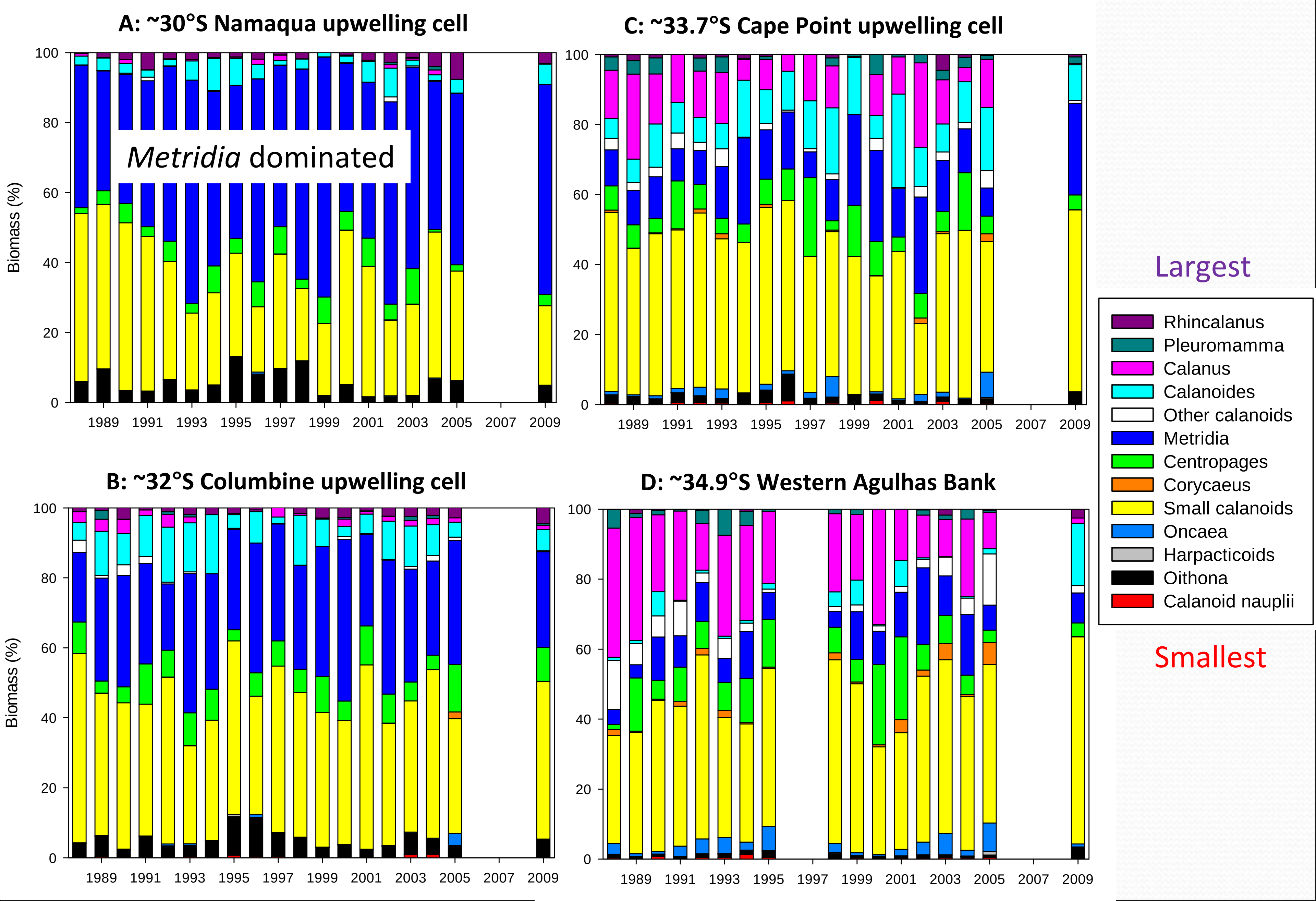


From Hans Verheye

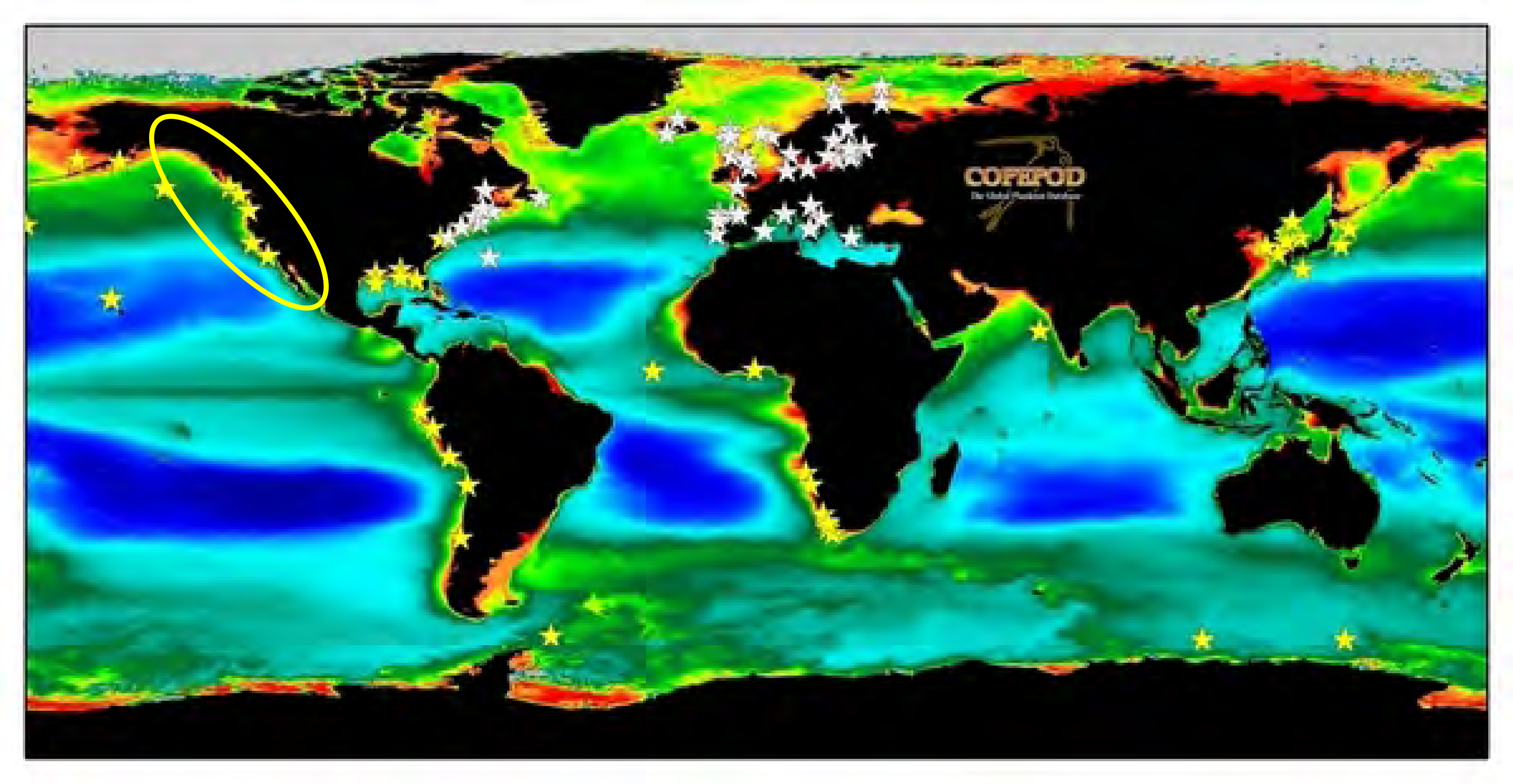
Interannual variability in % Abundance by area in Winter



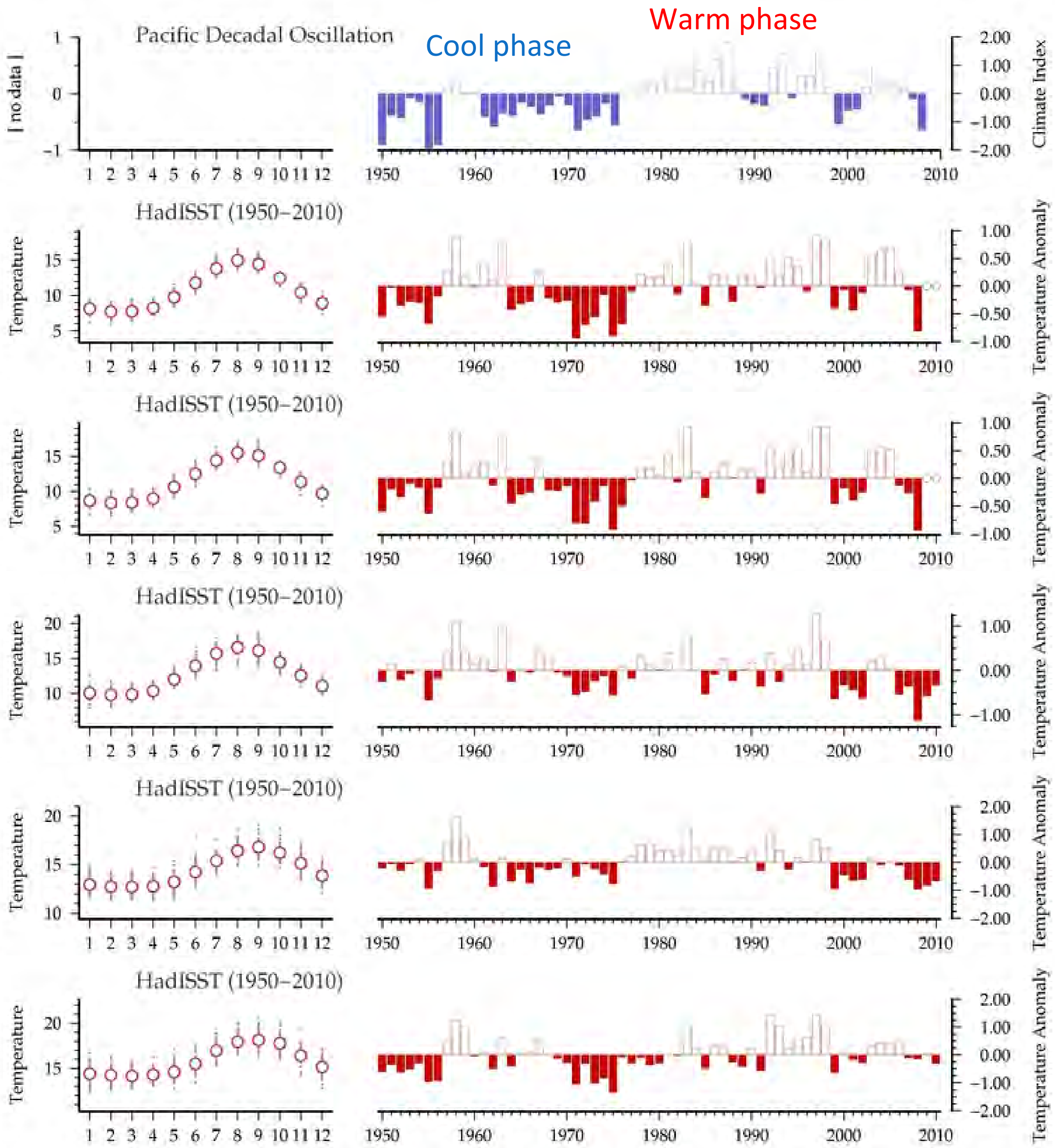
Interannual variability in % Biomass by area in Winter



California Current



California Current: Latitudinal variability - Climate & SST



Vancouver Is. North

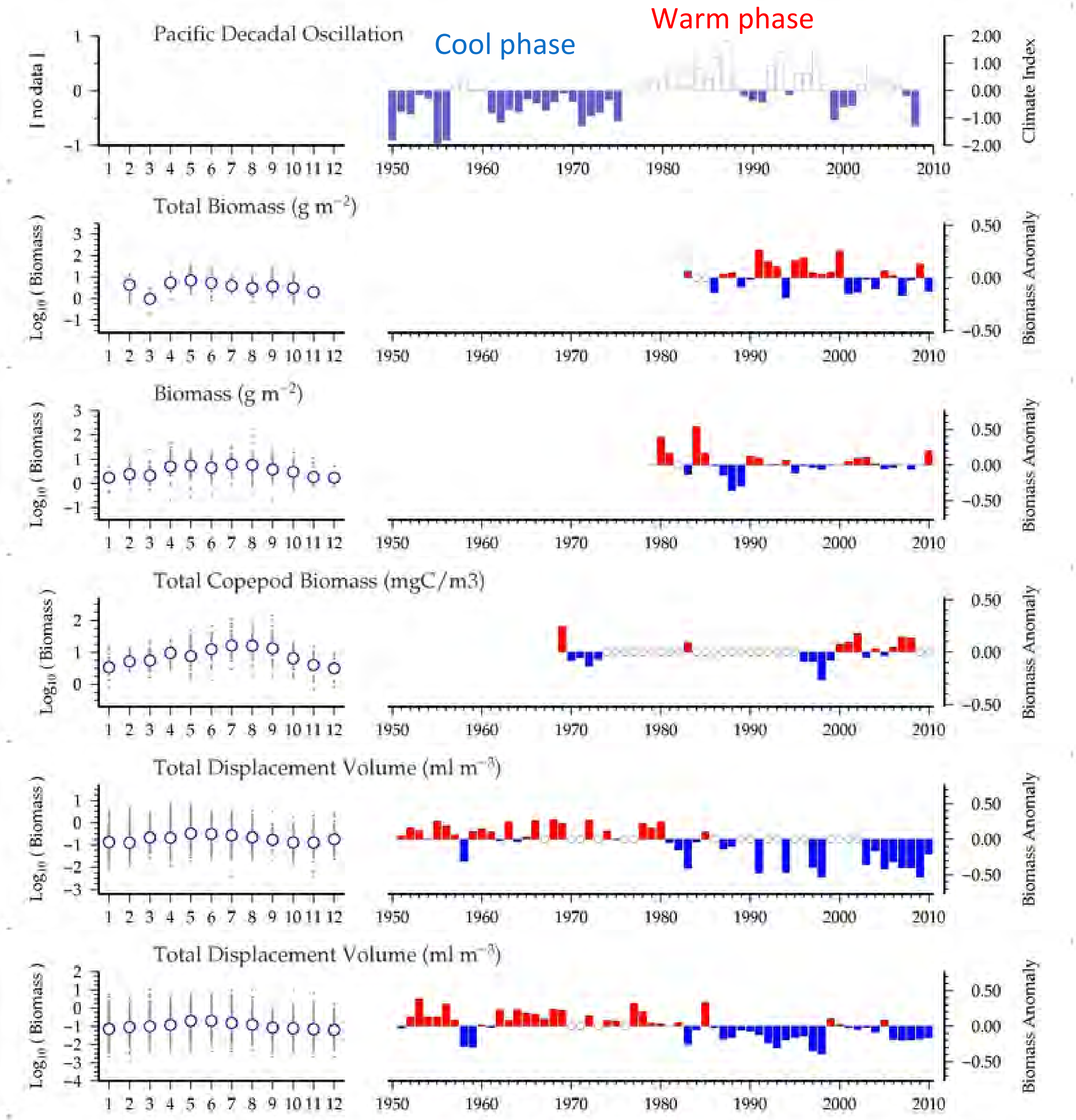
Vancouver Is. South

Newport, Oregon

Central California

Southern California

California Current: Latitudinal variability - Climate & Zooplankton



Vancouver Is. North

Vancouver Is. South

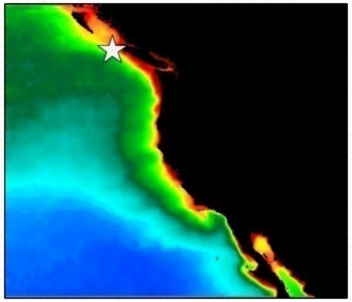
Newport, Oregon

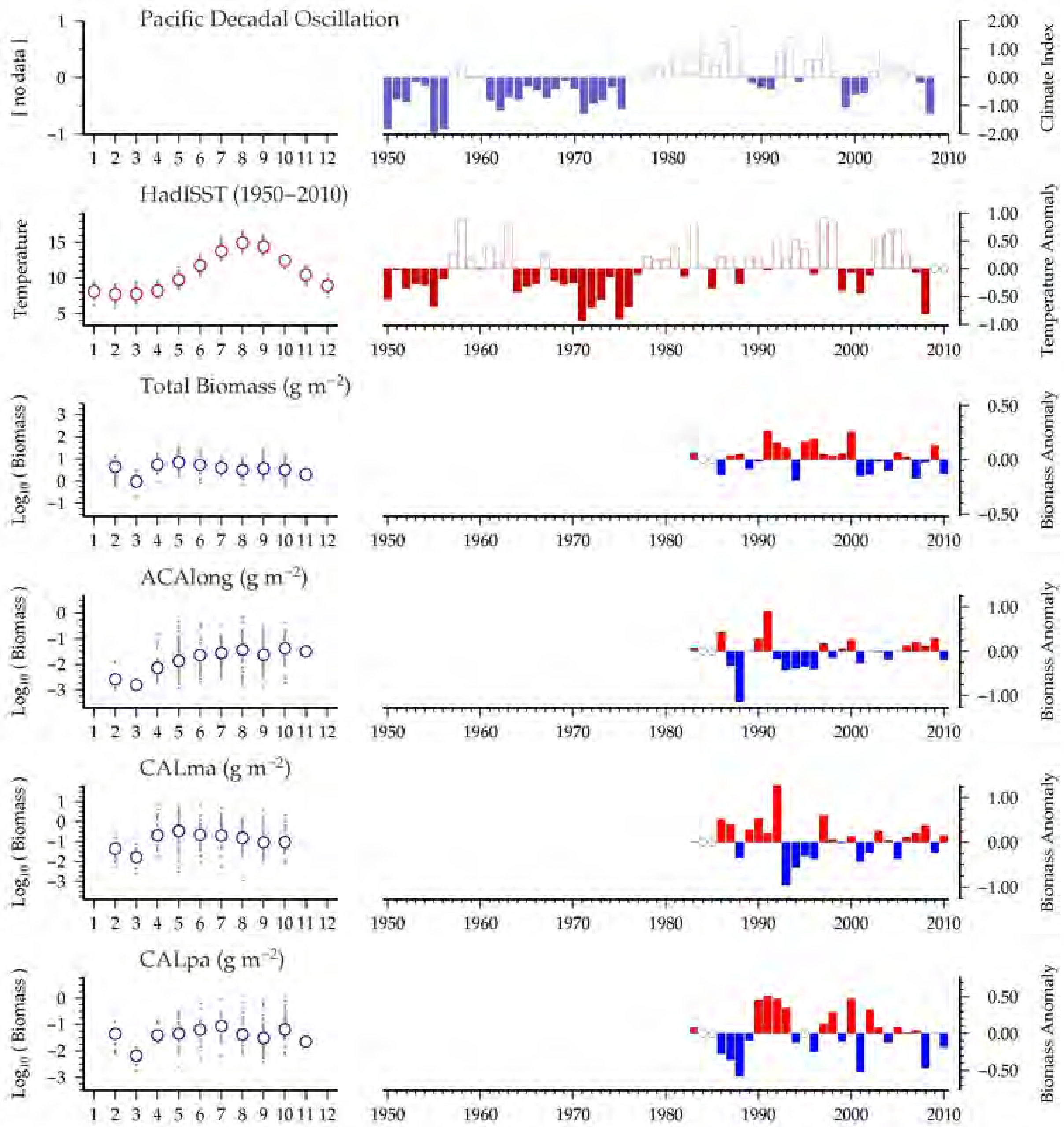
Central California

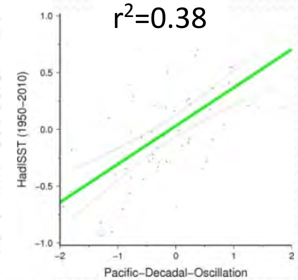
NB decline in salps

Southern California

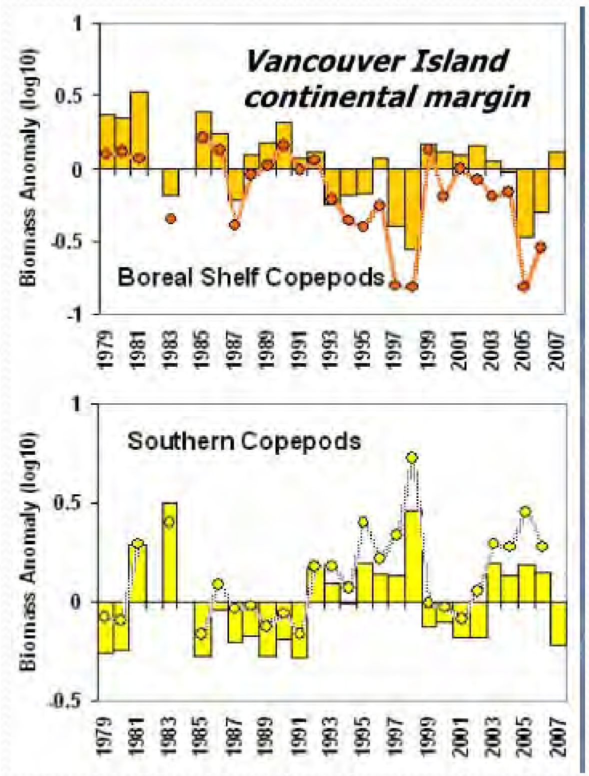
California Current: Northern Vancouver Is.



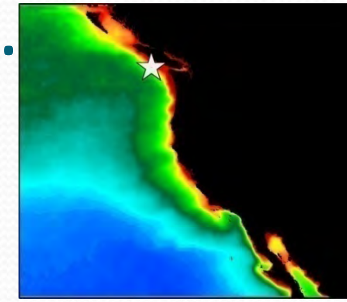


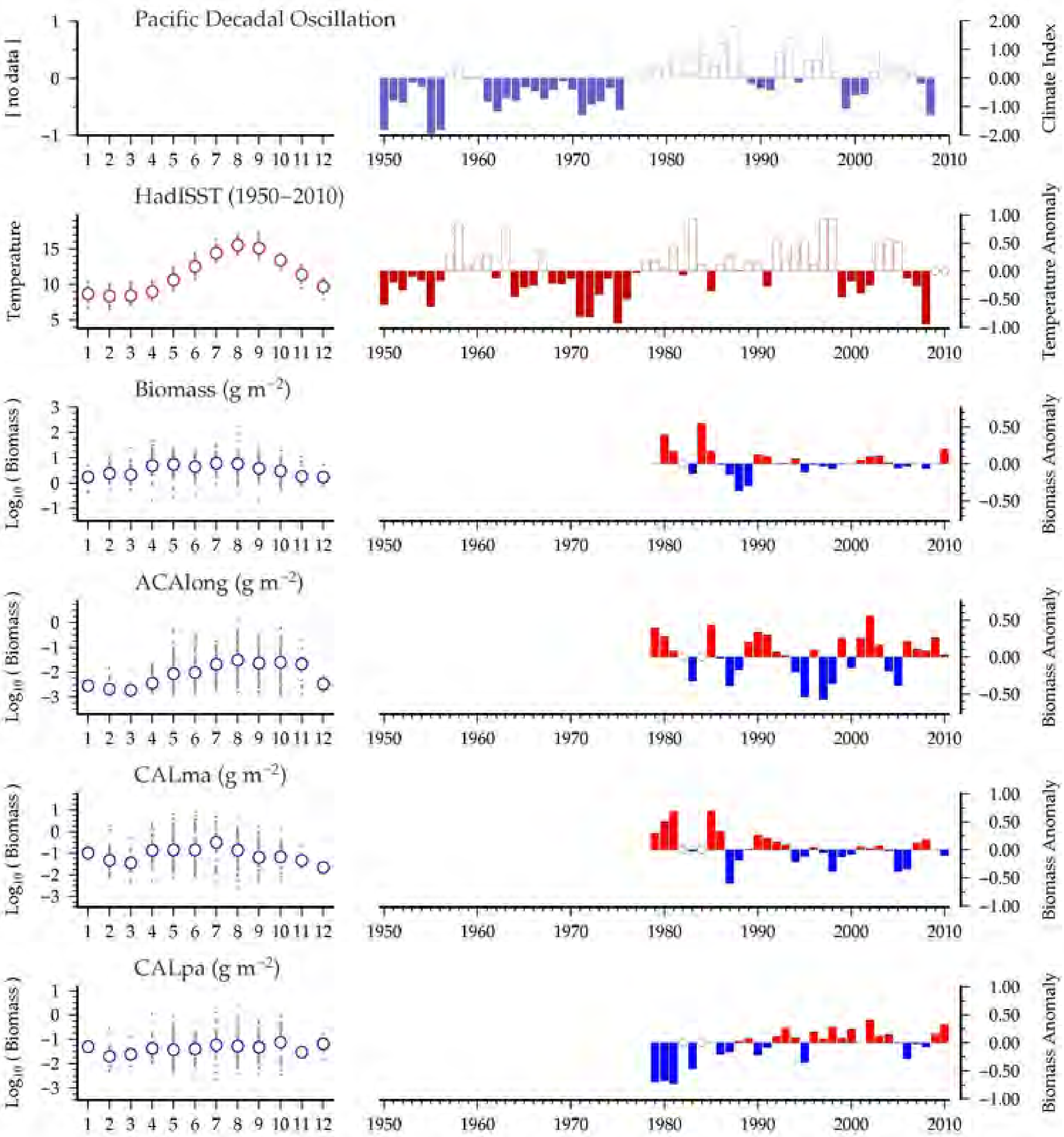


N/S spp shifts; Mackas

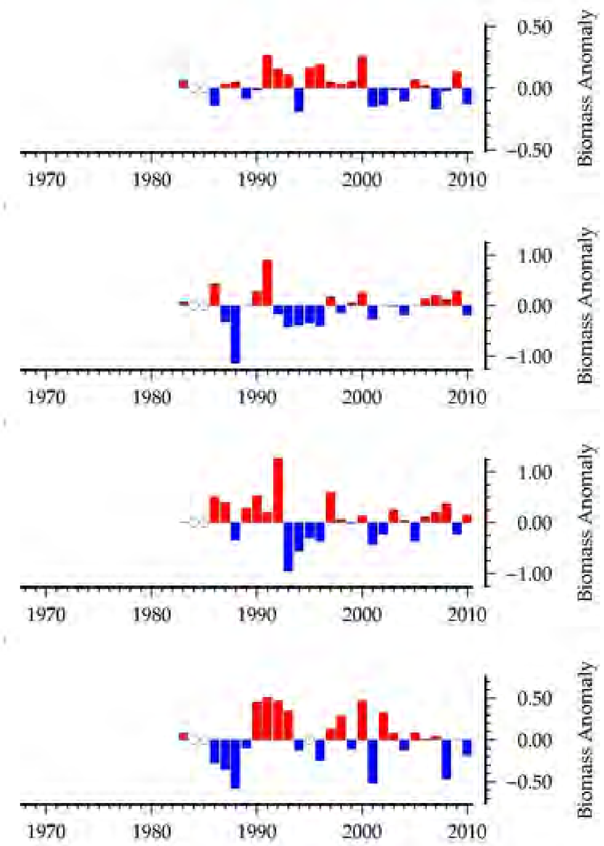


California Current: Southern Vancouver Is.

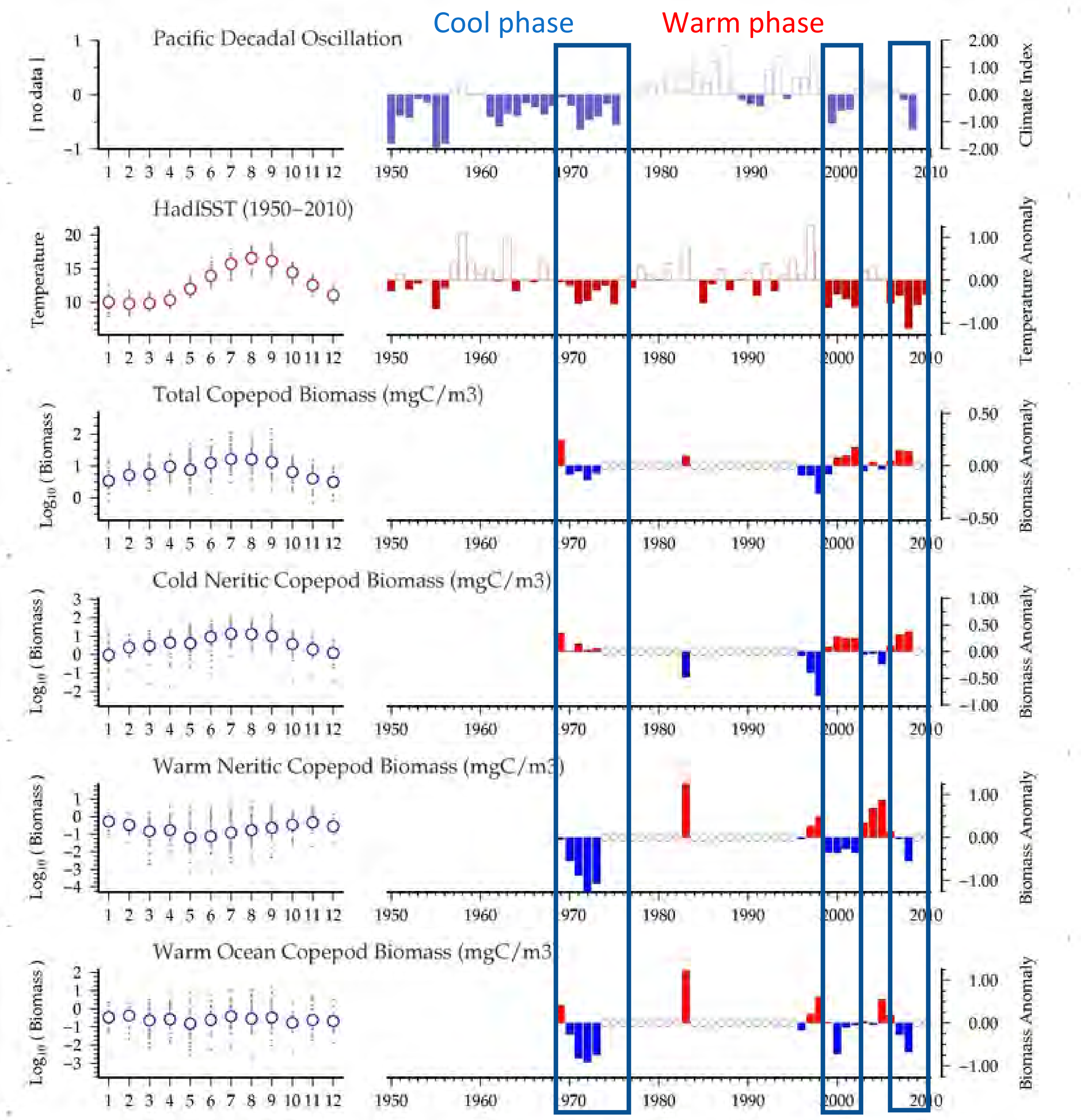


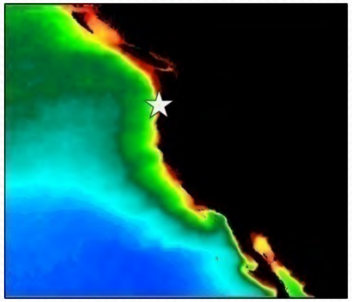


Northern Vancouver Is.



California Current: Newport, Oregon

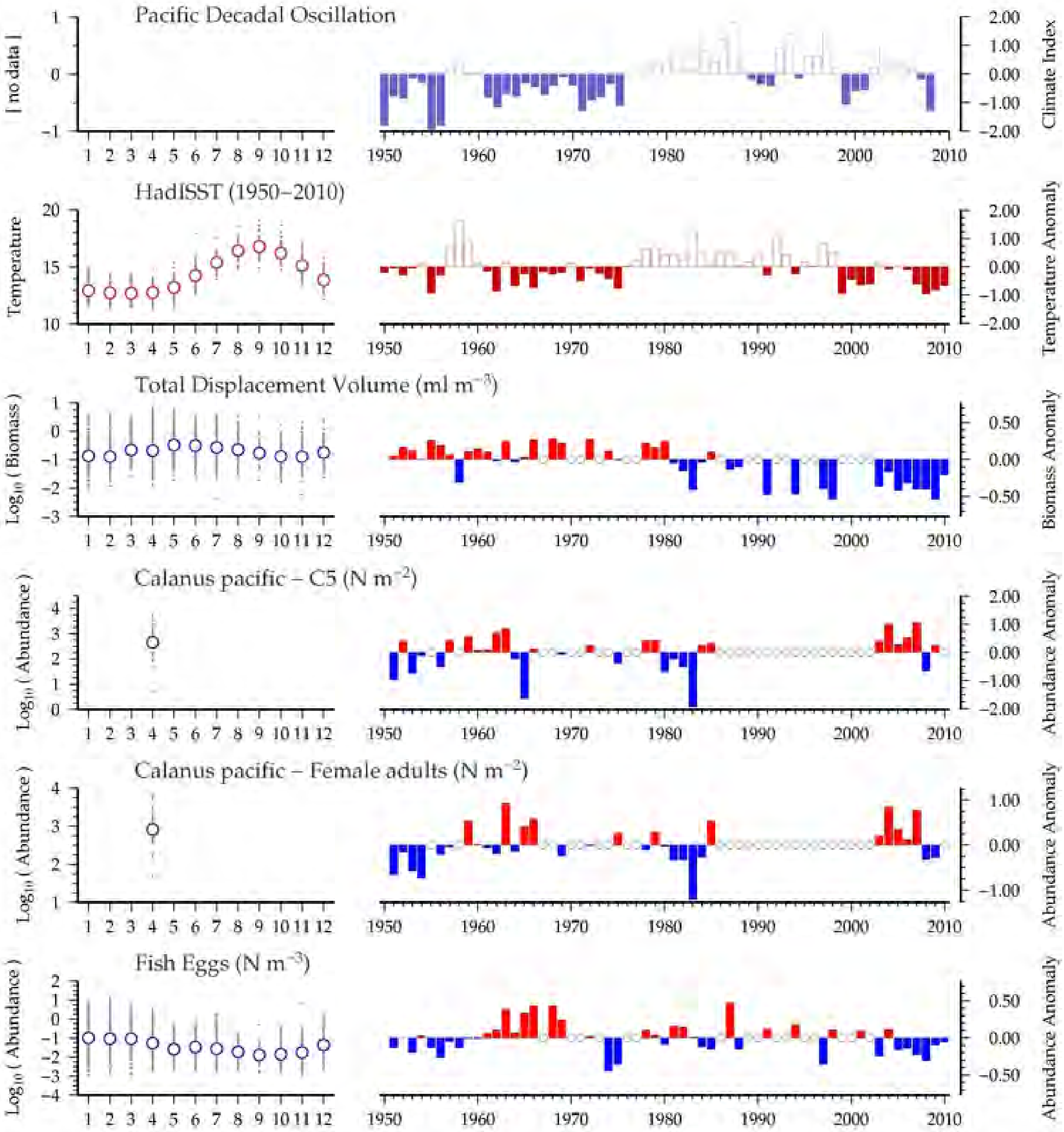


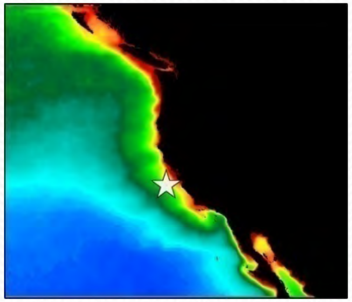


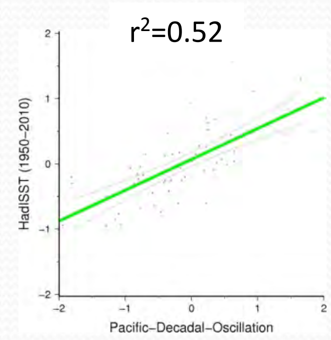
Cool PDO phase:

- -ve SST anomalies
- -ve anomalies in abundance of warm neritic & oceanic spp
- +ve anomalies in abundance of cold neritic spp.

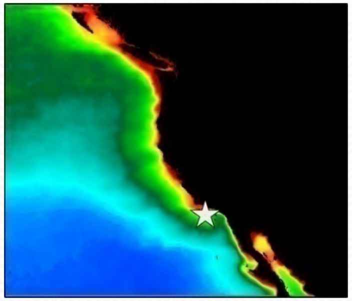
California Current: California

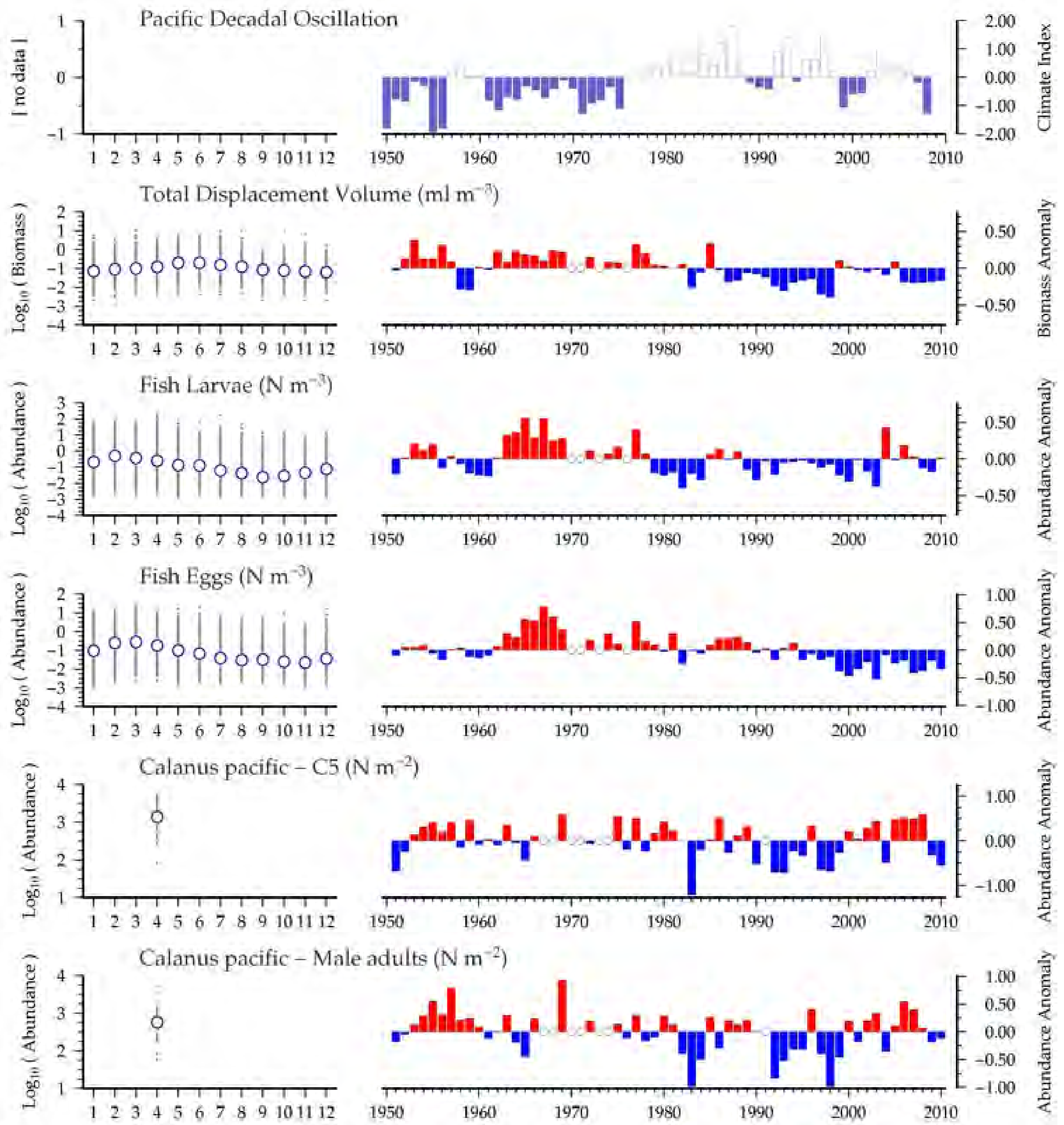


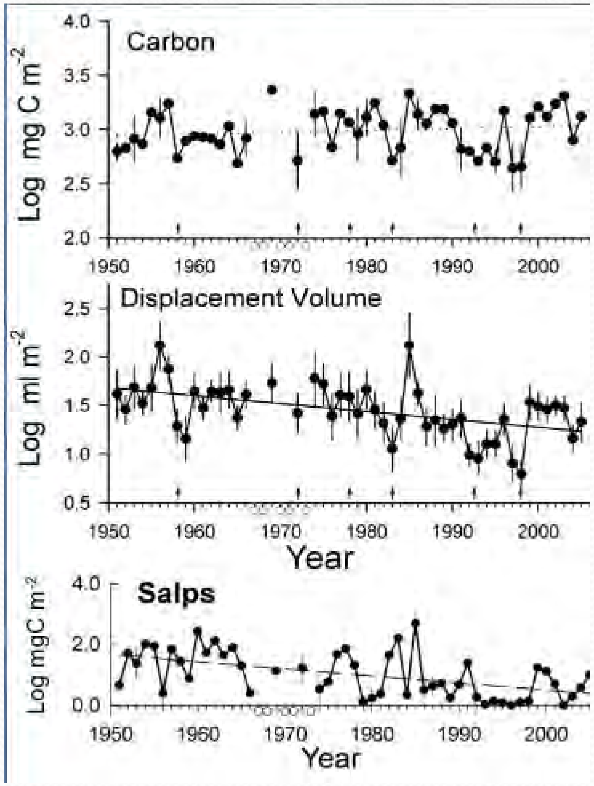




California Current: Southern California

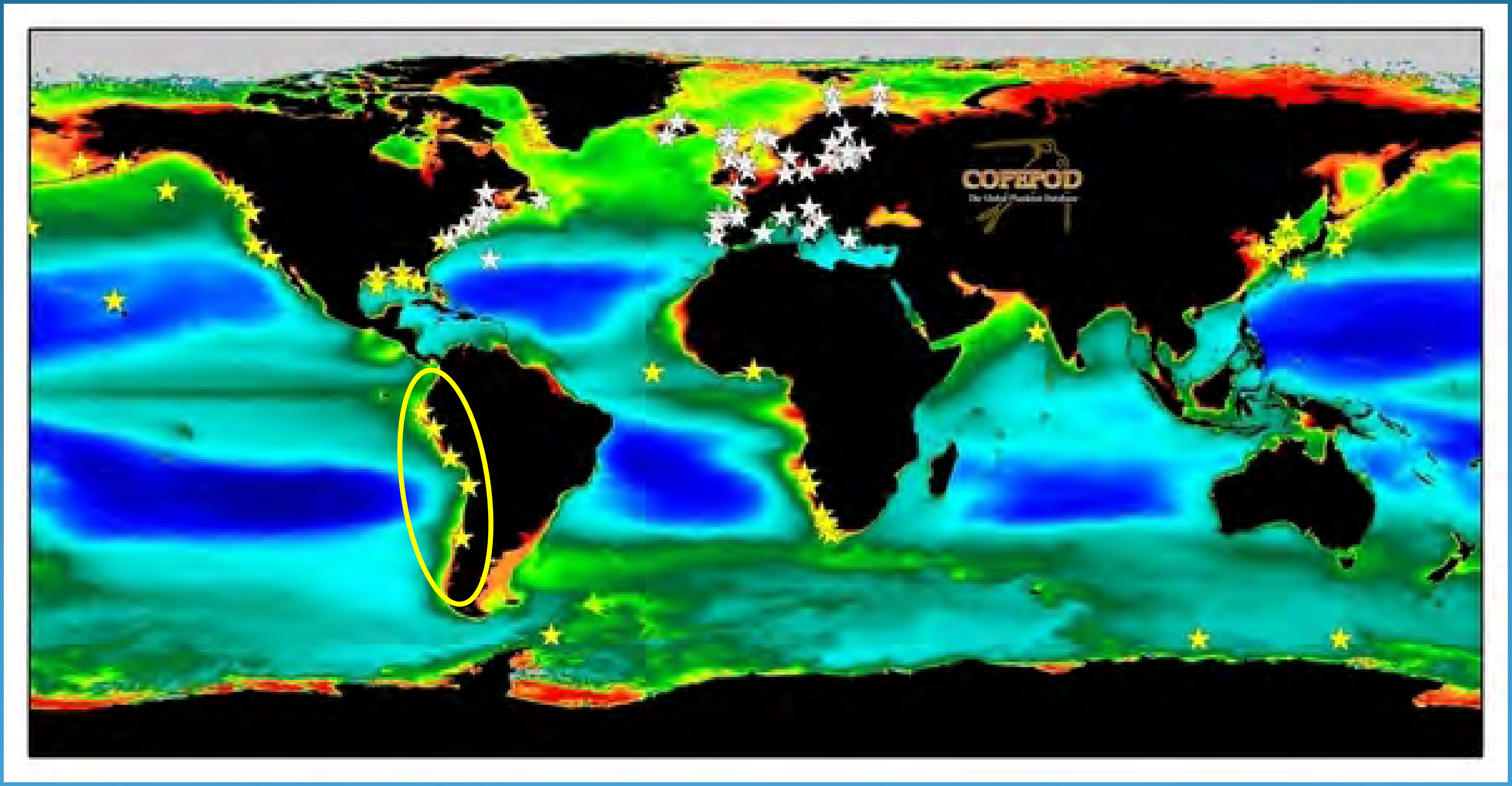




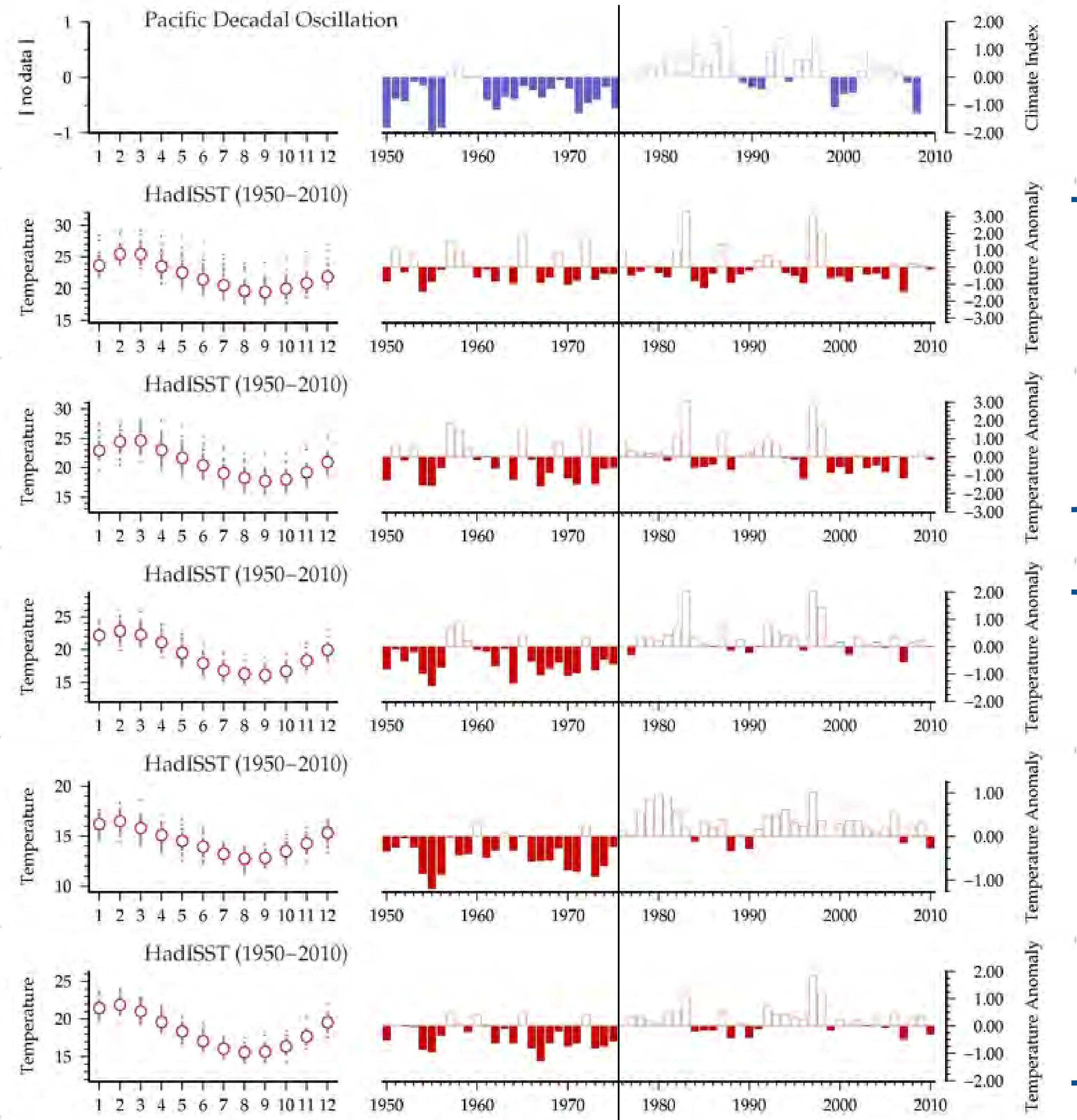


Lavaniegos & Ohman 2007

Humboldt Current



Humboldt: Latitudinal variability – Climate & SST



shift from -ve to +ve anomalies in 1976/7

Peru A (3-6°S)

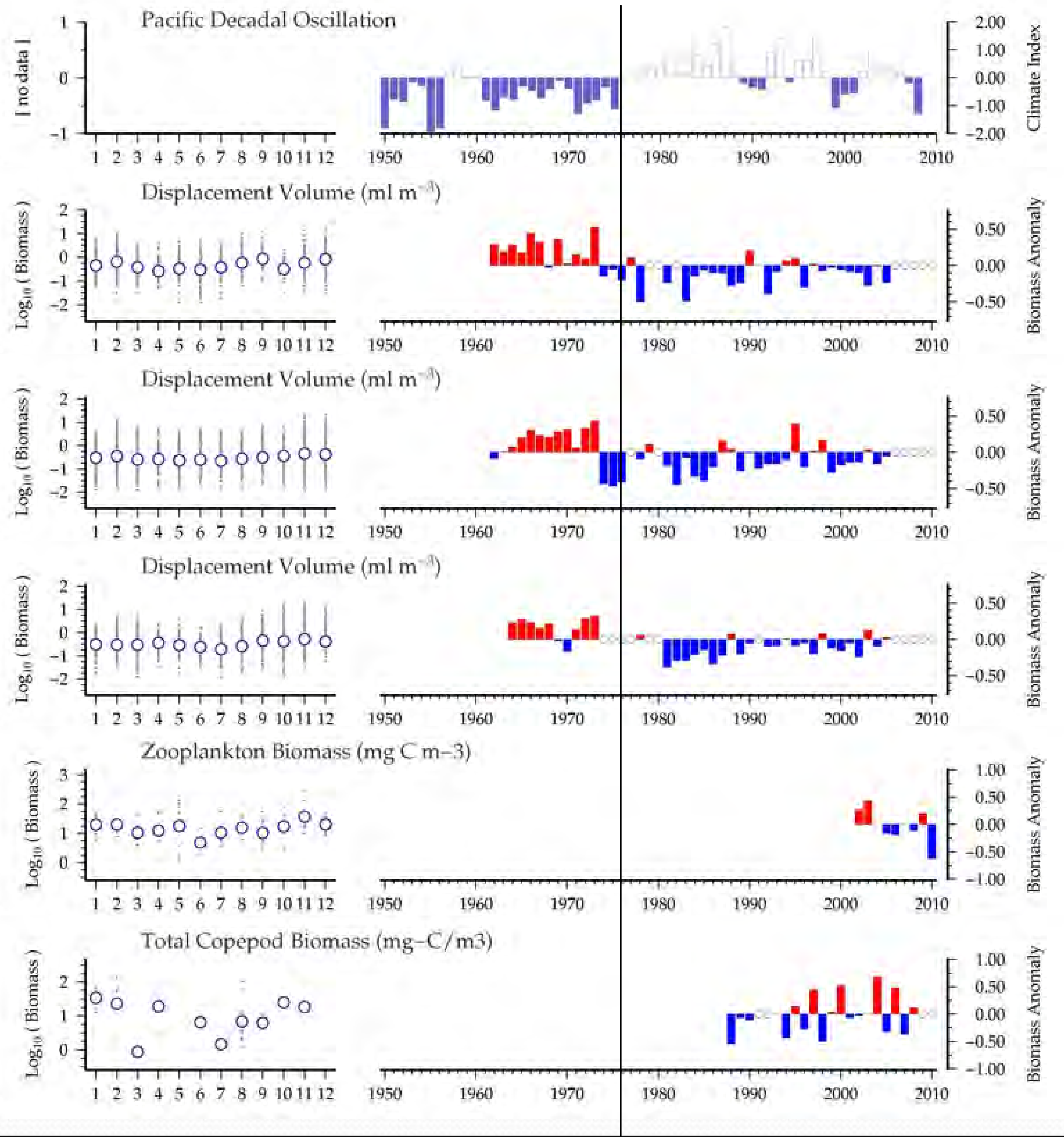
Peru B (6-14°S)

Peru C (14-18.5°S)

Chile - Concepcion

Chile - Mejillones

Humboldt: Latitudinal variability – Climate & Zooplankton



shift from -ve to +ve anomalies in 1976/7

Peru A (3-6°S)

Peru B (6-14°S)

Strong switch from +ve to –ve anomalies in 1974

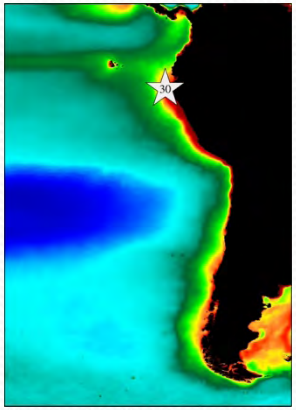
Peru C (14-18.5°S)

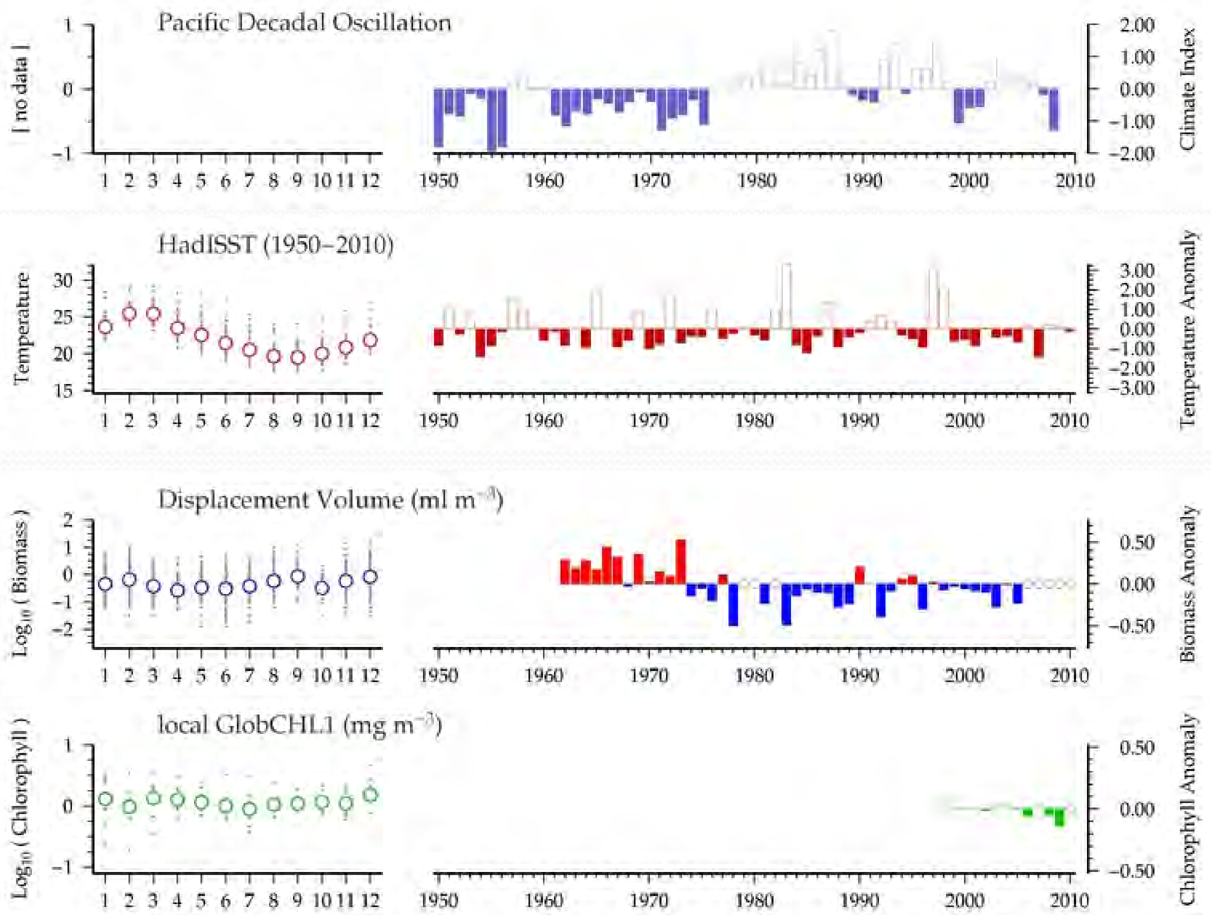
Chile - Concepcion

Chile - Mejillones

high interannual variability

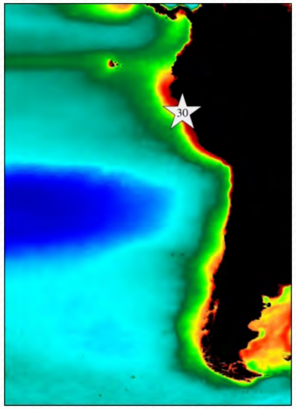
Humboldt: Peru Site A

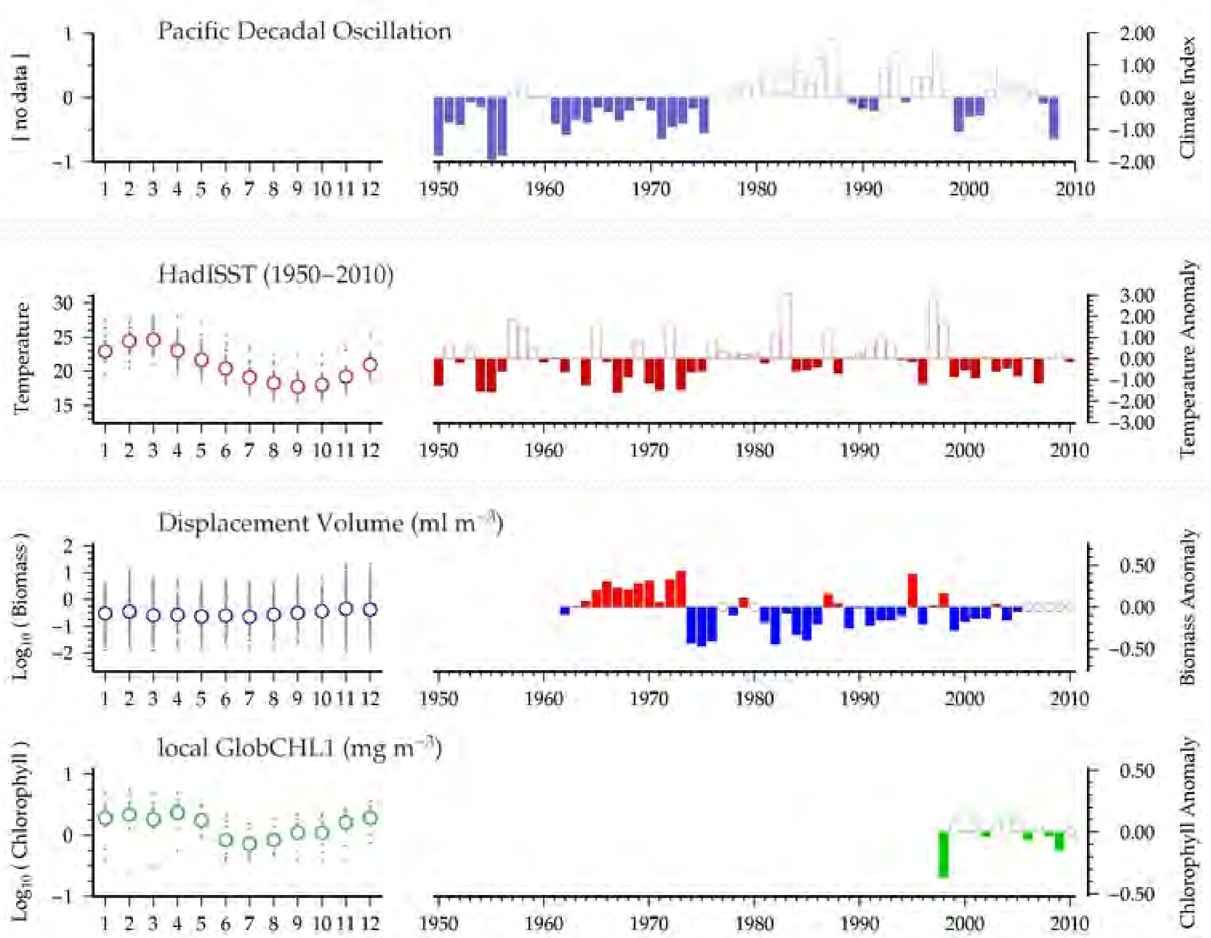




No spp data for Peru

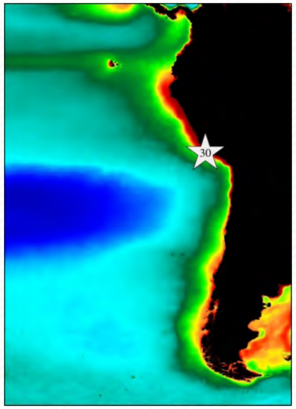
Humboldt: Peru Site B

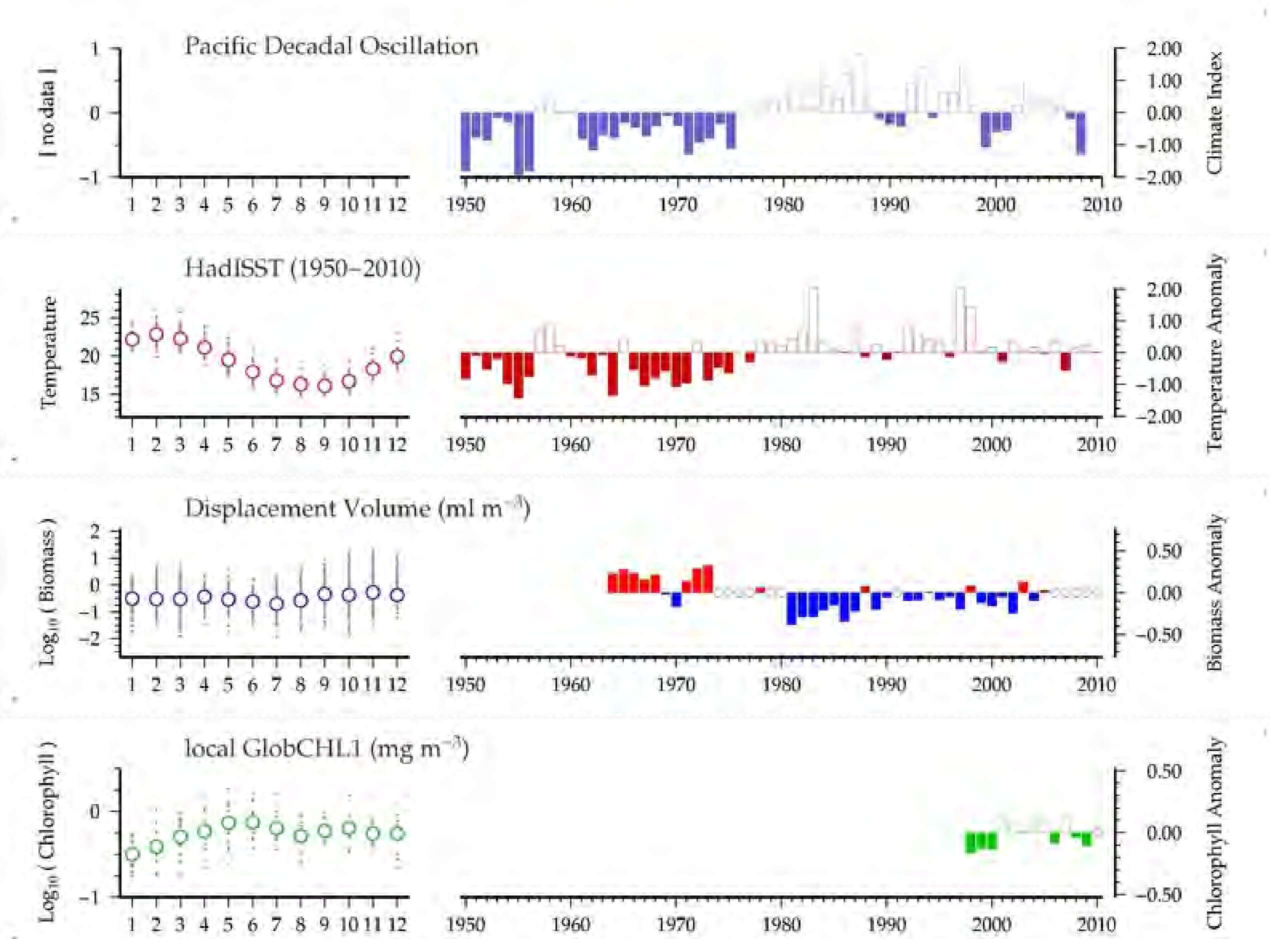


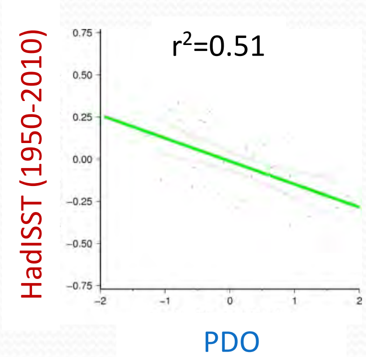


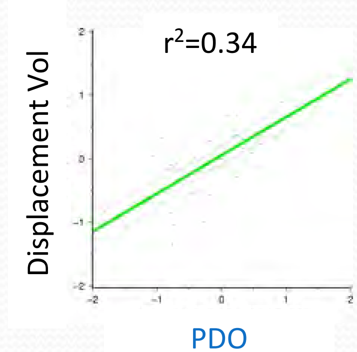
No spp data for Peru

Humboldt: Peru Site C



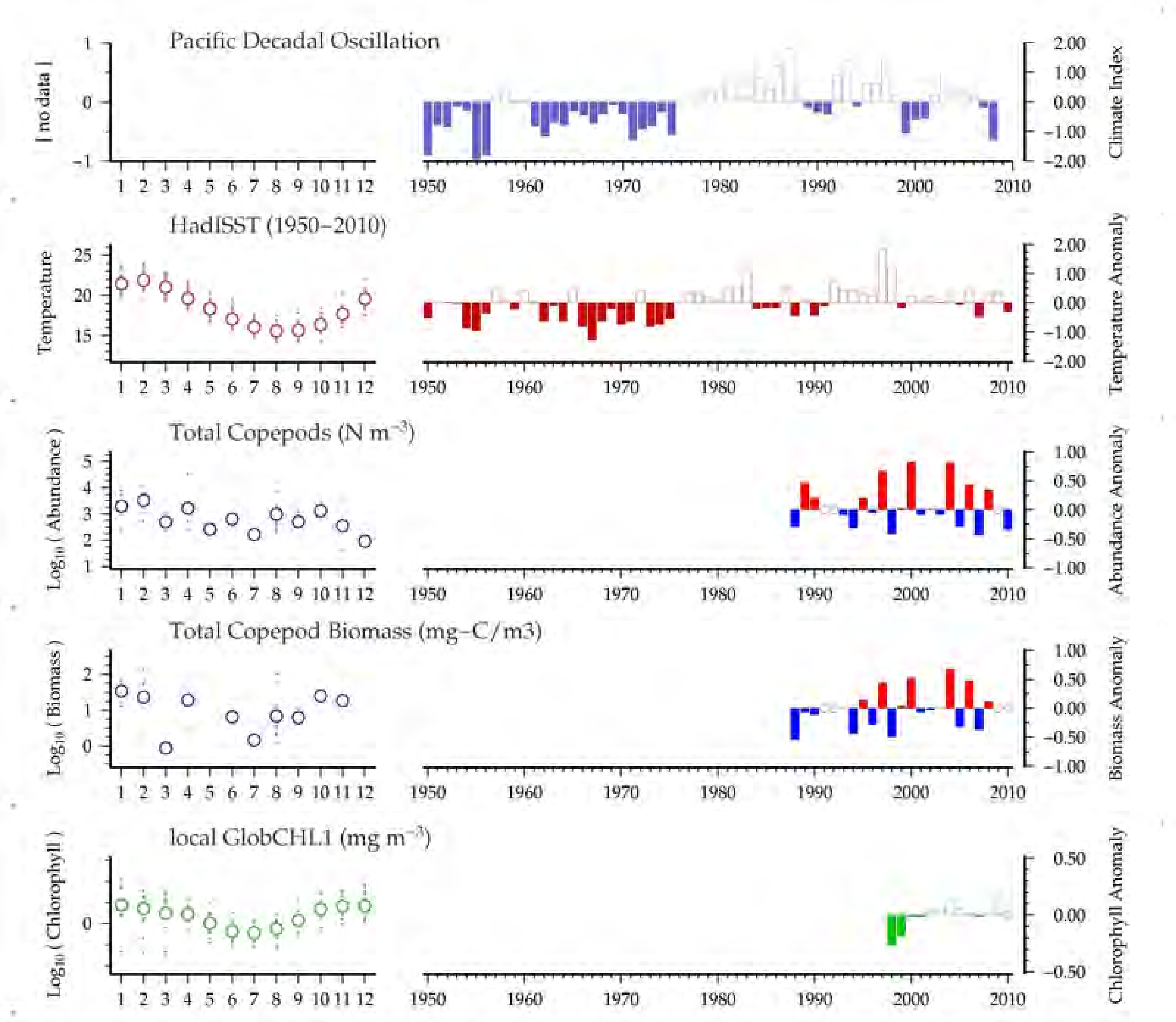


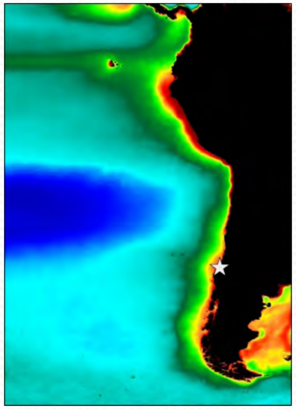




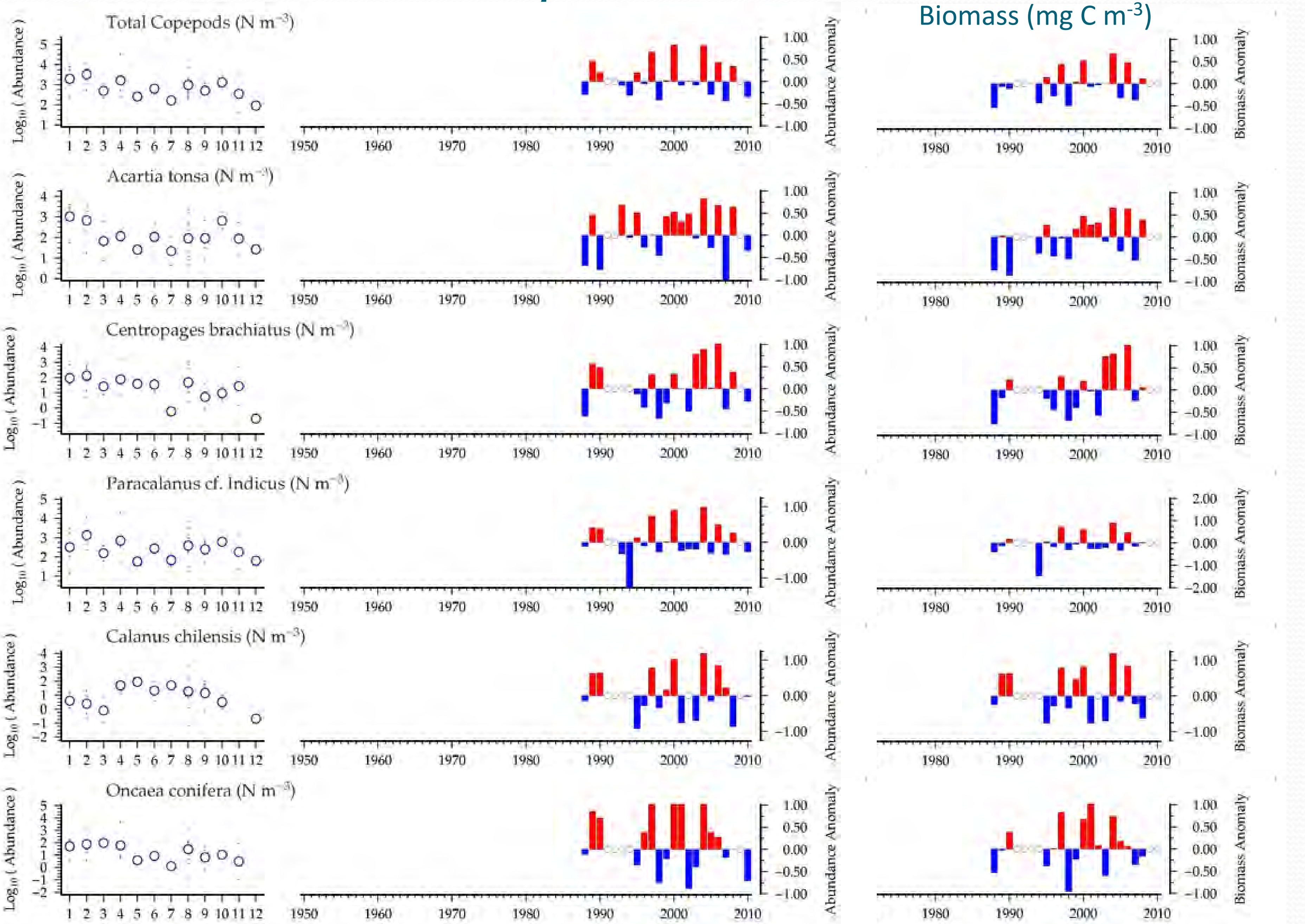
No spp data for Peru

Humboldt: Chile – Mejillones Station

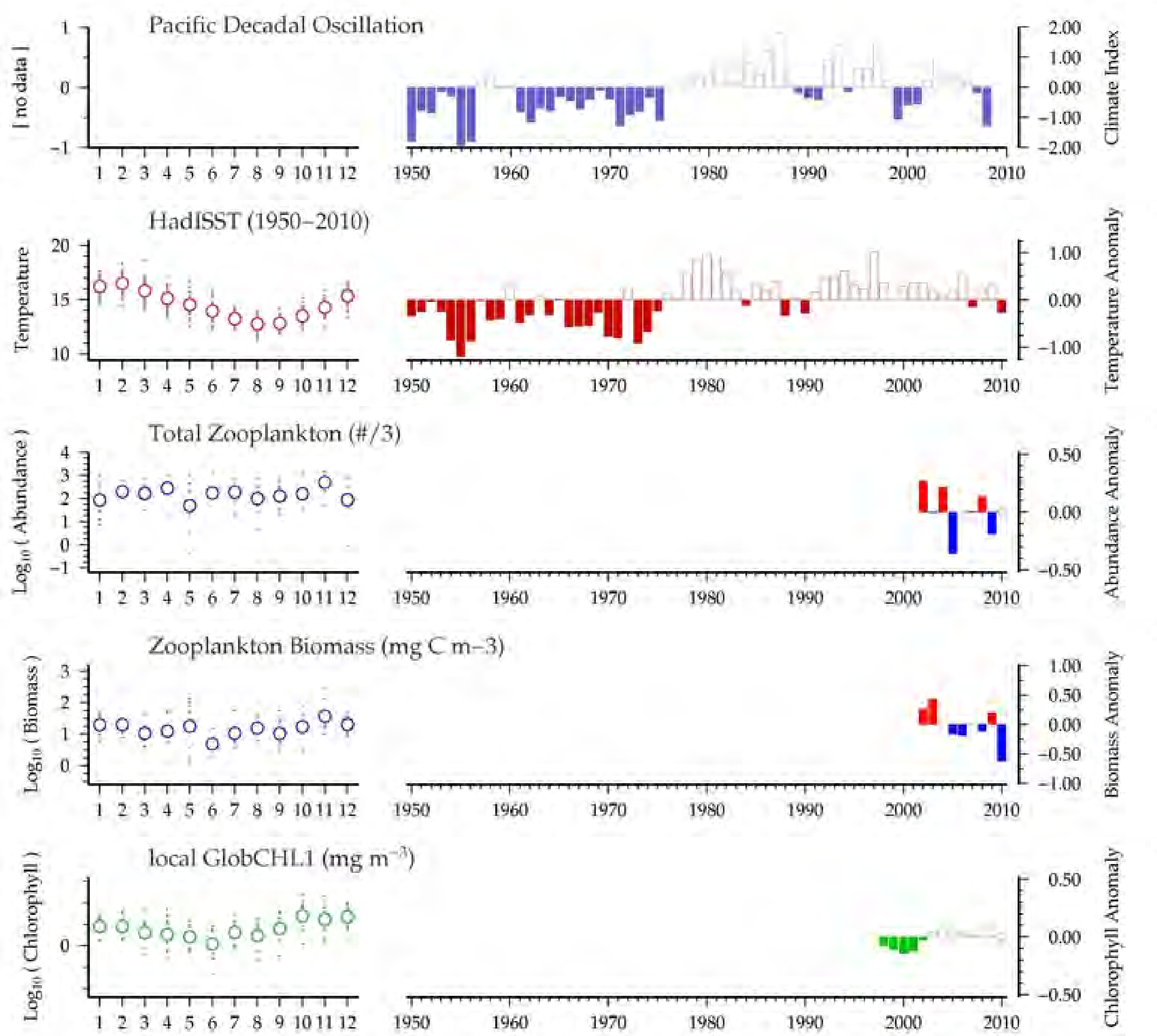


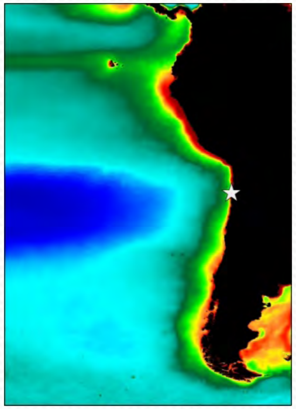


Humboldt: Chile – Mejillones Station

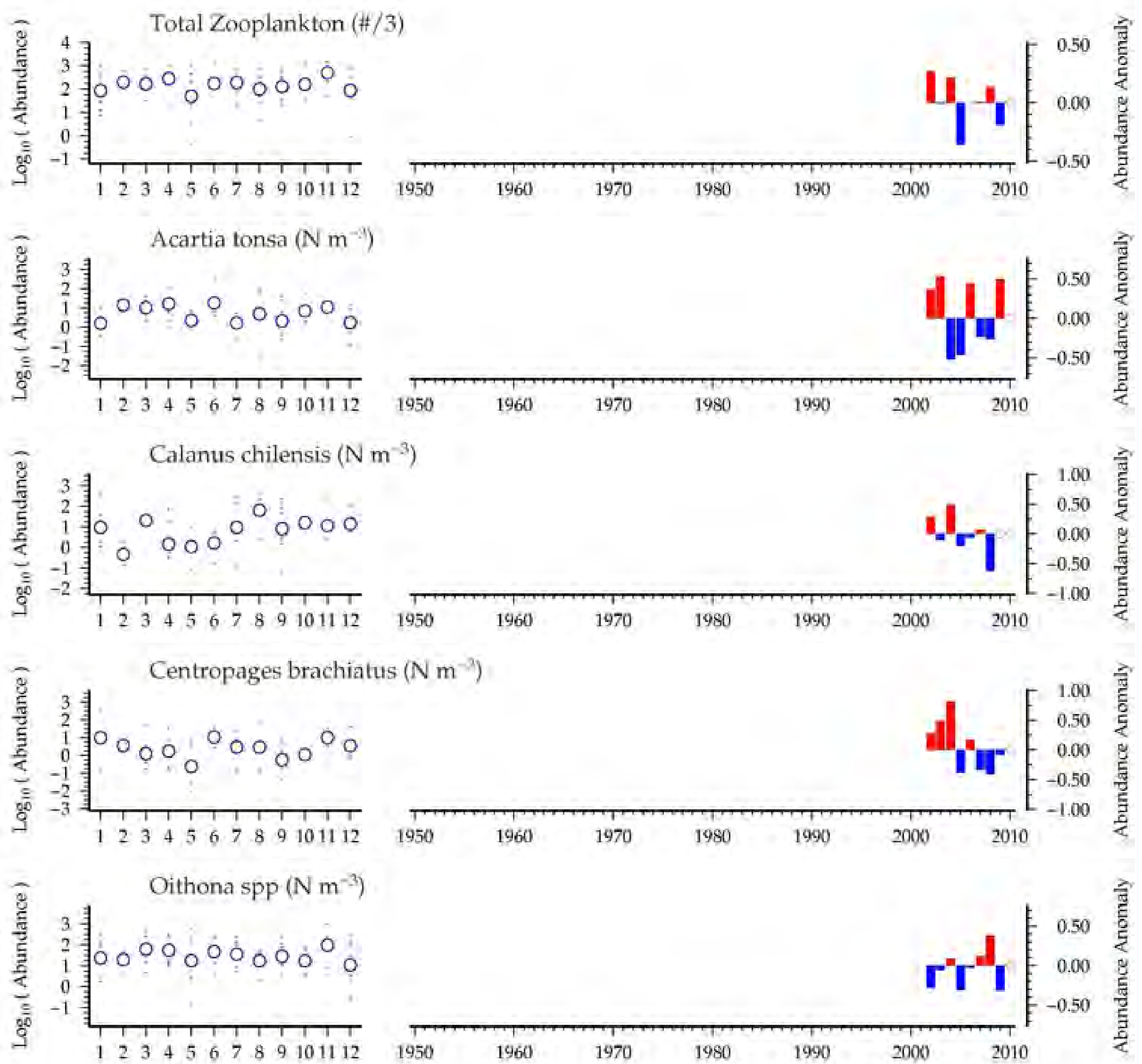


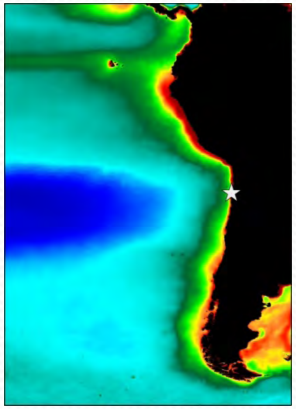
Humboldt: Chile – Concepcion Station 18



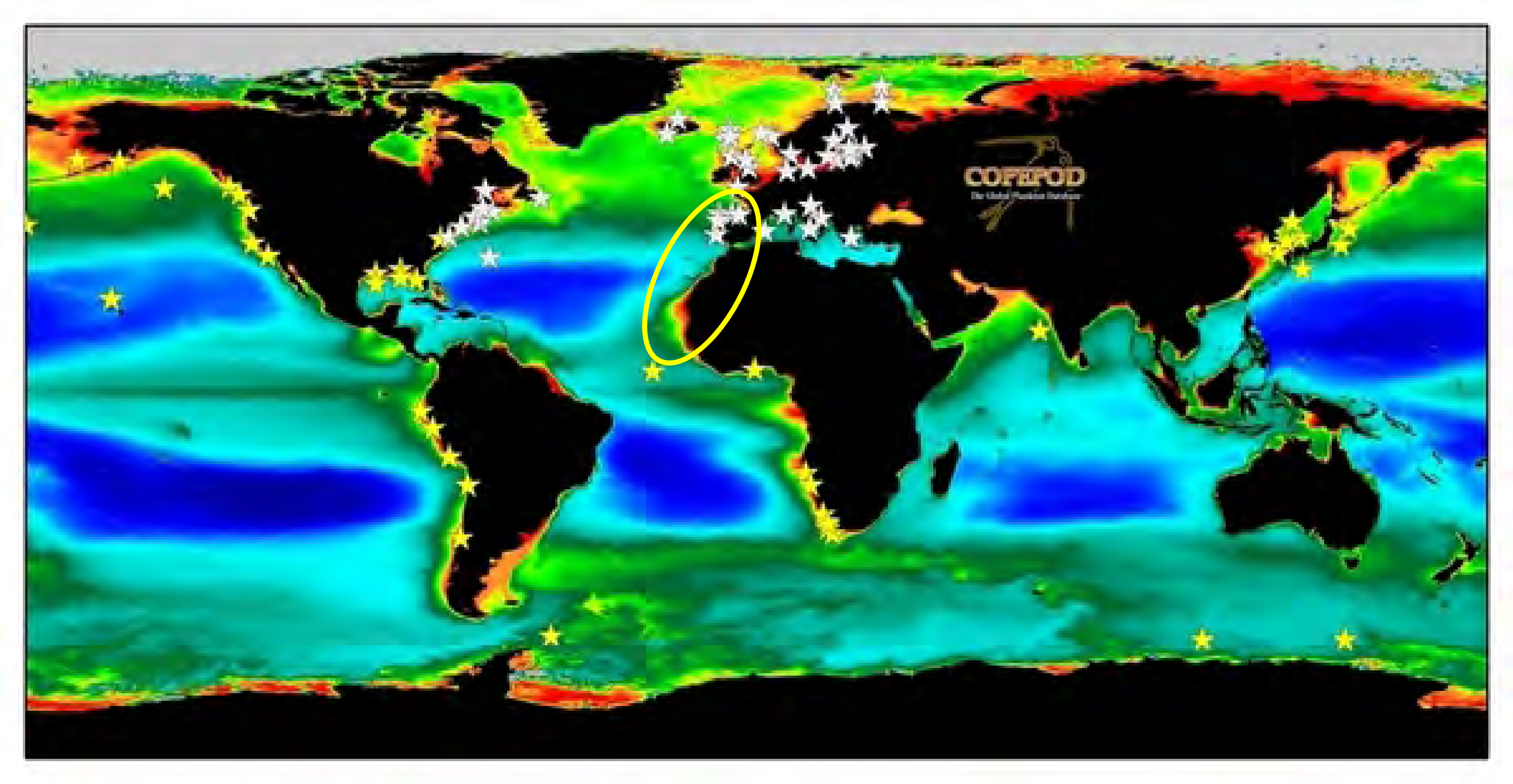


Humboldt: Chile – Concepcion Station 18

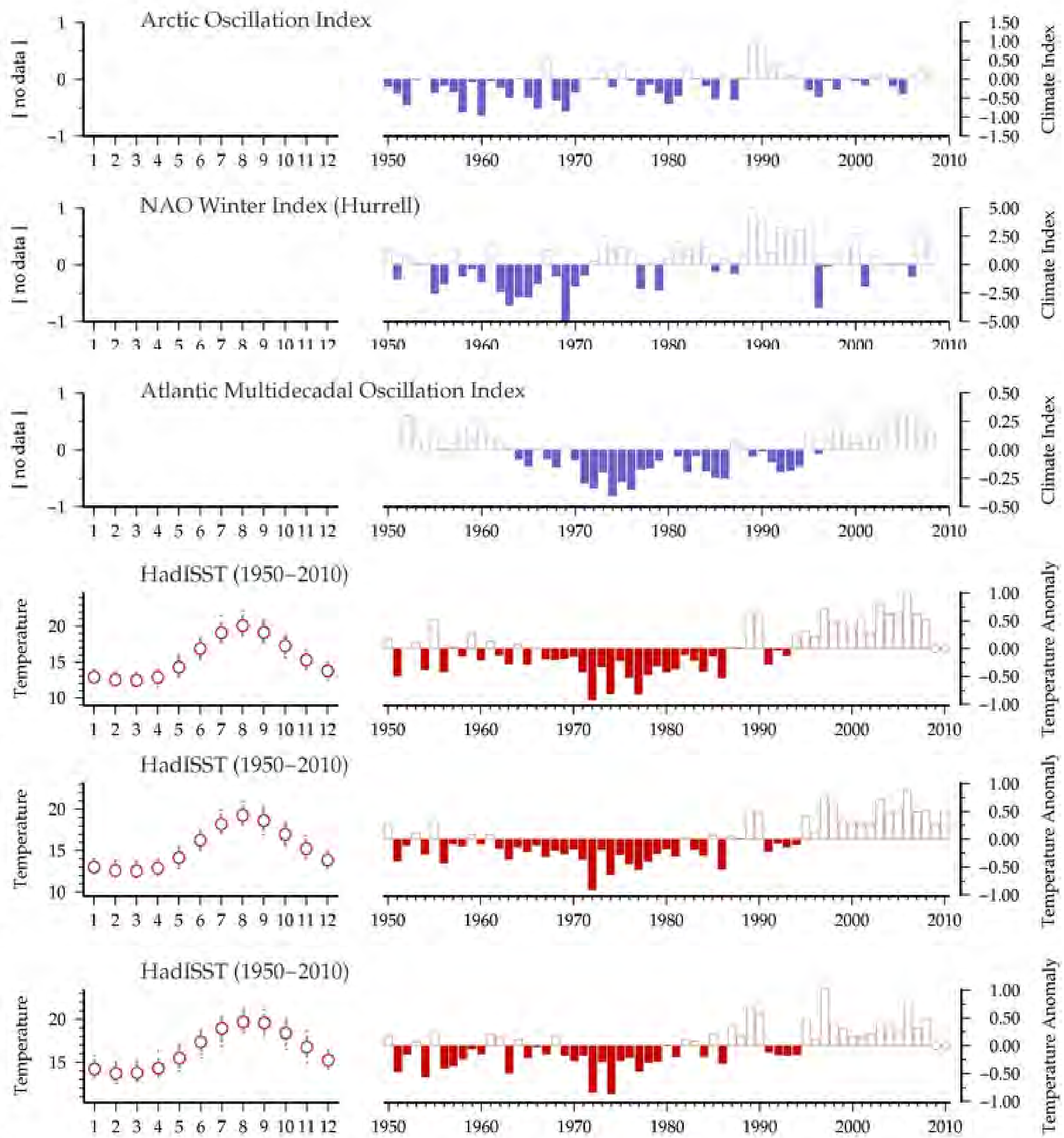




Canary - Iberian Peninsula



Iberian Peninsula: Climate & SST

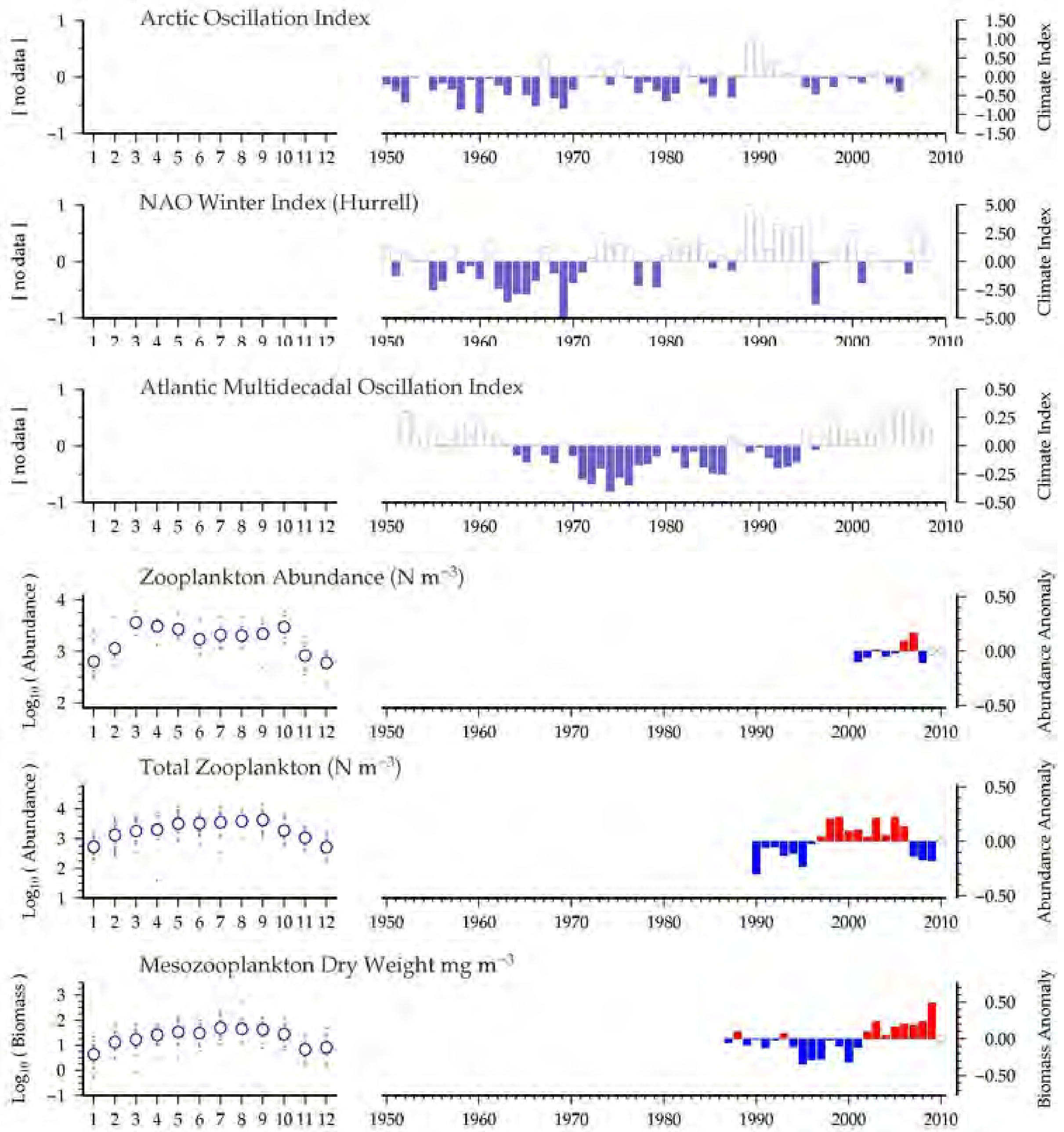


Gijon Station 3 (NE Peninsula)

A Coruna (NW Peninsula)

Vigo (NW Peninsula)

Iberian Peninsula: Climate & Zooplankton

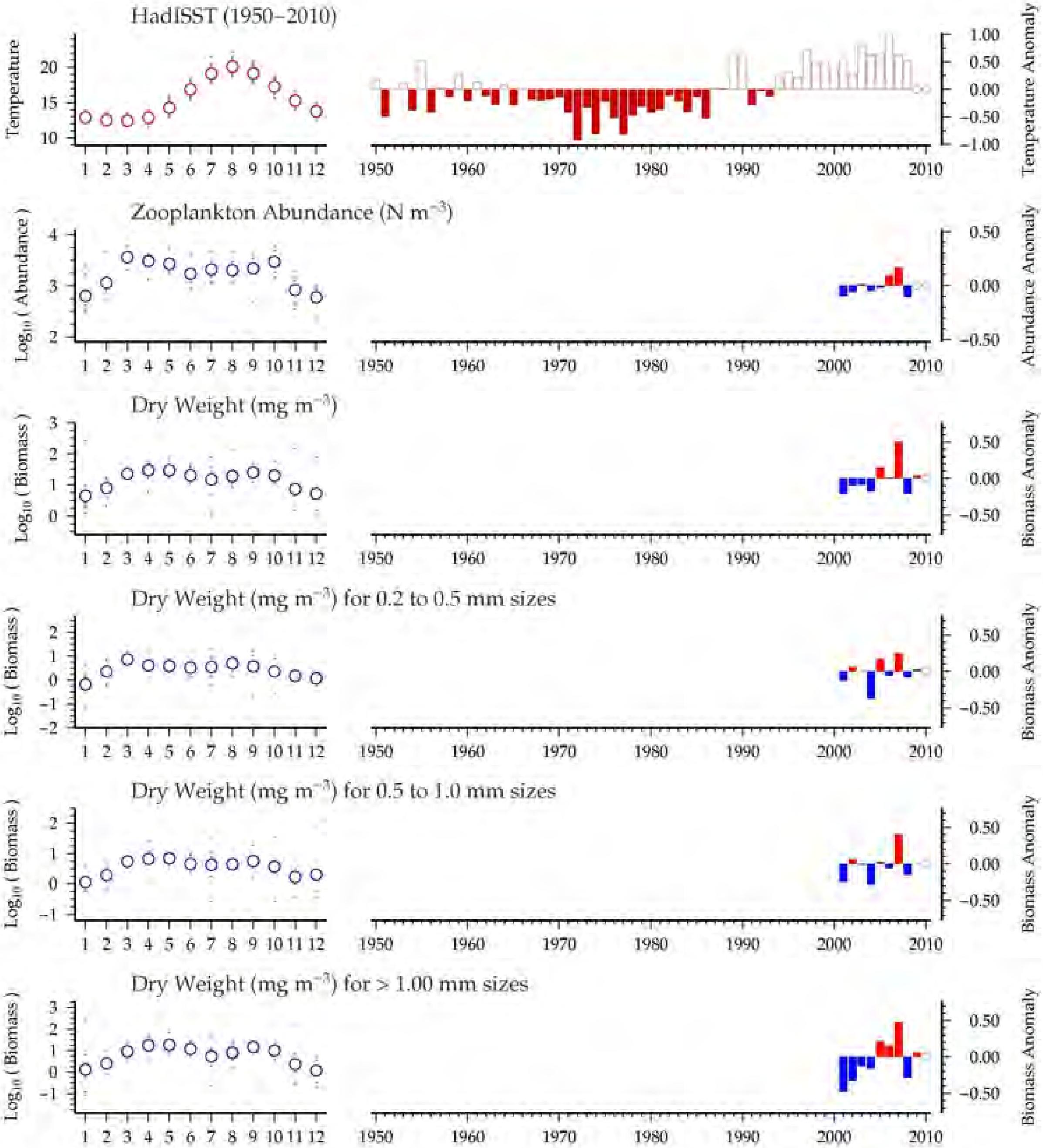


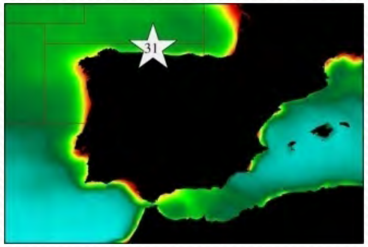
Gijon Station 3 (NE Peninsula)

A Coruna (NW Peninsula)

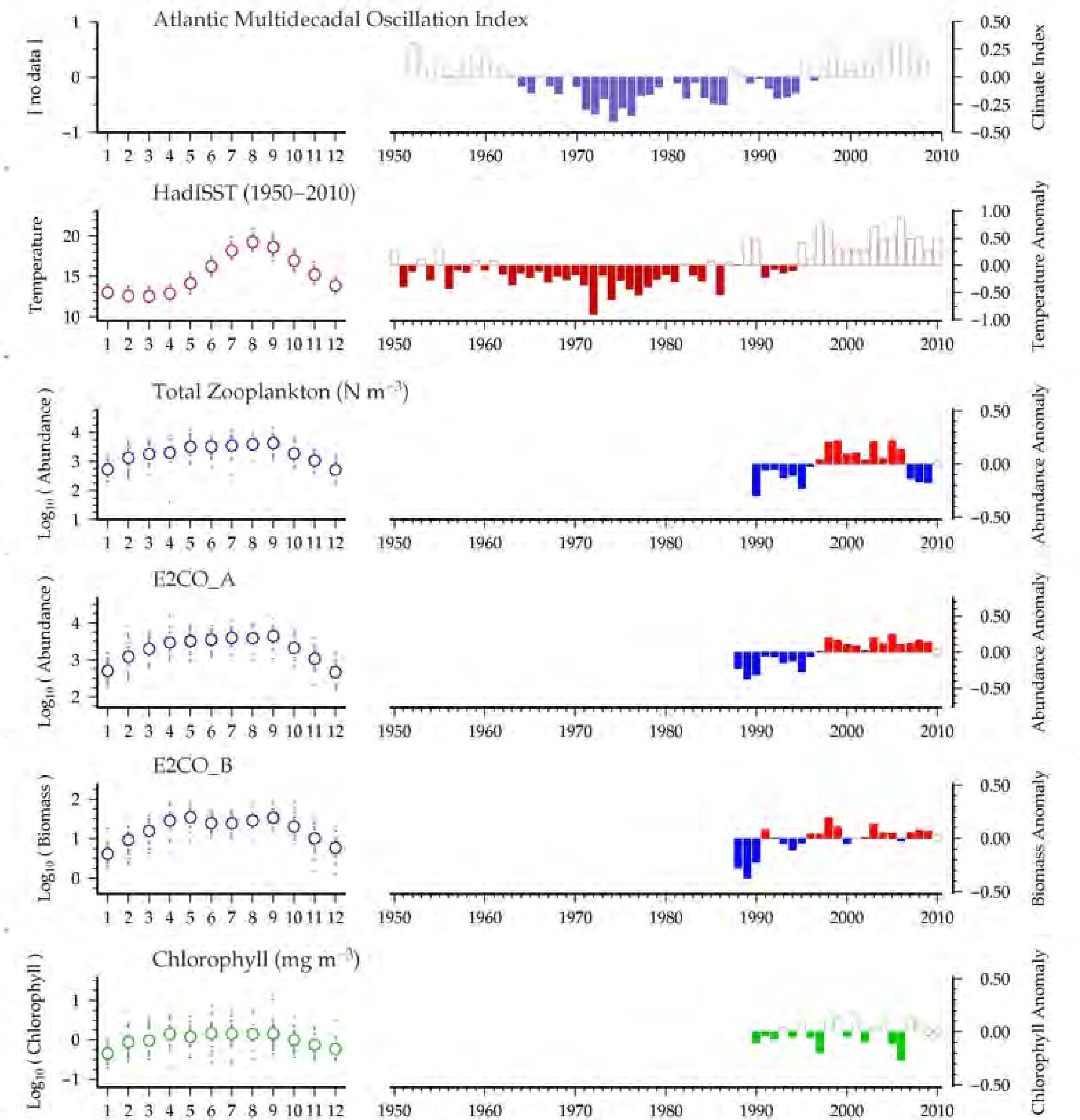
Vigo (NW Peninsula)

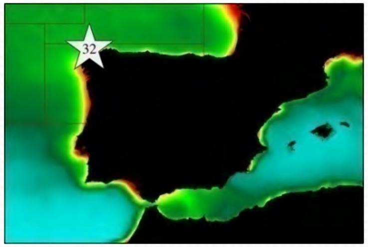
Gijon Station 3 (Northeast Iberian Peninsula)



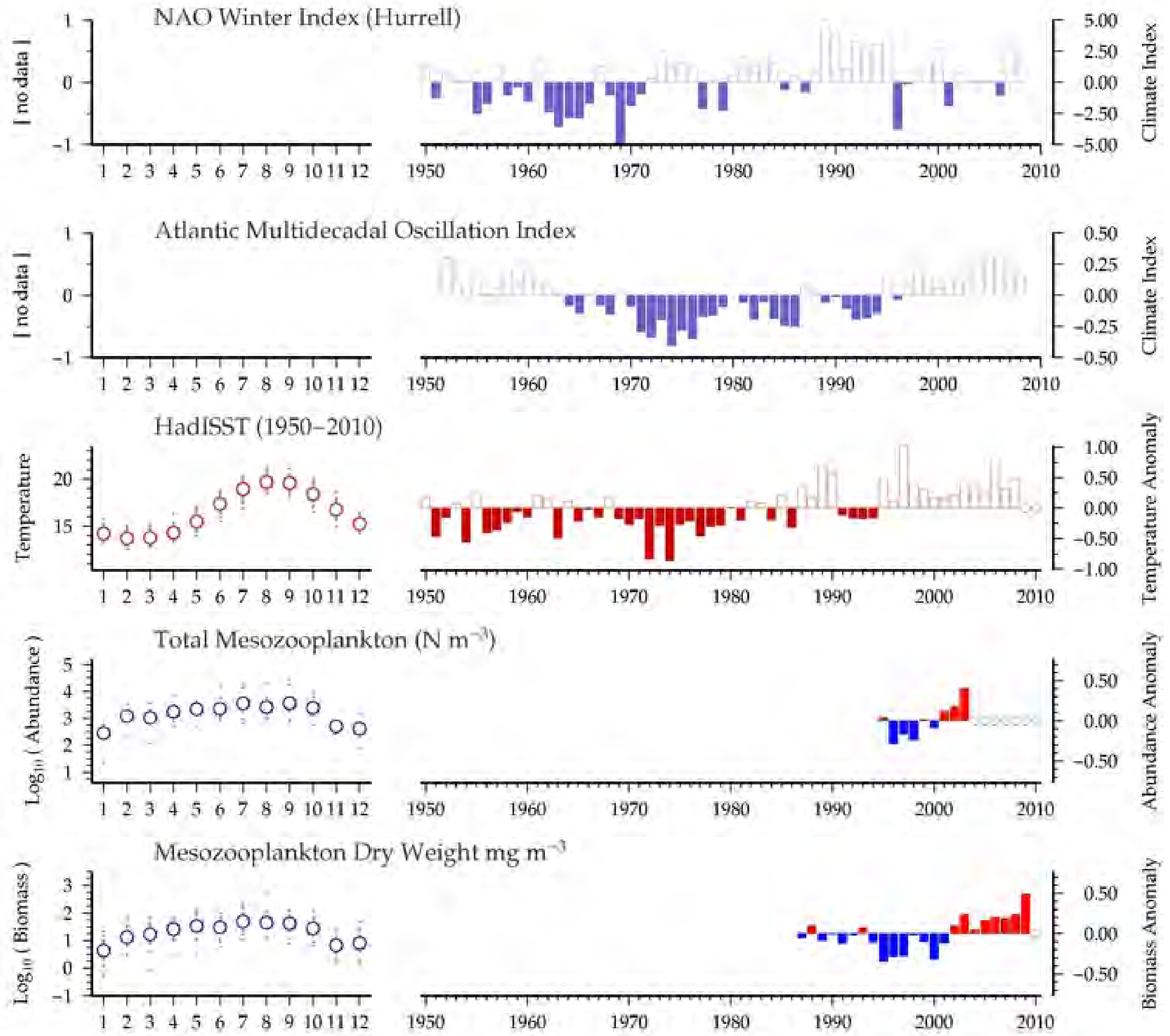


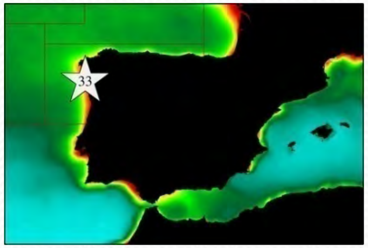
A Coruna (Northwest Iberian Peninsula)





Vigo (Northwest Iberian Peninsula)





A Coruna & Vigo: Zooplankton abundance decreased significantly offshore (CPR data), but increased near the coast. Warm water spp like *Temora stylifera* were increasingly abundant. ~5-month lag in copepod response to environmental variability.

Bode et al. (2009) P in O 83; Bode et al. In review

Thank you

Dave Mackas & Martin Edwards (I think ☺)

Todd O'Brien

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