Drivers of interannual and decadal-scale variability in the lower trophic levels of the marine ecosystem off Vancouver Island, Canada

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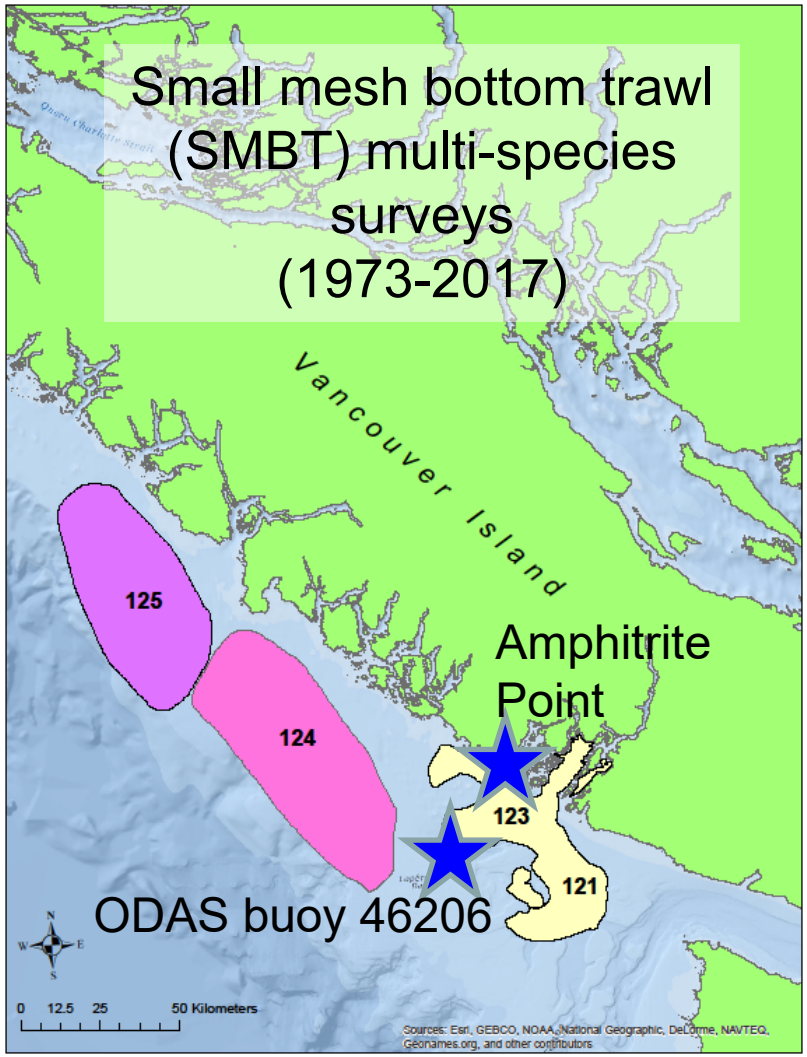
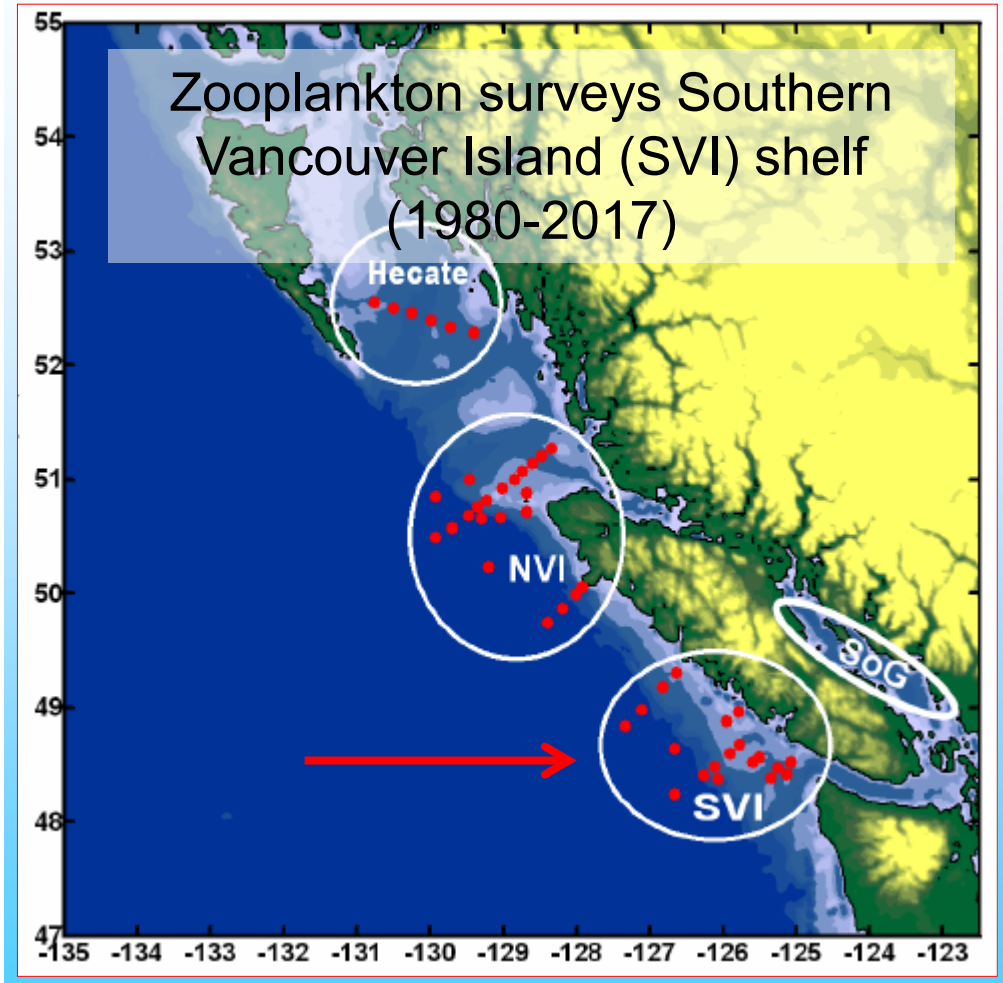
Background and Objective

- Marine ecosystem west of Vancouver Island, Canada, experiences warm and cool conditions related to ENSO and other events.
- These conditions influence the species composition and biomass of zooplankton and fish
- Objective: use nearly four decade-long time series of zooplankton and small demersal invertebrates and finfish to explore the decadal patterns of biomass when the interannual variability of these warm-cool episodes is removed.

The Data: Locations (southwest coast Vancouver Island)





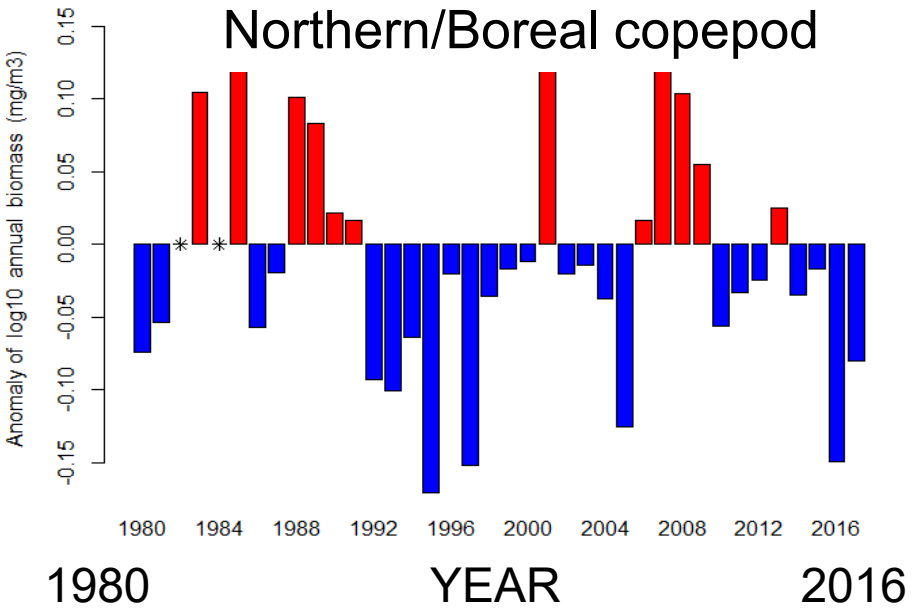
The Data: ZooplanktonTaxa

Standardised annual anomalies of log10 biomass, e.g.

$$\frac{\text{Annual average of [Biomass}_{(\text{seaon,year})} - \text{mean Biomass}_{(\text{season})}]}{\text{Standard deviation of annual averages}}$$

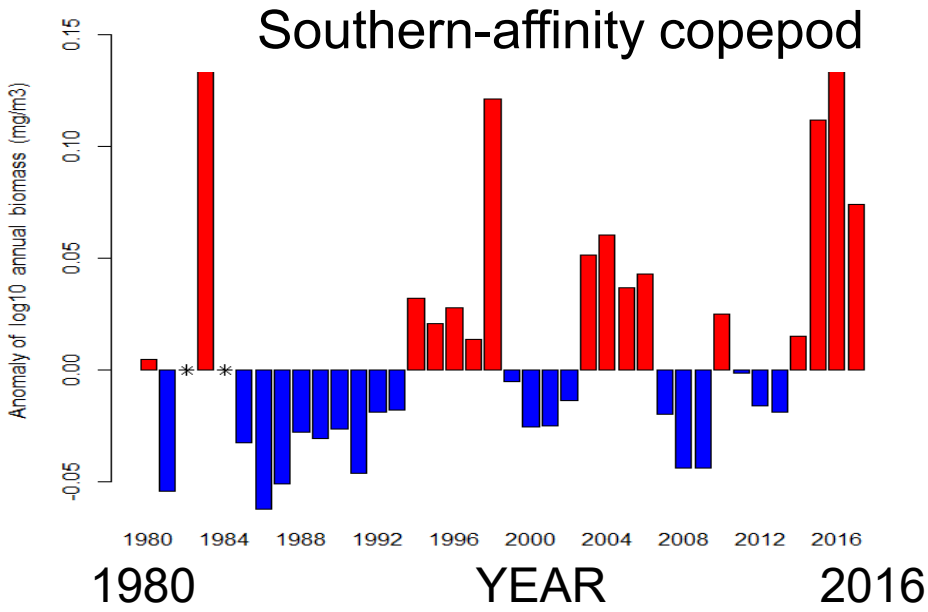
Acartia longiremis

Northern/Boreal copepod



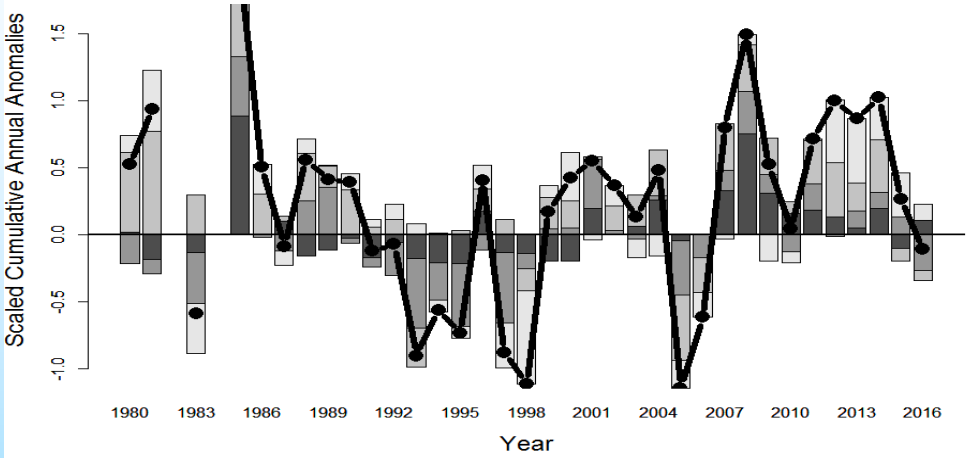
Ctenocalanus vanus

Southern-affinity copepod



The Data: Zooplankton Cumulative Anomaly Indices

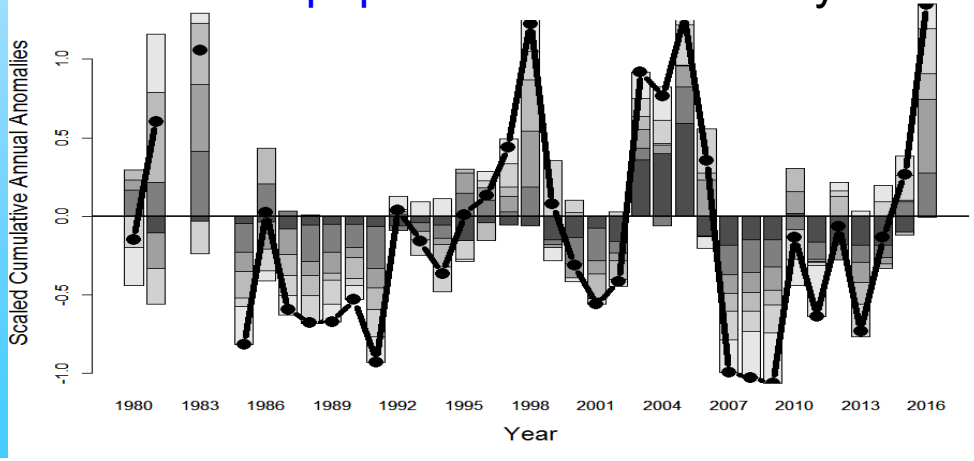
Copepods: Northern-affinity



1980 2016

Calanus marshallae,
Pseudocalanus mimus,
Acartia longiremis,
Acartia hudsonica

Copepods: Southern-affinity



Acartia tonsa,
Paracalanus parvus,
Paracalanus quasimodo,
Ctenocalanus vanus,
Mesocalanus tenuicornis,
Clausoscalanus spp.,
Calocalanus spp.,
Metridia pseudopacifica

Statistical analysis

Annual Anomalies of Explanatory Variables:

Physical variables:
Multivariate ENSO Index
Pacific Decadal Oscillation
North Pacific Gyre Oscillation index
Amphitrite Point SST
Upwelling index (49° - 50° N)
ODAS Buoy 46206 SST at 3m
ODAS Buoy 46206 Surface Atmospheric Pressure

Human variable:
Catches of commercial species (BC coastwide, species selected to match those caught in Small-mesh bottom trawl survey off Vancouver Island)
(Source: Sea Around Us Project, UBC)

?

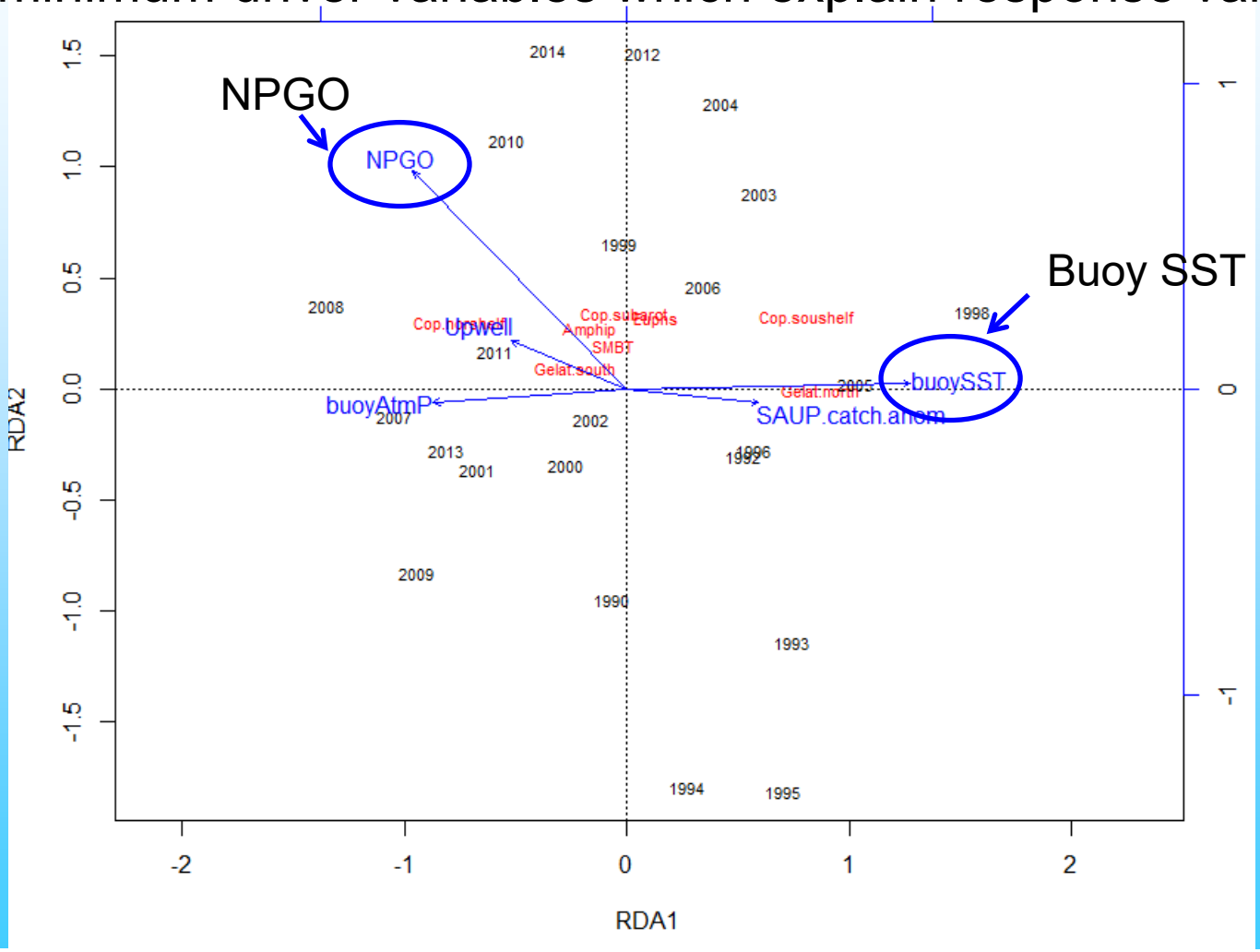
Annual Anomalies of Response Variables:

Zooplankton:
Northern-affinity copepods
Southern-affinity copepods
Subarctic oceanic-affinity copepods
Euphausiids
Amphipods
Northern-affinity gelatinous plankton
Southern-affinity gelatinous plankton

Small-mesh trawl survey data:
Small-mesh bottom trawl survey (selected species)

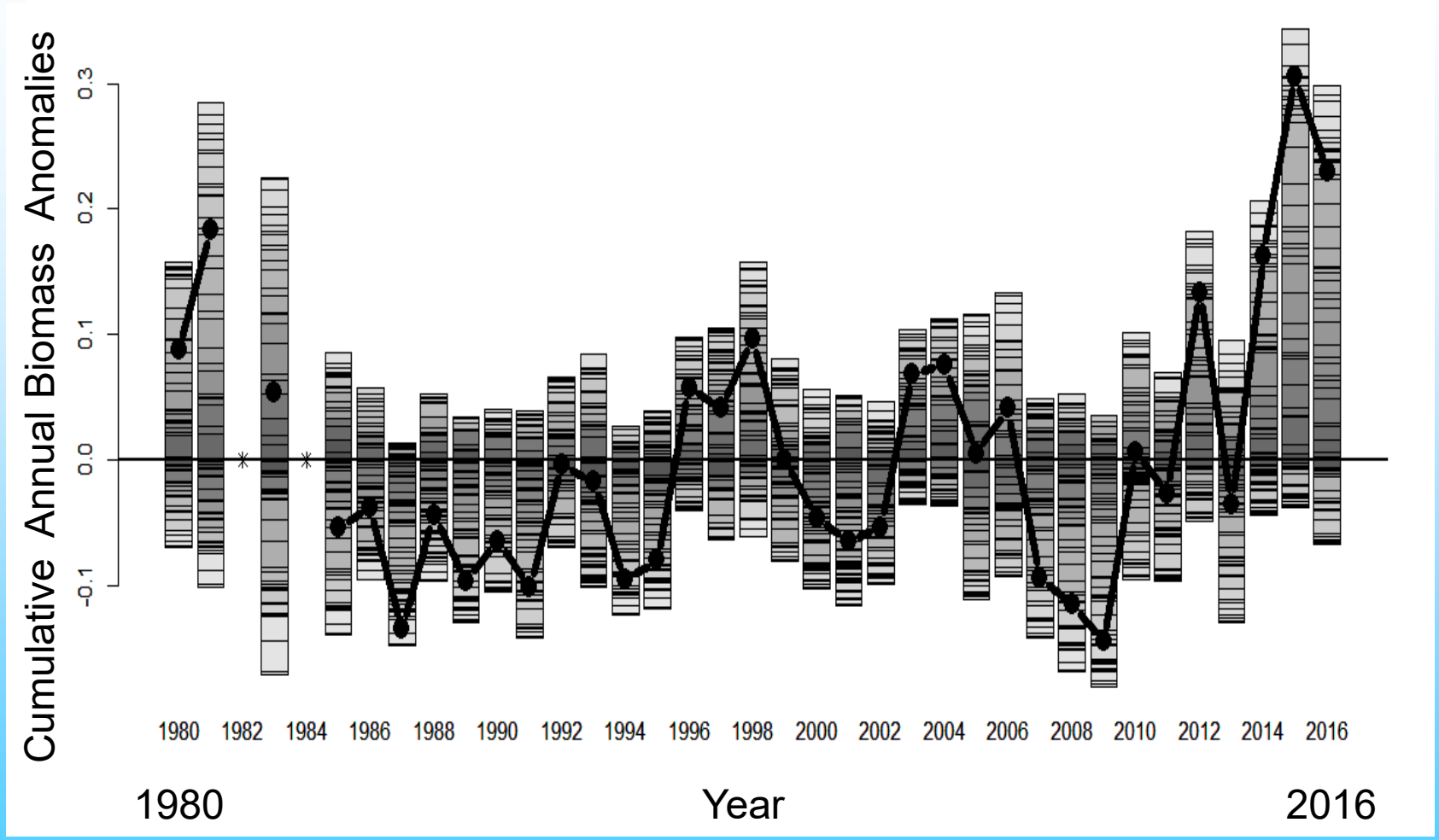
Results: Redundancy Analysis

Multiple step-wise regression selected Buoy SST and NPGO as minimum driver variables which explain response variables

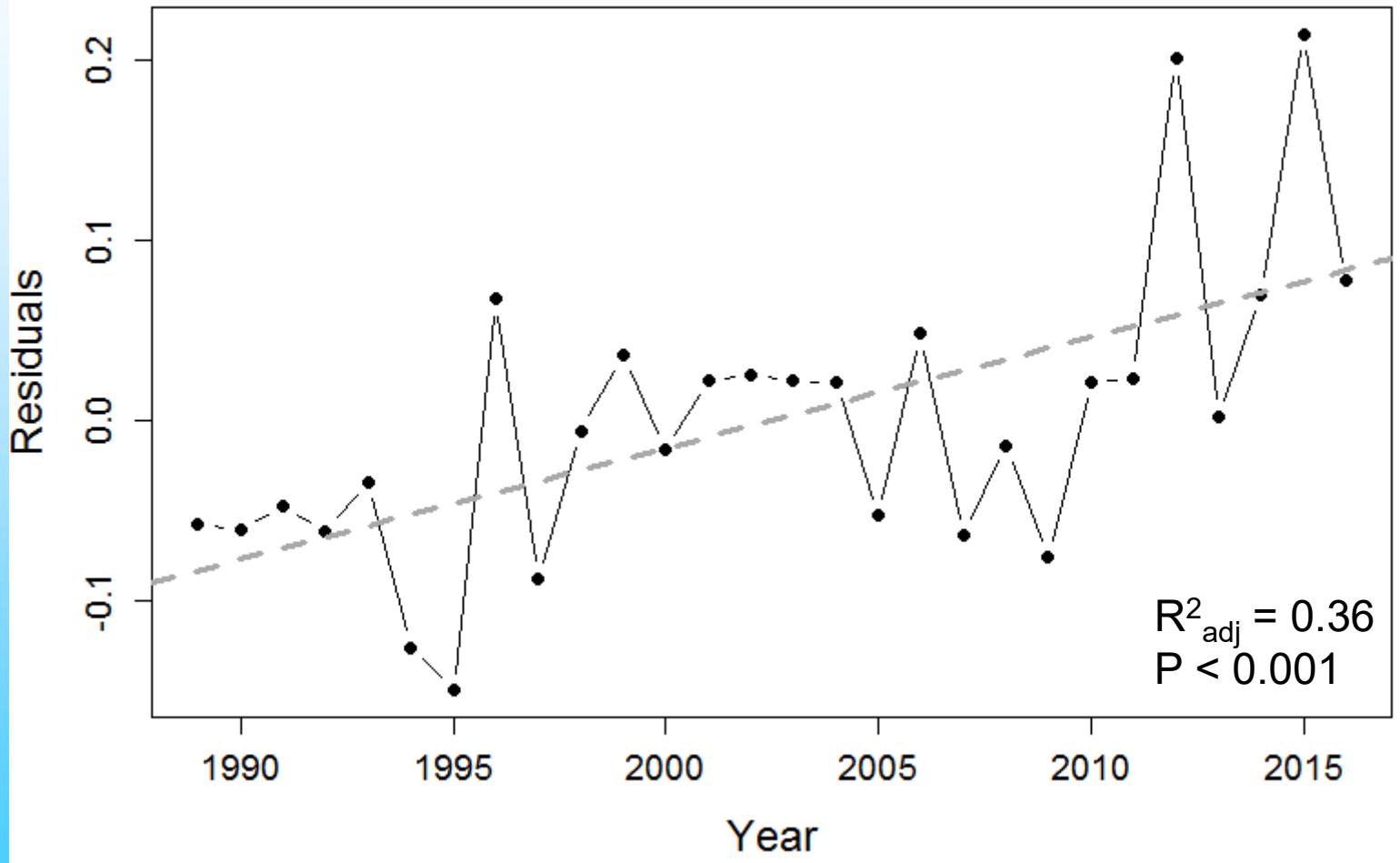


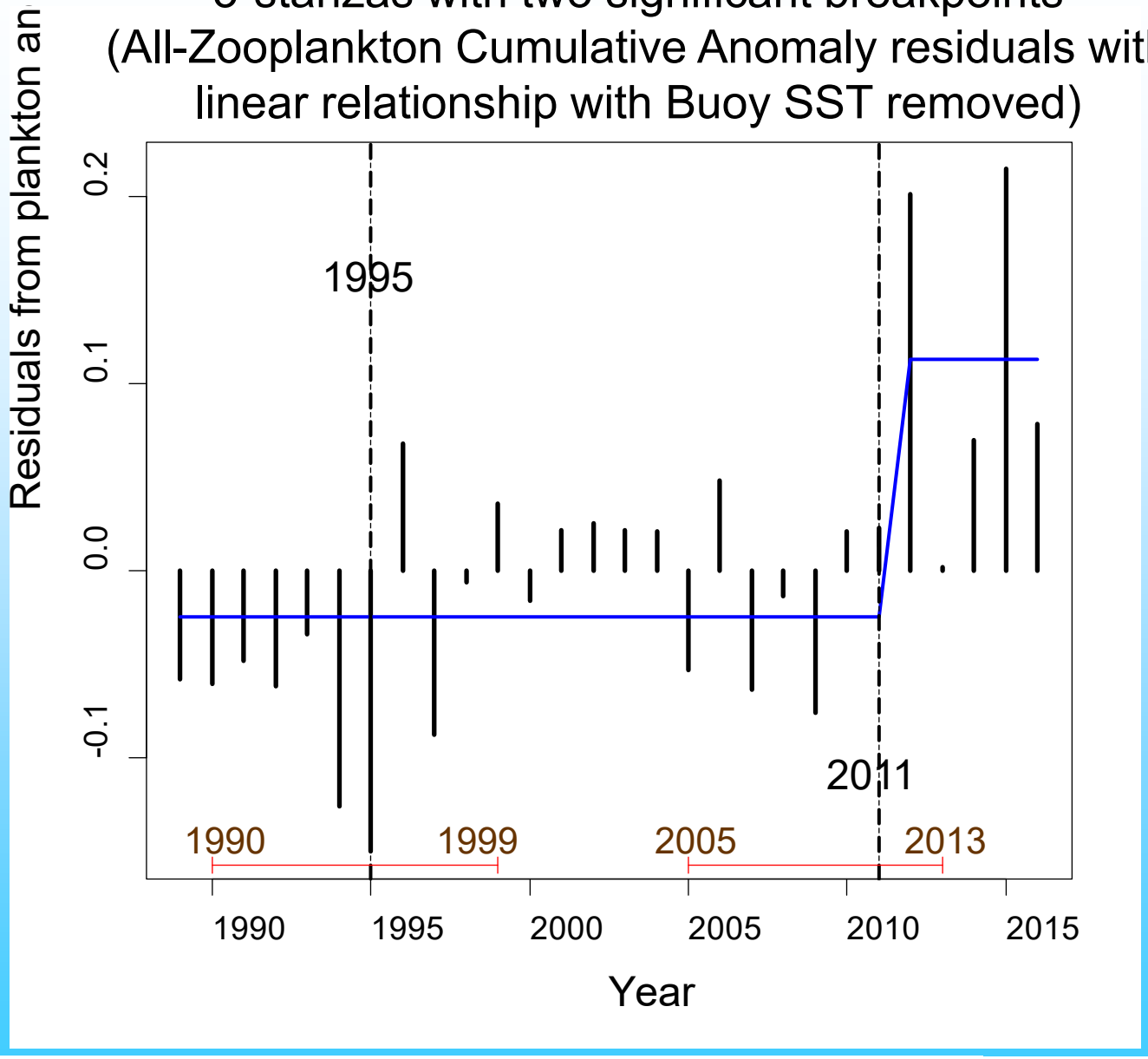
Southern West Coast Vancouver Island continental shelf

Stacked bar plot of annual anomalies of All Zooplankton



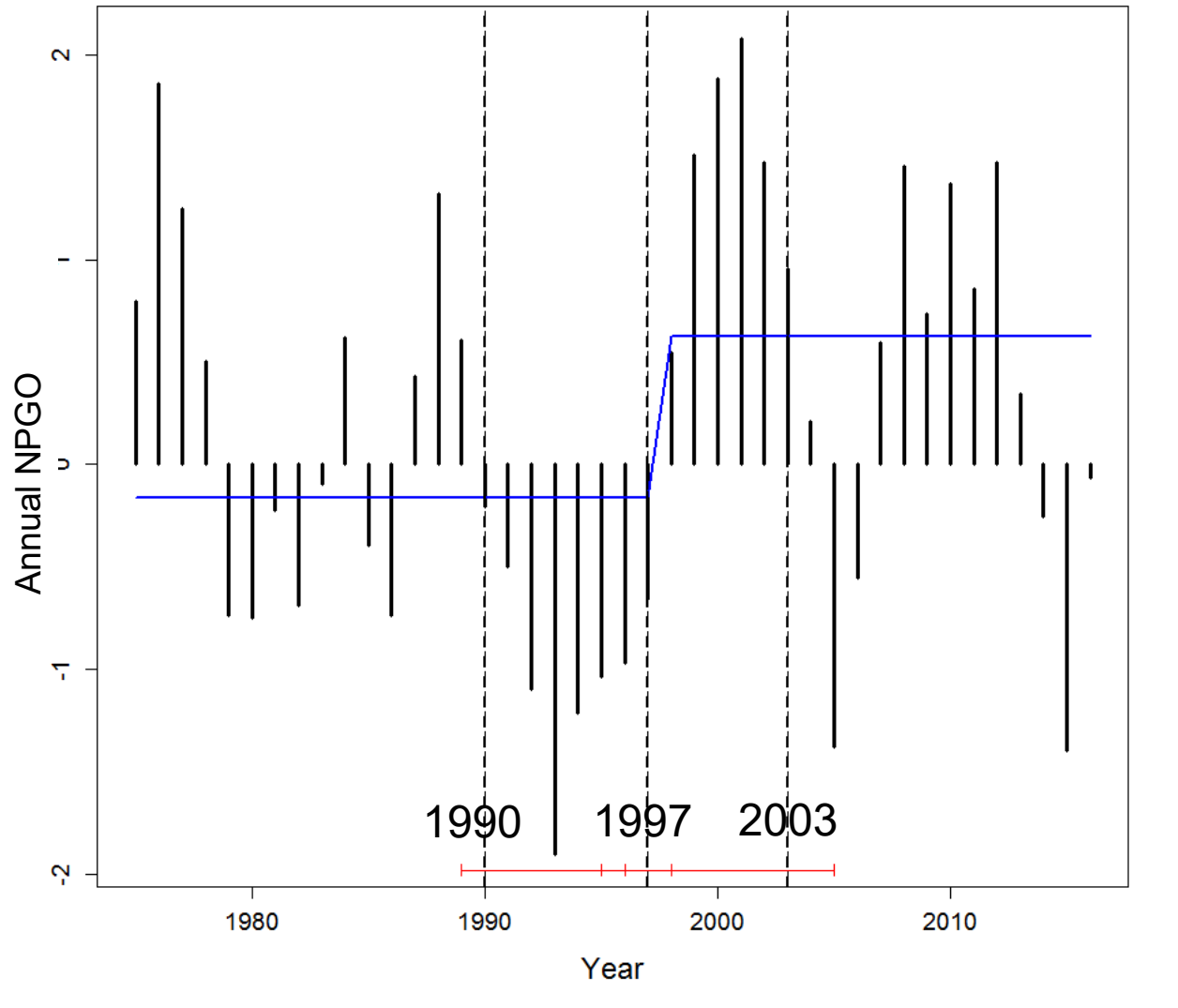
Significant positive trend over time of All Zooplankton Cumulative Anomaly residuals when relationship with Buoy SST is removed



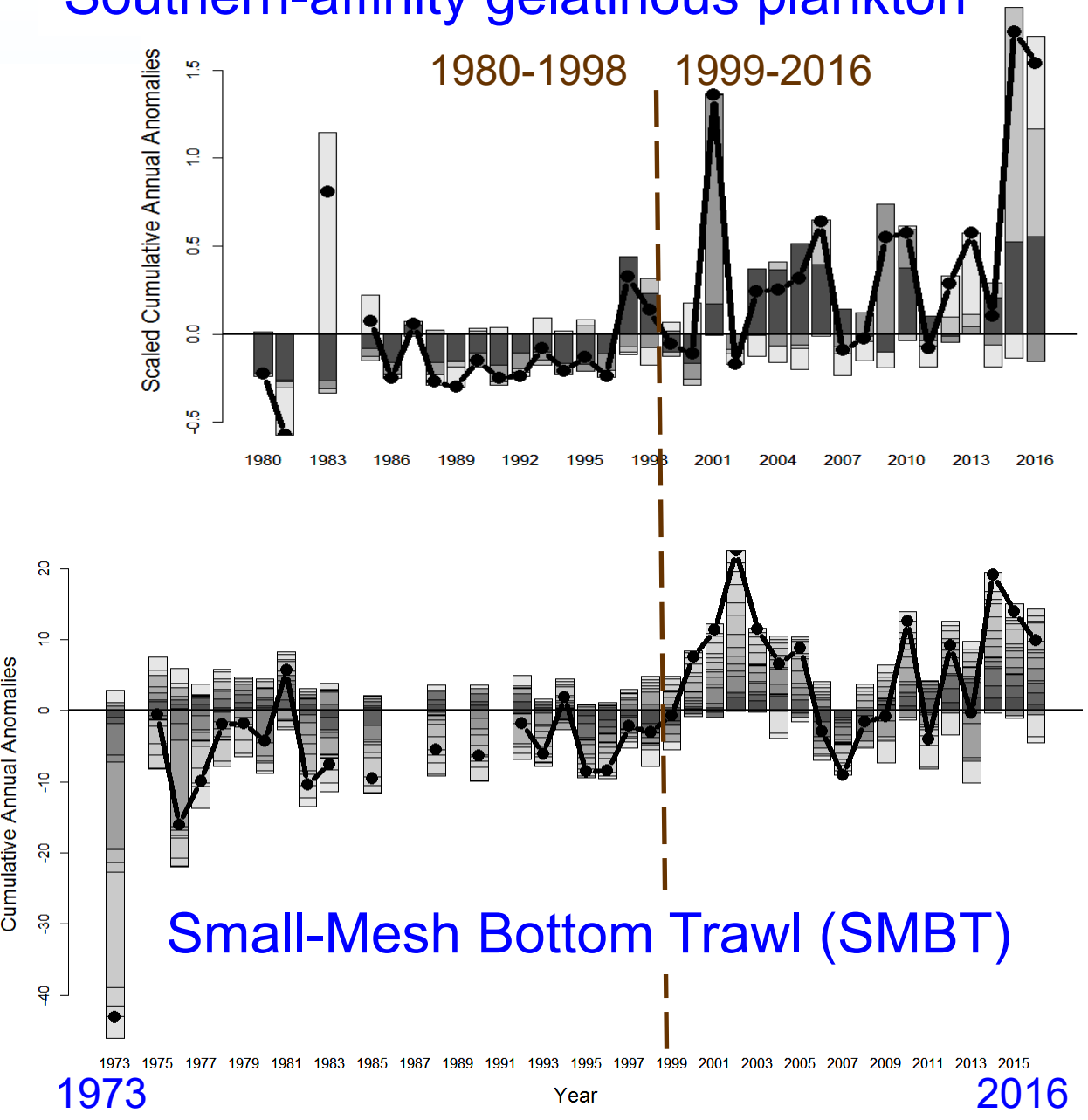

3-stanzas with two significant breakpoints
(All-Zooplankton Cumulative Anomaly residuals with
linear relationship with Buoy SST removed)
Residuals from plankton an
0.2
0.1
0.0
-0.1
1995
2011
1990
1999
2005
2013
1990
1995
2000
2005
2010
2015
Year

NPGO reflects changes in the North Pacific Gyre circulation and influences upwelling and nutrient inputs to upper layers.

Significant change at 1997 for NPGO



Southern-affinity gelatinous plankton

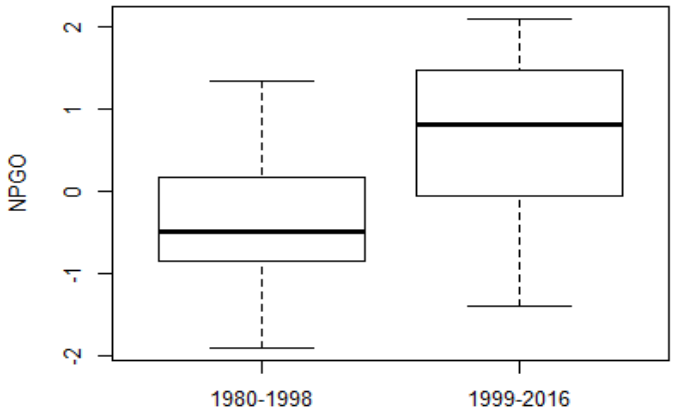


Clio spp.,
Dolioletta gegenbauri,
Oikopleura longicauda,
Aglaura hemistoma,
Salps

16 species: Eulachon, Walleye Pollock, Darkblotch Rockfish, Pacific Cod, Sablefish, Lingcod, Arrowtooth Flounder, Pacific Halibut, Dover Sole, Pacific Sanddab, Petrale Sole, Rex Sole, Flathead Sole, Slender Sole, Smooth Pink Shrimp

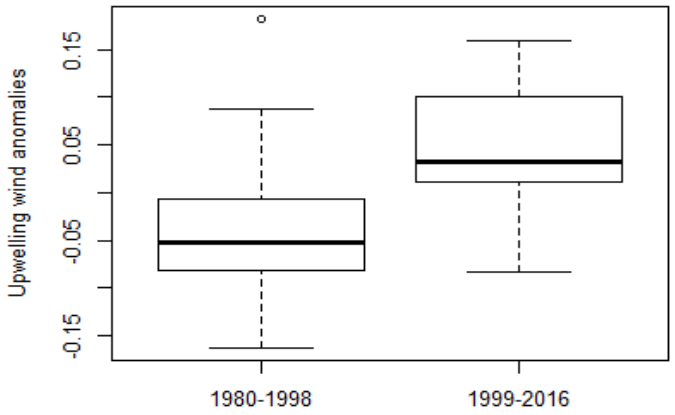
Comparisons before and after 1998

NPGO



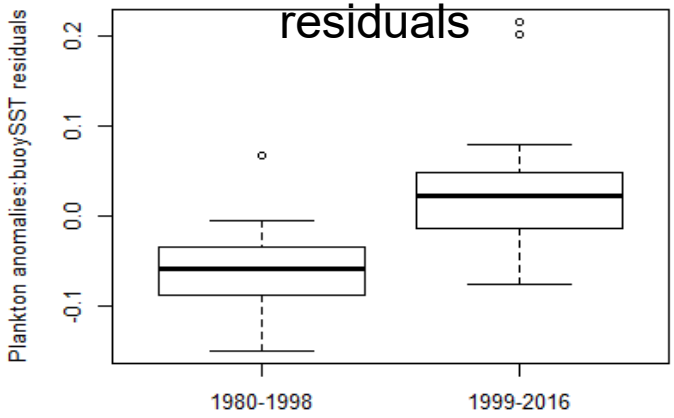
1980-1998 1999-2016

Upwelling anomalies



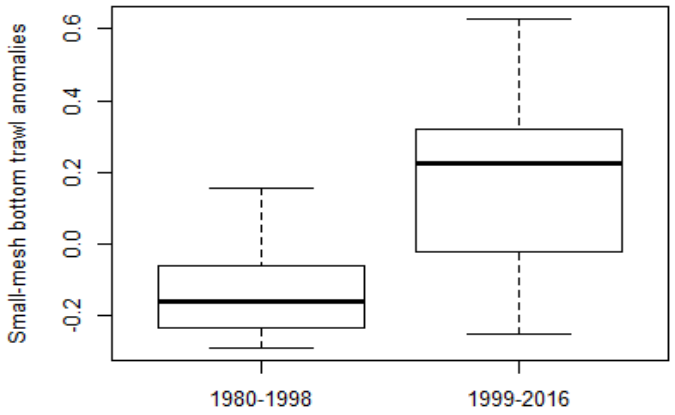
1980-1998 1999-2016

Plankton anomalies:BuoySST residuals



1980-1998 1999-2016

Bottom trawl anomalies



1980-1998 1999-2016

Taxa significantly related to temperature (linear regression):

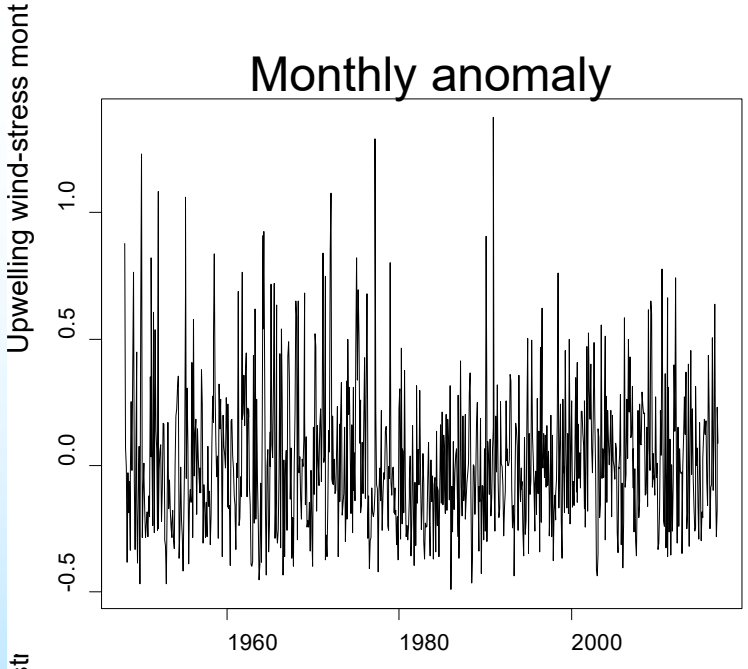
Dependent variable	Independent variable	R^2_{adj}	P-value
Northern copepods	Buoy SST	0.36	< 0.001
Southern copepods	Buoy SST	0.58	< 0.001
Northern gelatinous	Buoy SST	0.42	< 0.001
Southern gelatinous	Buoy SST	0.04	0.16

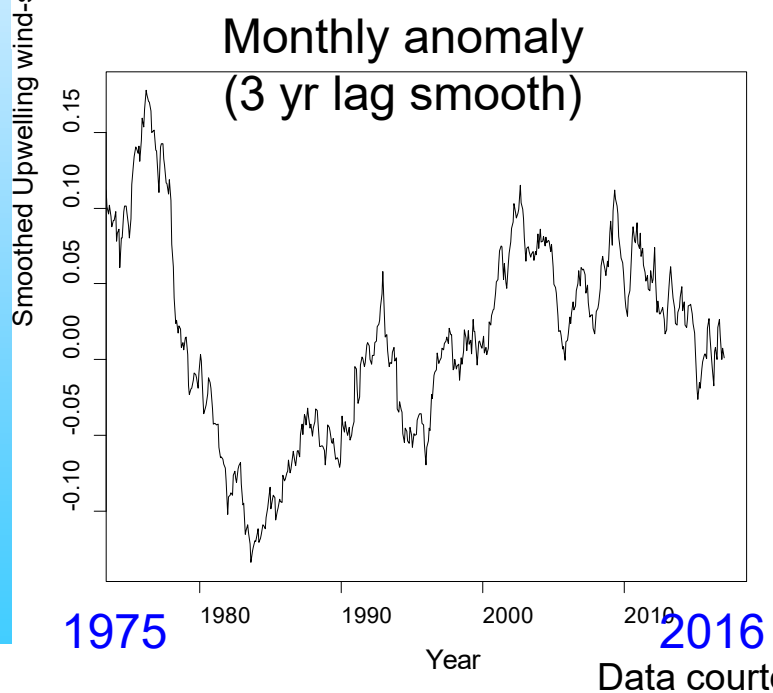
Variables significantly different pre- and post-1999 (ANOVA):

- North Pacific Gyre Oscillation Index (NPGO)
- Upwelling-favourable wind stress
- Southern gelatinous plankton
- Small-mesh bottom trawl survey taxa
- Residuals from linear regression of all zooplankton groups Cumulative Anomaly Index vs Buoy SST

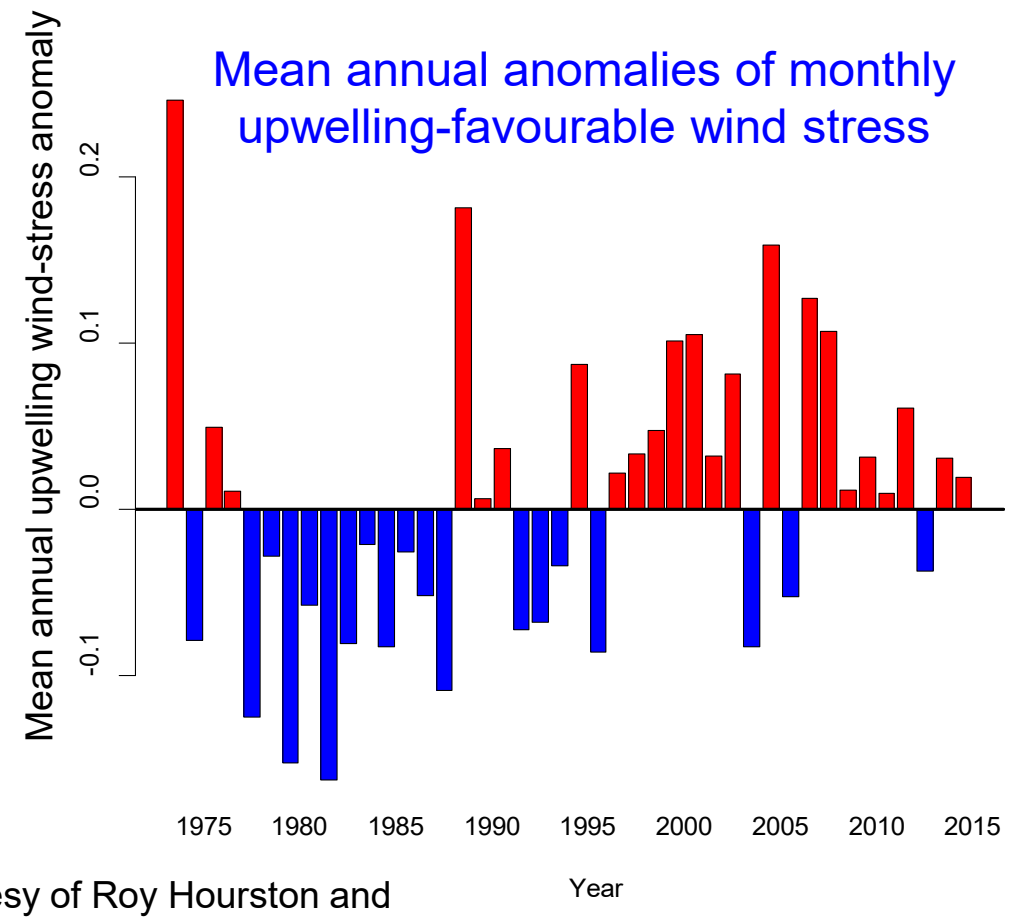
NPGO effect via influence on Upwelling?

Along-shore upwelling-favourable (335°T) wind stress anomalies, averaged between 49° and 50° N.
(Units are N m^{-2} day)





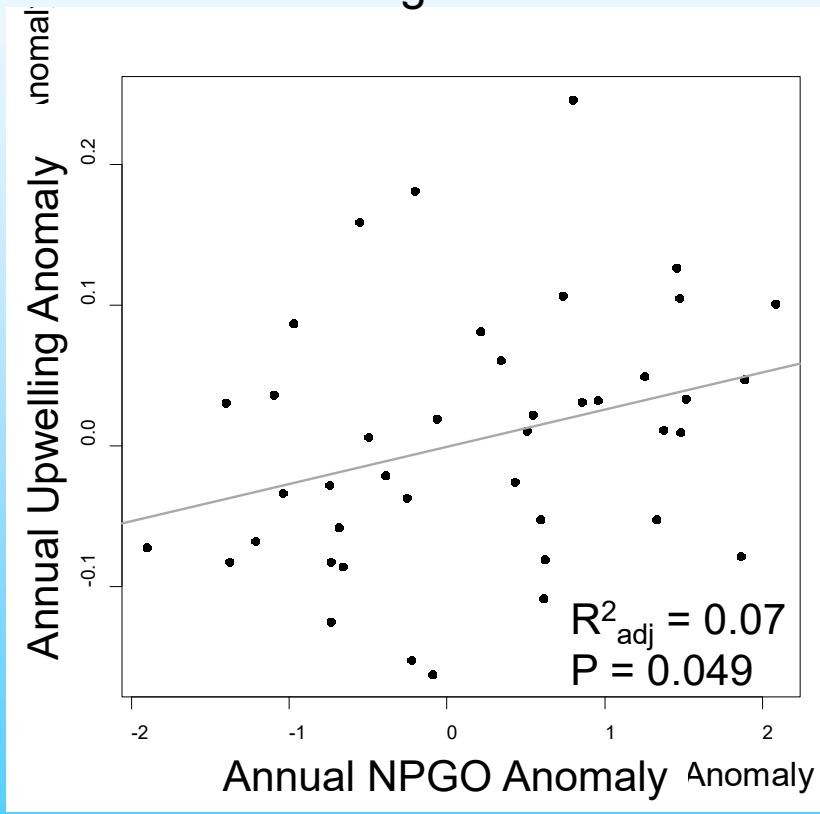
1975 2016



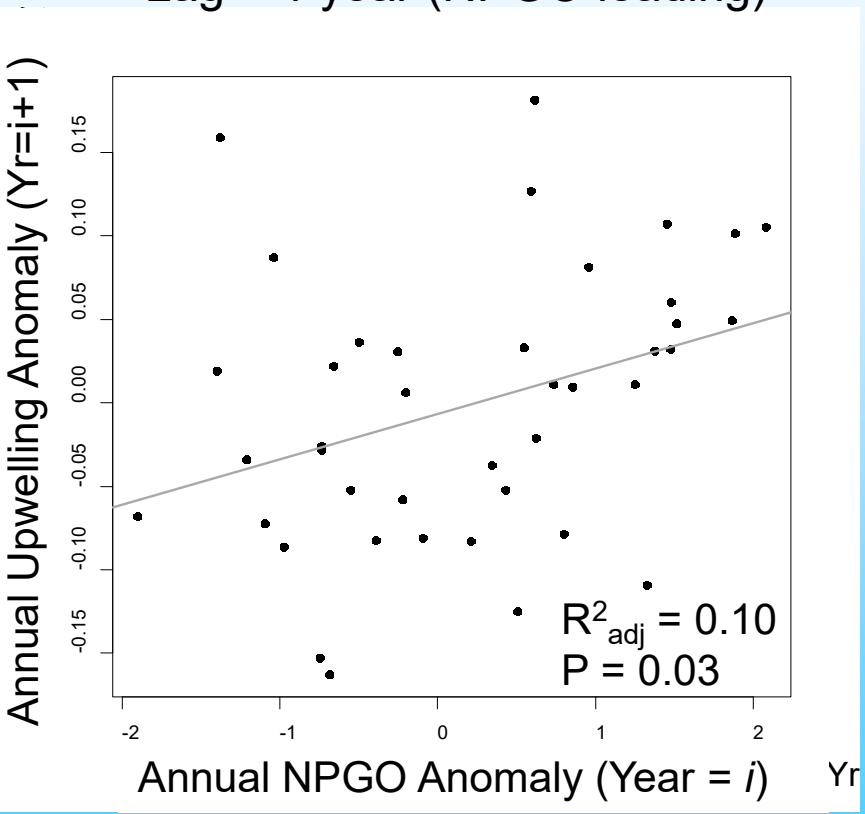
Data courtesy of Roy Hourston and Rick Thomson, IOS

Relationship between NPGO and Upwelling-favourable wind stress

Lag = 0



Lag = 1 year (NPGO leading)



Summary

1. Decadal and long term patterns of zooplankton and bottom fish and invertebrate populations on the continental shelf off southern Vancouver Island are forced by:
   - Interannual variability of sea temperature (largely related to El Niño processes)
   - Decadal-scale trends possibly related to atmospheric circulation patterns (represented by NPGO) and their influence on coastal upwelling
2. Changes in species composition driven by these processes are likely to influence the variability of important fish populations such as salmon;
3. Next steps: examine chlorophyll and nutrient data for evidence of enhanced upwelling.