The pelagic plankton and demersal fish communities of Pacific Canada over the past four decades: ecosystem variability or change?

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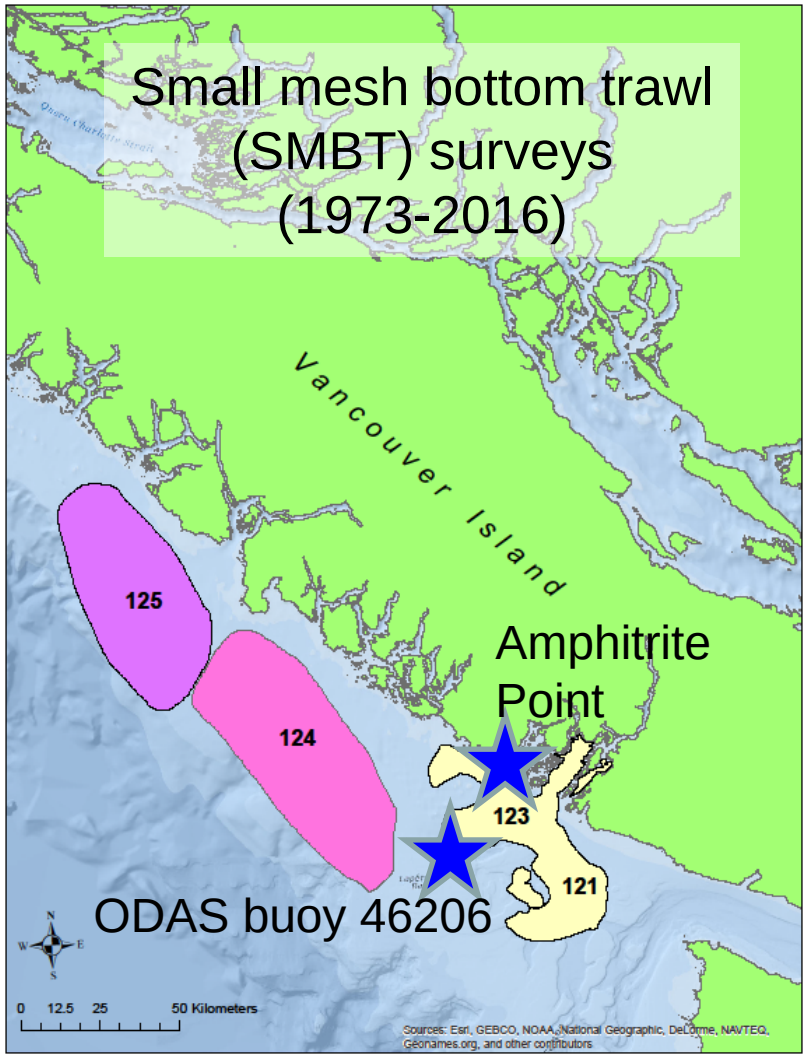
Context and Motivation

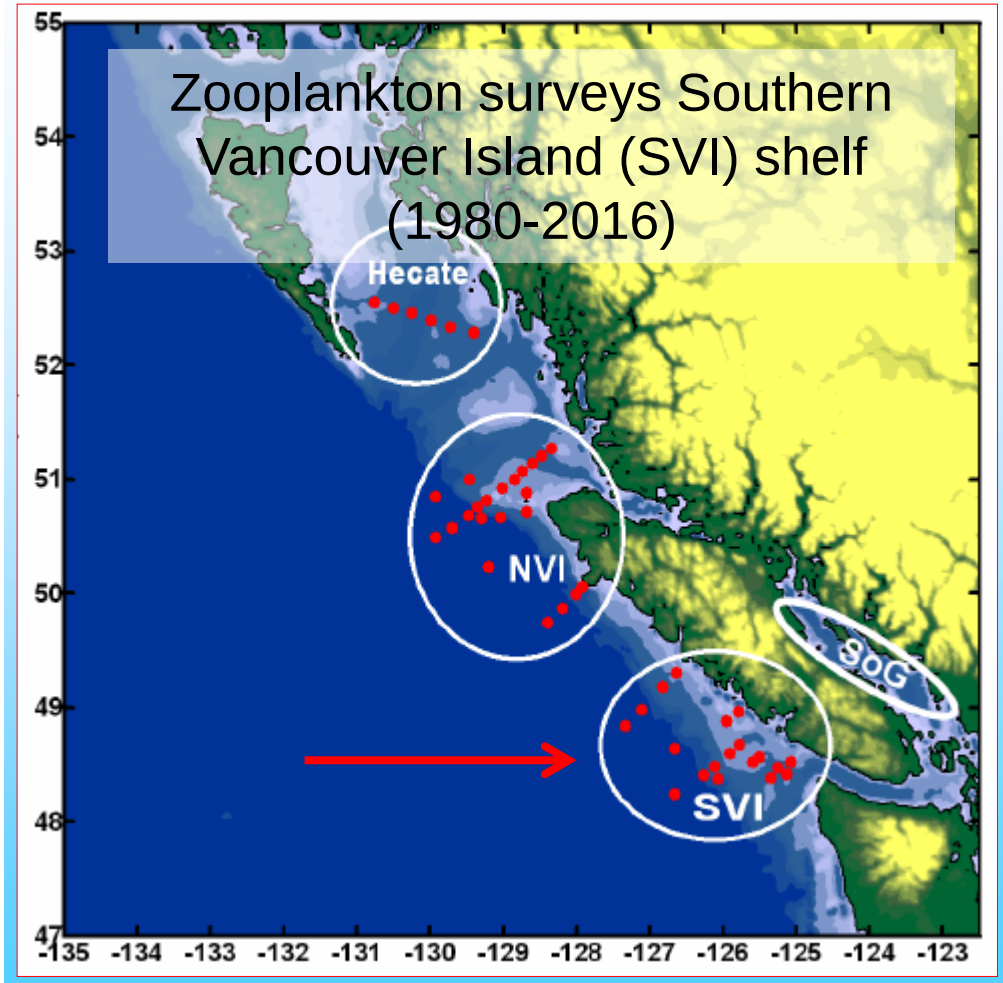
- Potential for changes in ecosystem productivity with changes in climate
- Availability of ‘long’ biological data sets (some >40 years)
- FUTURE goal of understanding natural and anthropogenic drivers of change on regional marine ecosystems

Objectives

- What has been the pattern of change in physical variables, pelagic biological variables, and demersal biological variables off southwest coast of Vancouver Island over past 40 years?
- Can we begin to determine which of natural (climate) or anthropogenic (human) drivers-of-change are more ‘influential’ to these changes?
- What might this understanding say about future directions of change in these regional marine ecosystems, and management options?

The Data: Locations (southwest coast Vancouver Island)



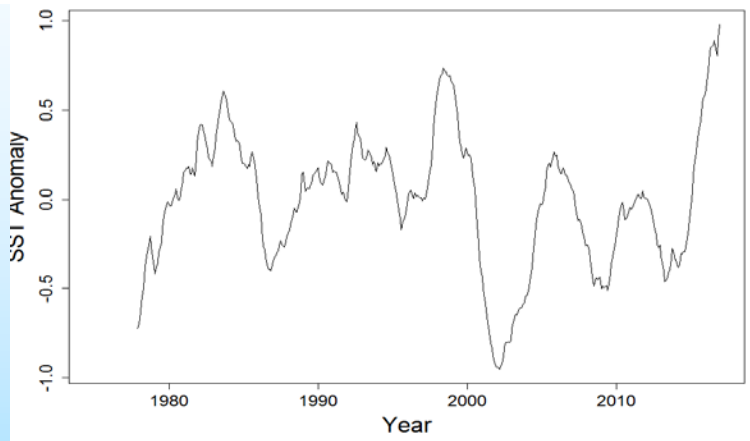


The Data: Time series variables

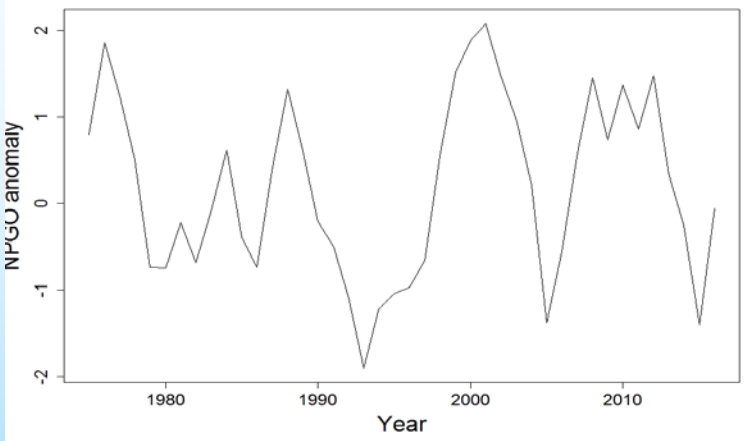
Physical (Driver) variables	Multivariate ENSO Index (MEI) Pacific Decadal Oscillation (PDO) North Pacific Gyre Oscillation index (NPGO) Amphitrite Point Sea Surface Temperature (AmphiSST) Upwelling index (49° - 50° N) (Upwell) ODAS Buoy 46206 SST (buoySST) ODAS Buoy 46206 Atmospheric Pressure at Sea Surface (buoyAtmP)
Human (Driver) variable	Catches of commercial species (BC coastwide, species selected to match those caught in Small-mesh bottom trawl survey off Vancouver Island) (SAUP.catch) (Source: Sea Around Us Project, UBC)
Biological (Response) variables	Northern-affinity copepods Southern-affinity copepods Subarctic oceanic-affinity copepods Euphausiids Amphipods Northern-affinity gelatinous plankton Southern-affinity gelatinous plankton Small-mesh bottom trawl survey

The Data: Physical variables

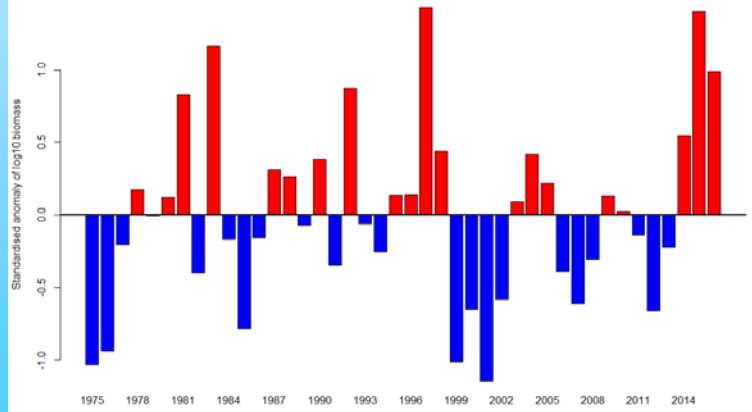
Amphitrite SST monthly anomalies



NPGO annual anomalies

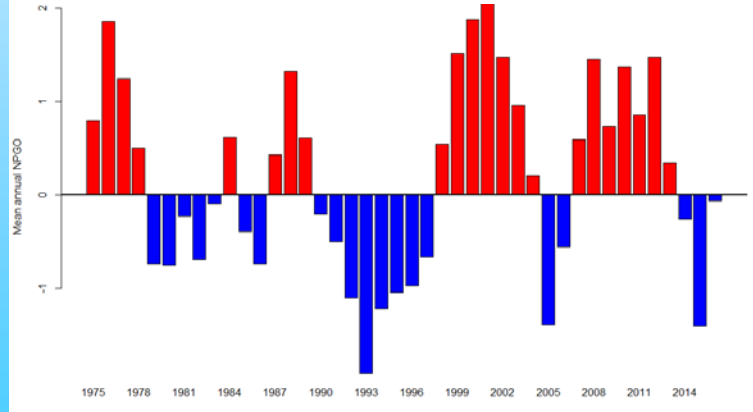


Amphitrite SST annual anomalies



1975 YEAR 2016

NPGO annual anomalies



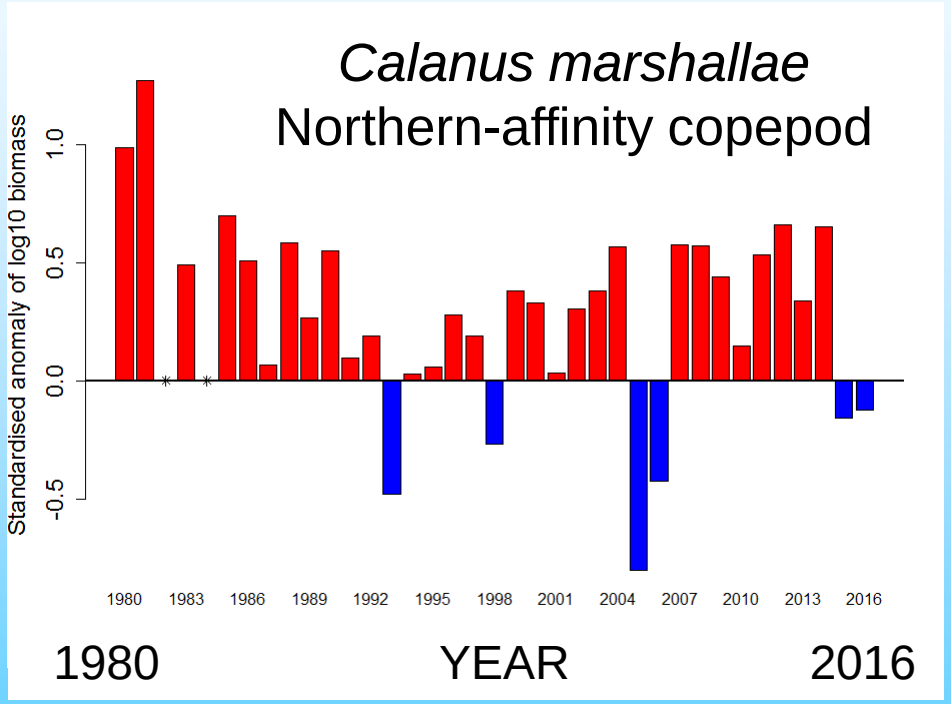
1975 YEAR 2016

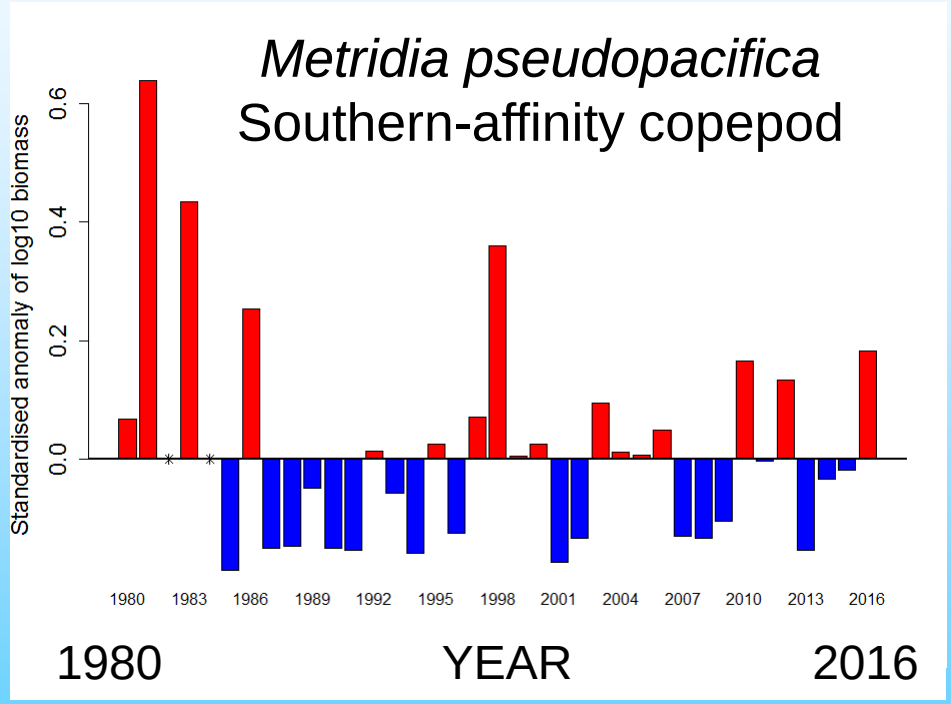
The Data: Biological Pelagic taxa

Northern shelf copepods	*Calanus marshallae, Pseudocalanus mimus, Acartia longiremis, A. hudsonica*
Southern shelf copepods	*Acartia tonsa, Paracalanus parvus, Paracalanus quasimodo, Ctenocalanus vanus, Mesocalanus tenuicornis, Clausoscalanus spp., Calocalanus spp., Metridia pseudopacifica*
Subarctic oceanic copepods	*Neocalanus plumchrus, N. cristatus, N. flemingeri, Eucalanus bungii, Metridia pacifica*
Euphausiids	*Euphausia pacifica, Thysanoessa spinifera*
Amphipods	*Primno* spp., *Themisto* spp.
Northern Gelatinous	*Oikopleura dioeca, Oikopleura labradorensis, Limacina helicina, Aglantha digitale*
Southern Gelatinous	*Clio* spp., *Dolioletta gegenbauri*, *Oikopleura longicauda, Aglaura hemistoma*, Salps

The Data: Biological Pelagic Taxa

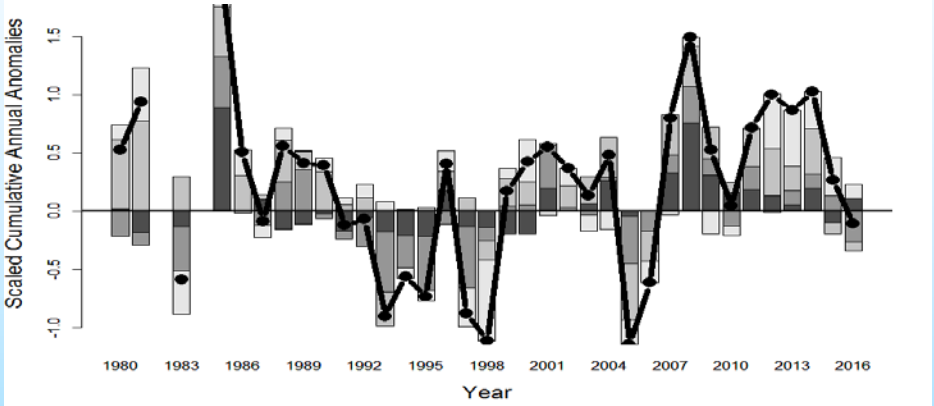
Standardised annual anomalies of log10 biomass





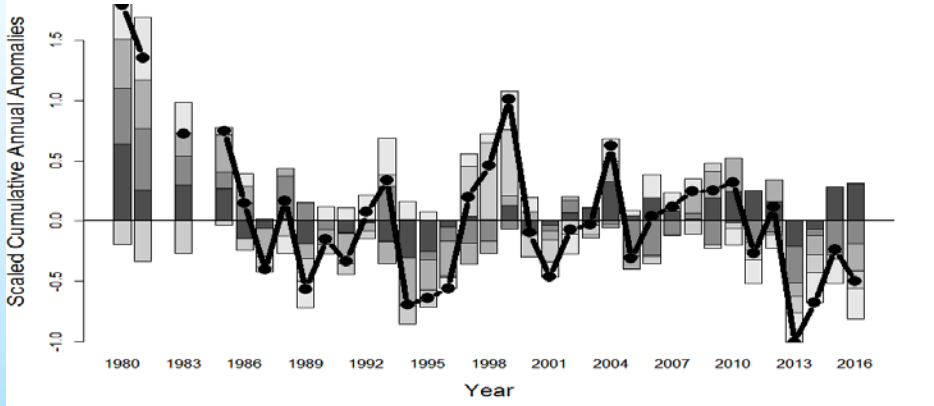
The Data: Biological Pelagic Cumulative Anomaly Index

Copepods: Northern-affinity



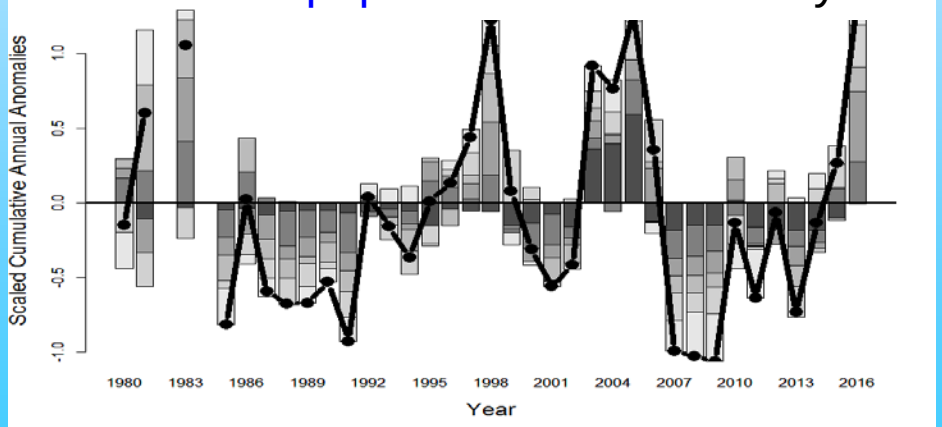
1980 2016

Copepods: Subarctic oceanic-affinity

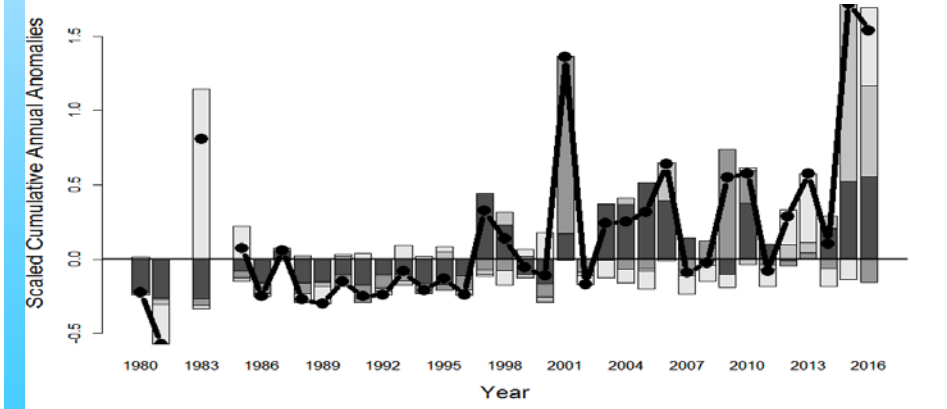


1980 2016

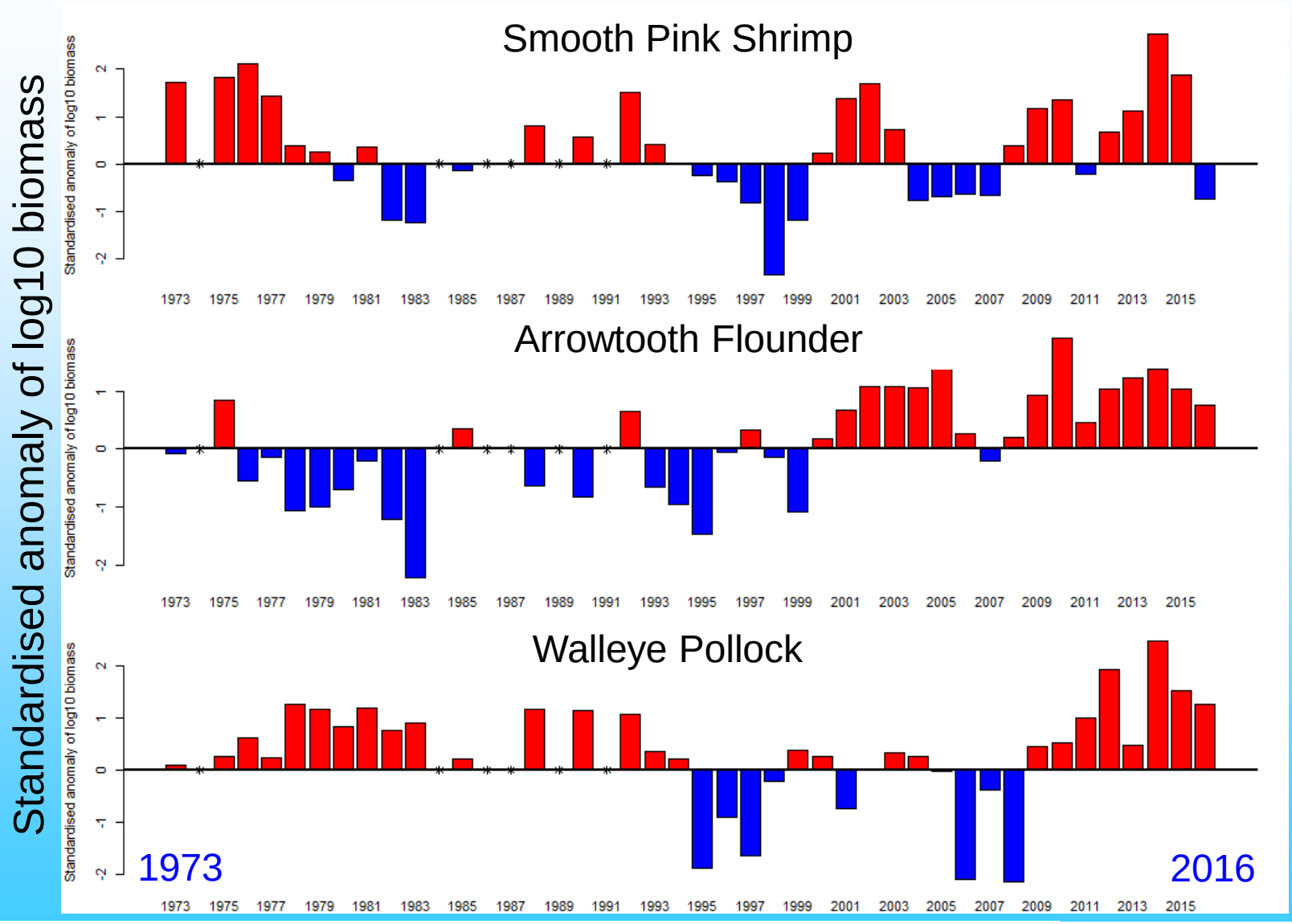
Copepods: Southern-affinity



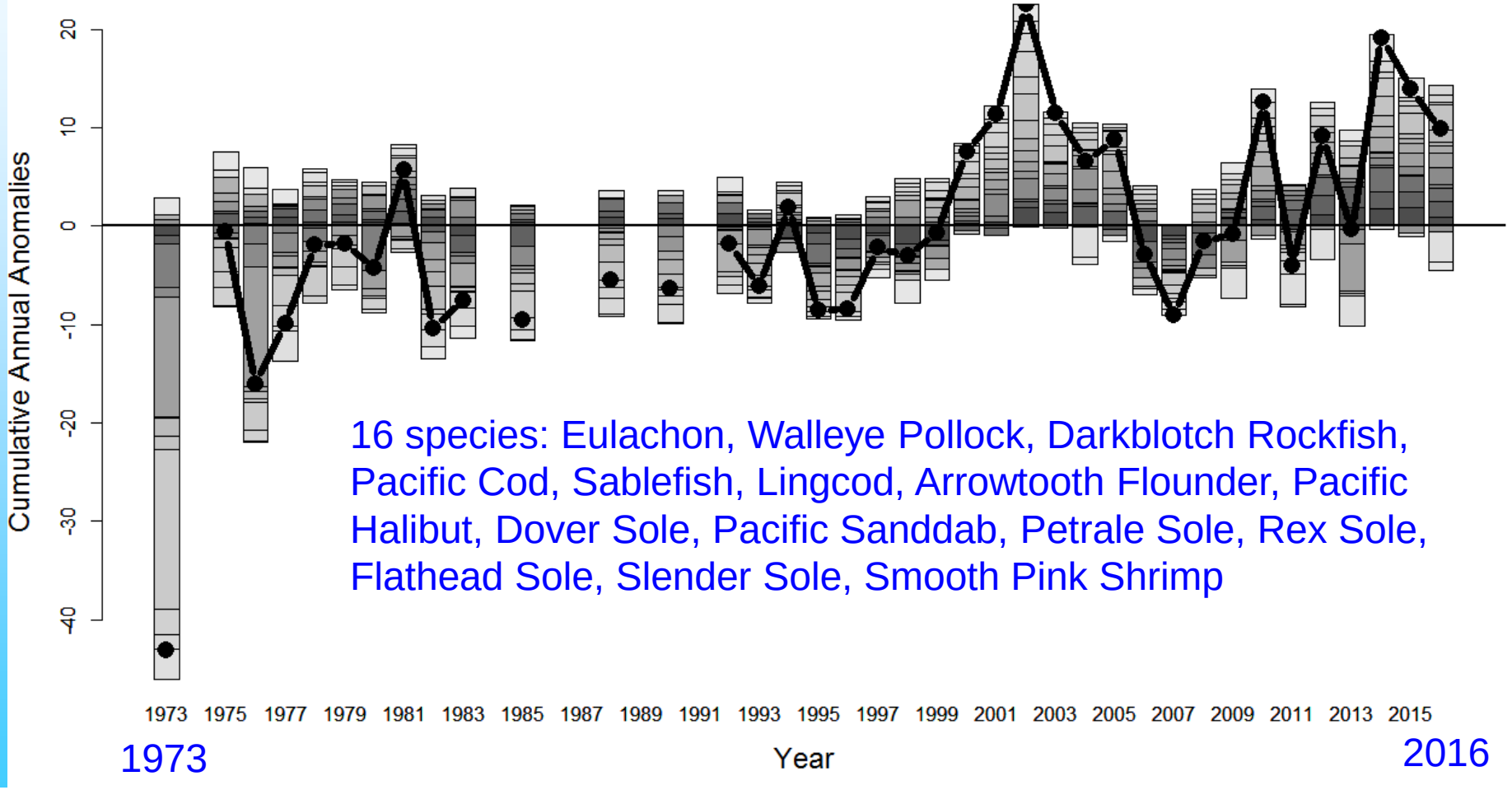
Gelatinous: Southern-affinity



The Data: Biological Demersal: Small-mesh bottom trawl

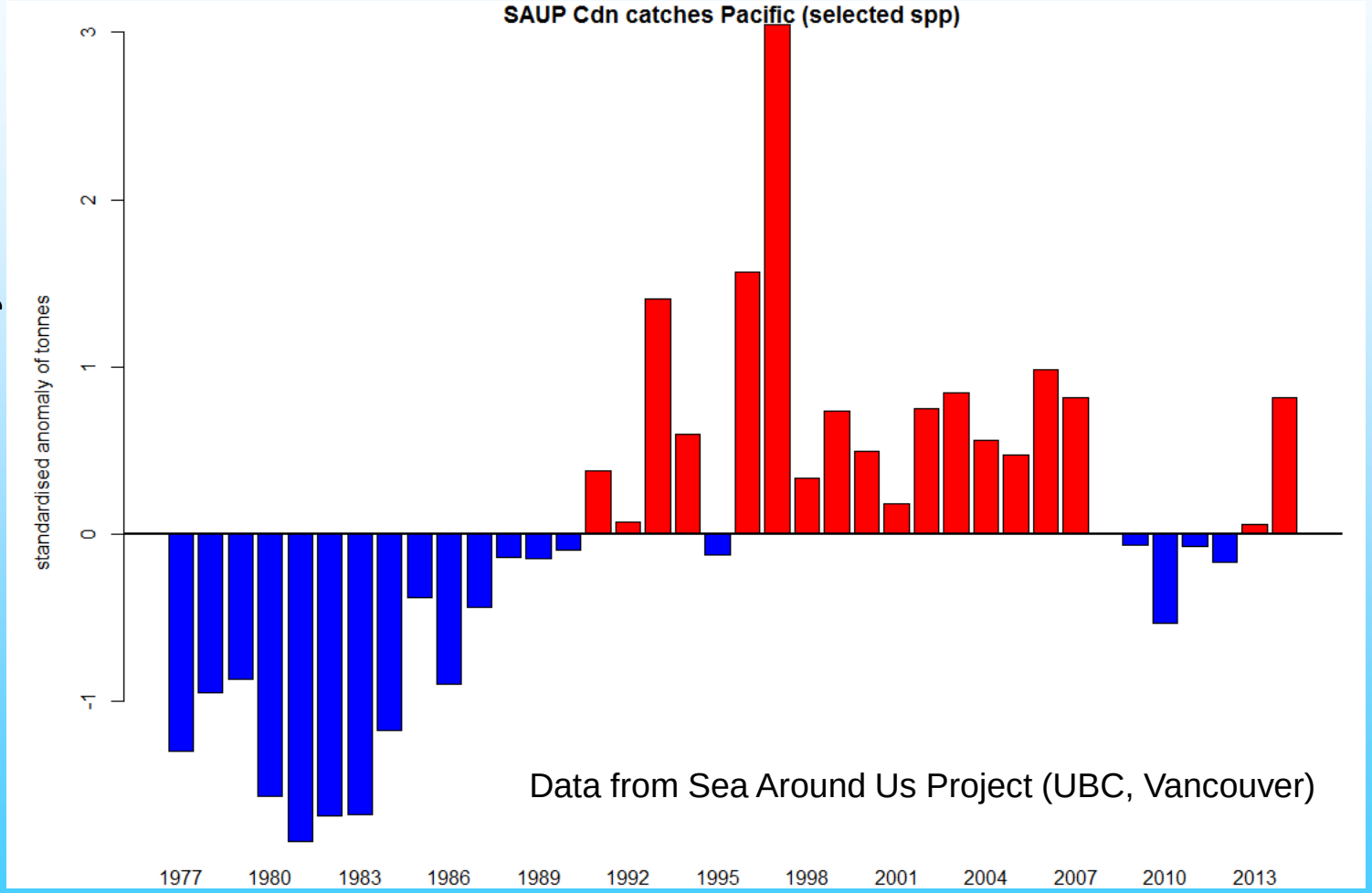


The Data: Biological Demersal (SMBT) Cumulative Anomaly Index



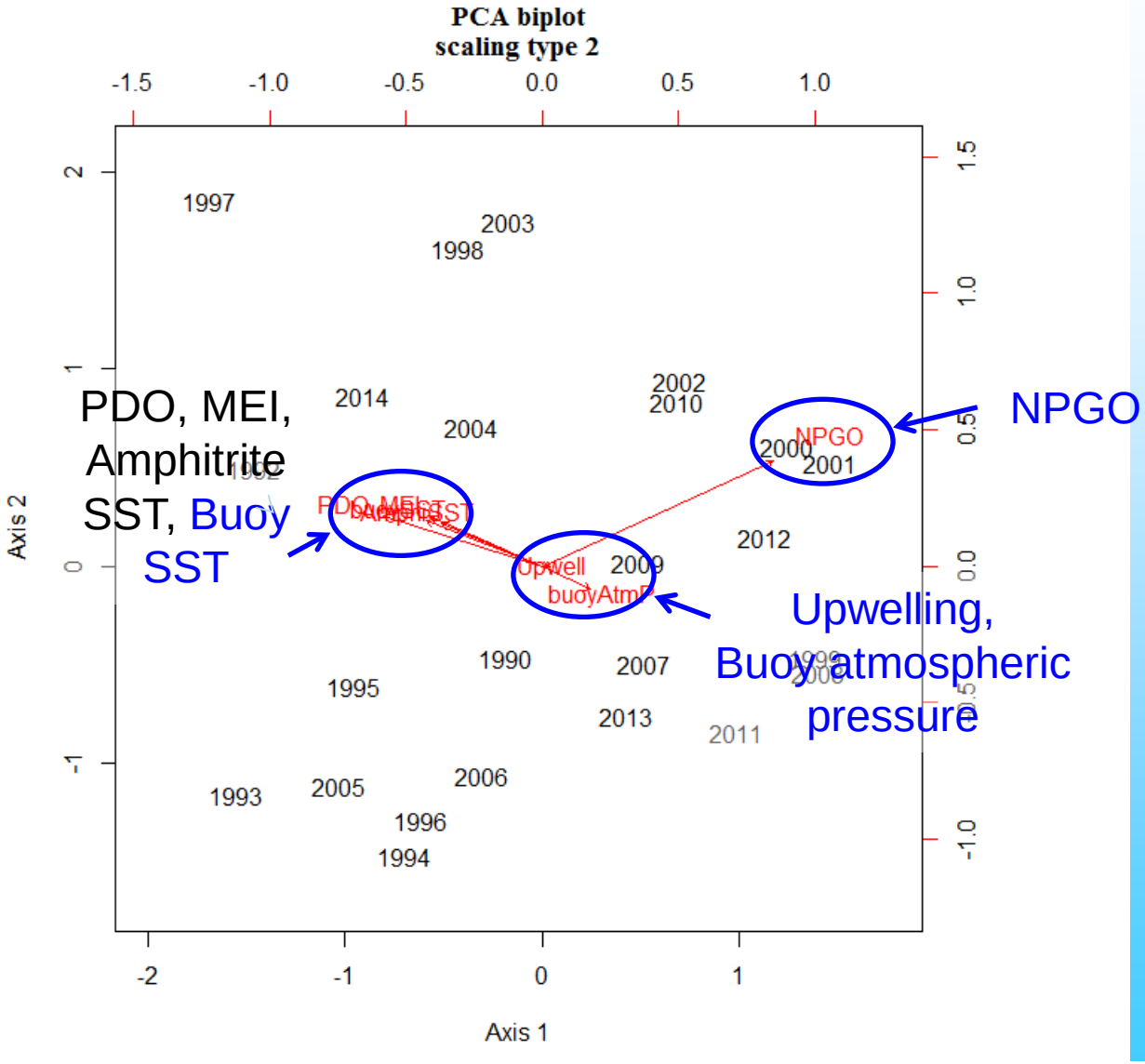
The Data: Human Driver: Canadian Pacific Catch (same species as with SMBT data)

Standardised anomaly of biomass

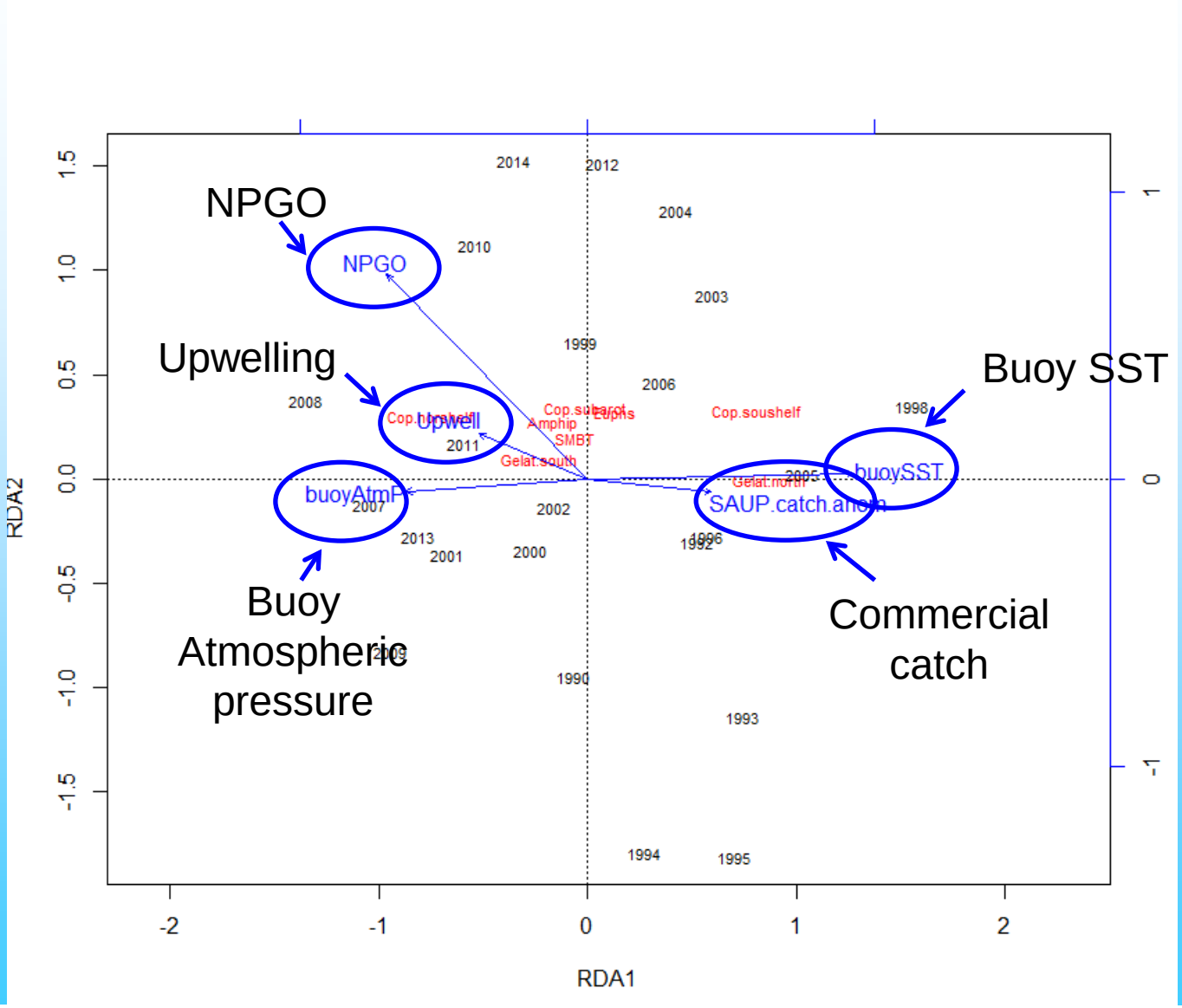


1977 2014

Results: Principal Components Analysis of Driver Variables

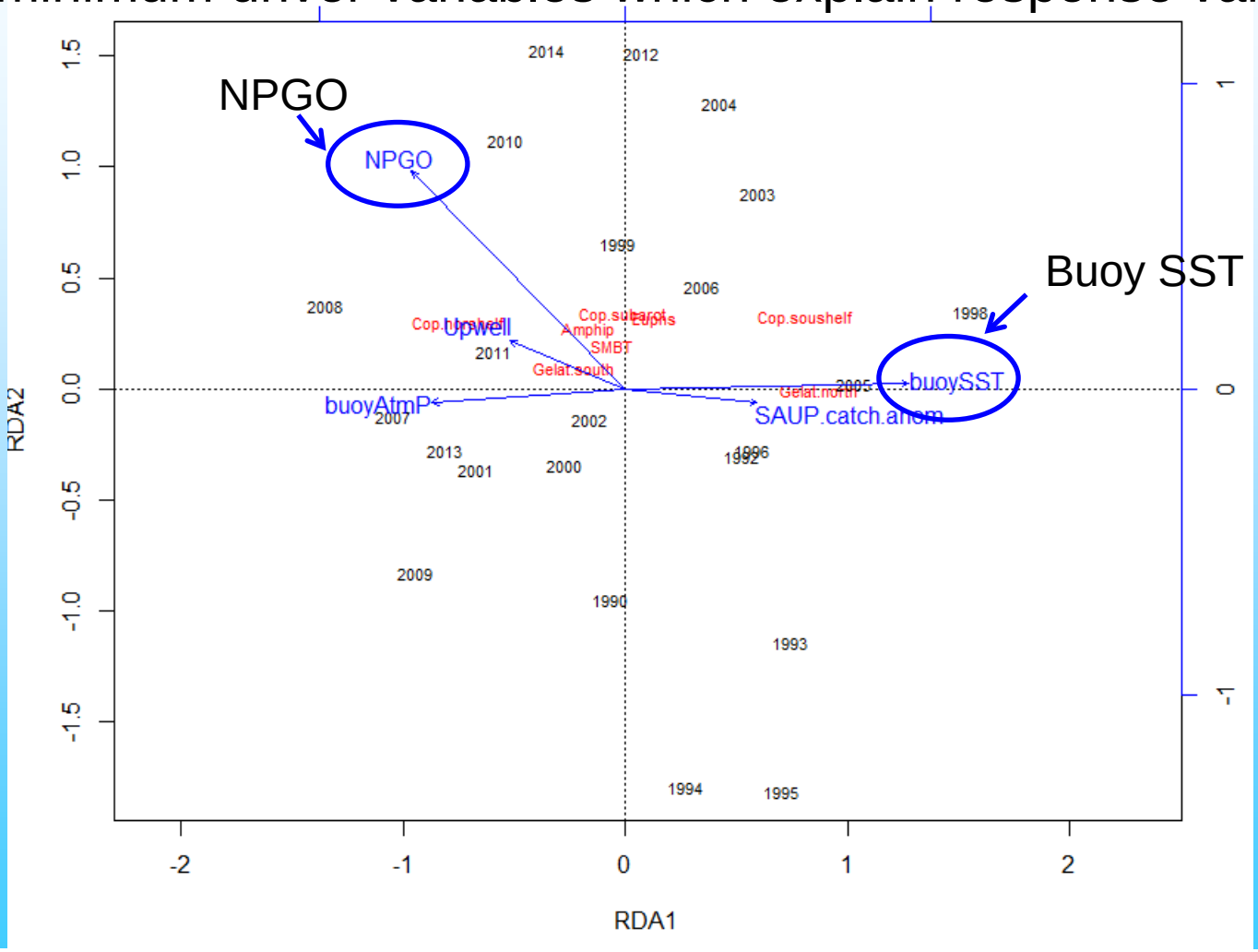


Results: Redundancy Analysis



Results: Redundancy Analysis

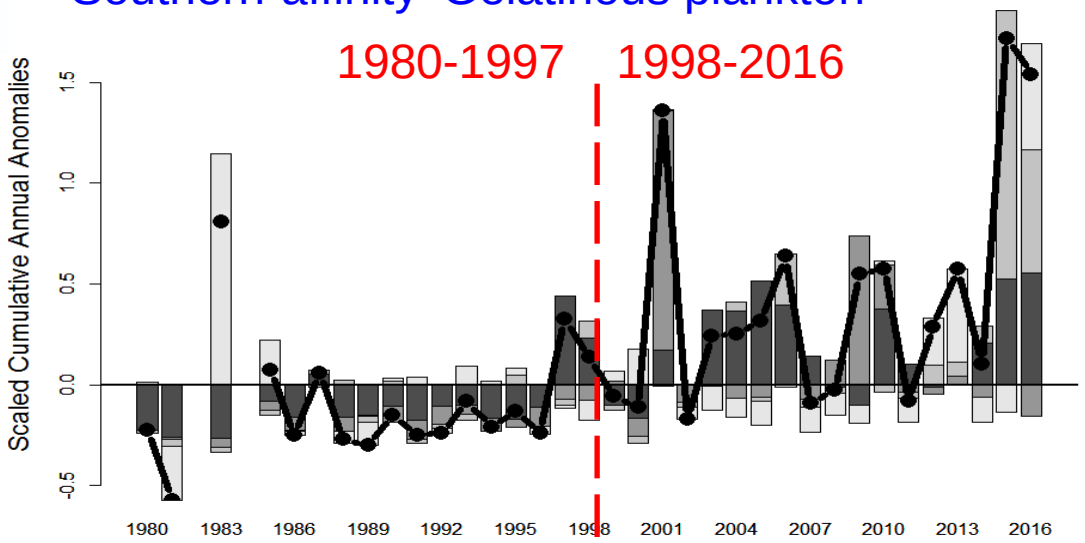
Multiple step-wise regression selected Buoy SST and NPGO as minimum driver variables which explain response variables

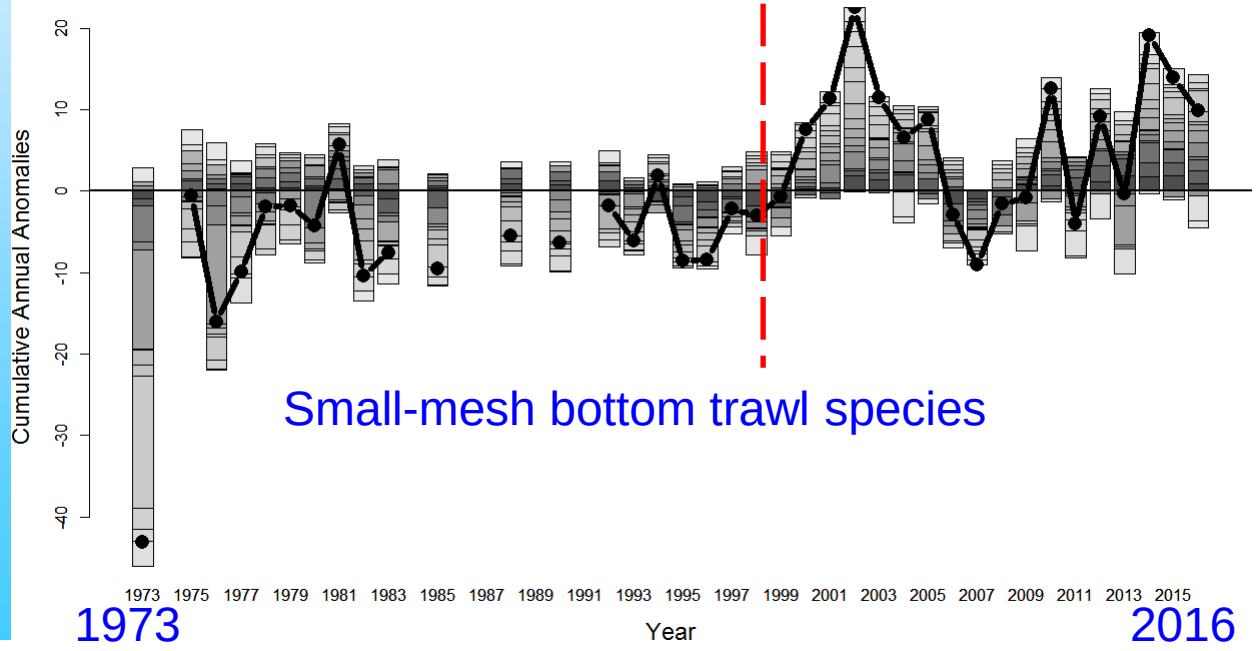


Results: Trend or variability? (max time series 1973-2016)

Physical (Driver) variables	Multivariate ENSO Index (MEI)	Variability
	Pacific Decadal Oscillation (PDO)	Variability
	North Pacific Gyre Oscillation index	Variability
	Upwelling index (49° - 50° N)	Variability
	Amphitrite Point Sea Surface Temperature	Variability
	ODAS Buoy 46206 SST	Variability
	ODAS Buoy 46206 Atmospheric Pressure	Variability
Human (Driver) variable	Catches of commercial species (BC coastwide, selected species)	Trend
Biological (Response) variables	Northern-affinity copepods	Variability
	Southern-affinity copepods	Variability
	Subarctic oceanic-affinity copepods	Trend (negative)
	Euphausiids	Trend
	Amphipods	Trend
	Northern-affinity gelatinous plankton	Variability
	Southern-affinity gelatinous plankton	Trend
	Small-mesh bottom trawl survey	Trend

‘Southern-affinity’ Gelatinous plankton





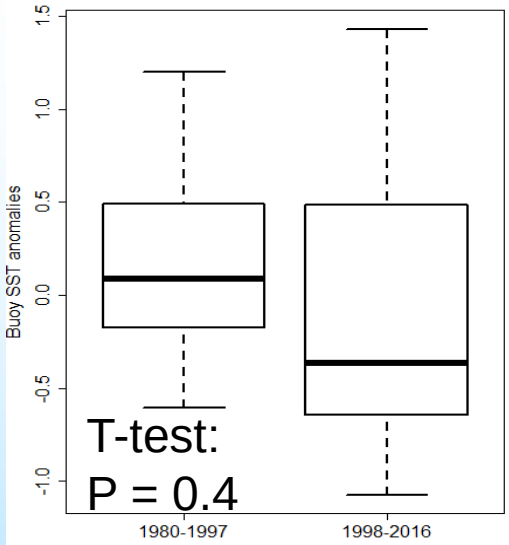
Small-mesh bottom trawl species

1973

2016

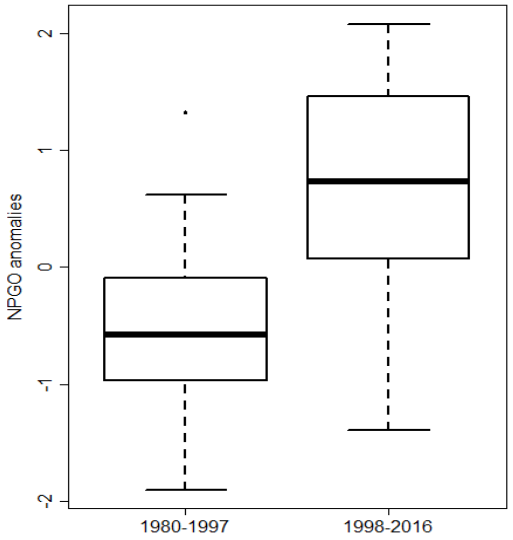
		Regression of variable *vs* year	t-test of means 1980-1997 *vs* 1998-2016
Physical (Driver) variables	Multivariate ENSO Index (MEI)	Variability	0
	Pacific Decadal Oscillation (PDO)	Variability	–
	North Pacific Gyre Oscillation index	Variability	+
	Upwelling index (49° - 50° N)	Variability	+
	Amphitrite Point Sea Surface Temperature	Variability	0
	ODAS Buoy 46206 SST	Variability	0
	ODAS Buoy 46206 Atmospheric Pressure	Variability	0
Human (Driver) variable	Catches of commercial species (BC coastwide, selected species)	Trend	0
Biological (Response) variables	Northern-affinity copepods	Variability	0
	Southern-affinity copepods	Variability	0
	Subarctic oceanic-affinity copepods	Trend (negative)	0
	Euphausiids	Trend	+
	Amphipods	Trend	+
	Northern-affinity gelatinous plankton	Variability	0
	Southern-affinity gelatinous plankton	Trend	+
	Small-mesh bottom trawl survey	Trend	+

Buoy SST anomalies

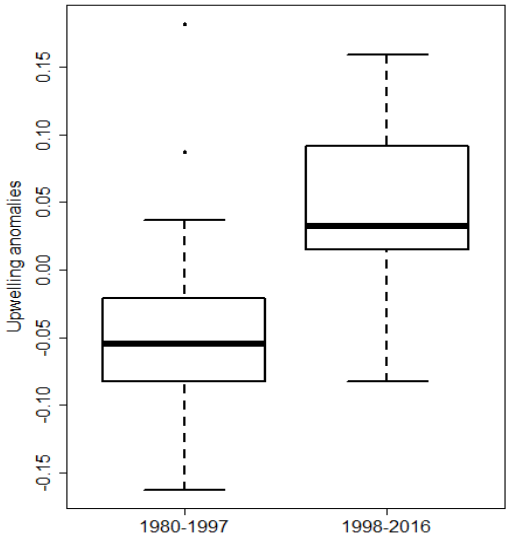


T-test:
P = 0.4

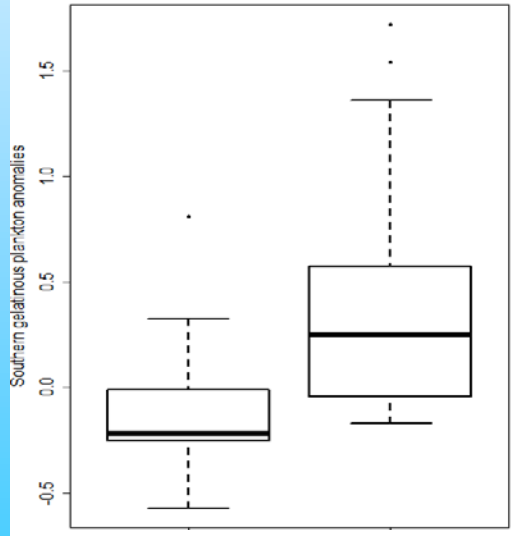
NPGO anomalies



Upwelling anomalies

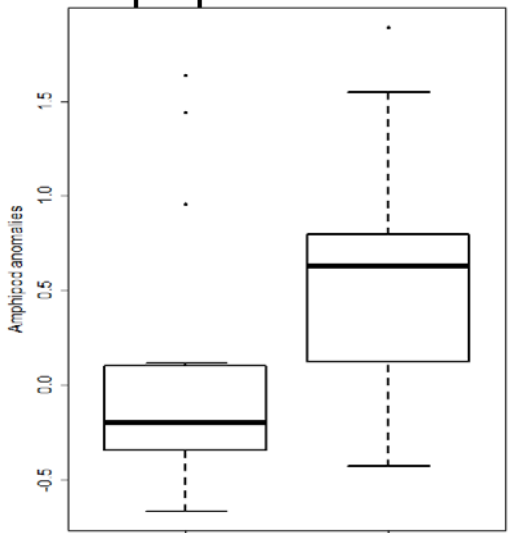


'Southern' Gelatinous



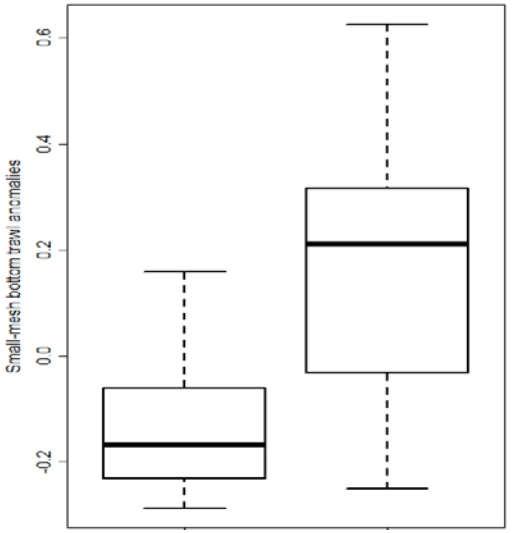
1980-1997 1998-2016

Amphipod anomalies



1980-1997 1998-2016

Bottom trawl anomalies



1980-1997 1998-2016

The story so far: variability *vs* trend

SW Vancouver Island since 1980 affected by both variability and trend of physical and biological time series:

- Variability appears to be driven by temperature
  - (not shown) most strongly affected are zooplankton with 'southern affinities'; zooplankton taxa with 'northern affinities' are affected by SST and NPGO
- Trend, defined as significant difference in mean values before and after 1997-98, is driven by NPGO, likely acting to increase upwelling-favourable winds (and therefore to increase nutrients)
  - 'southern affinity' gelatinous plankton; amphipods; and fishes caught by small-mesh bottom trawl
  - gelatinous plankton imported to the area by warmer waters may be able to respond faster to increased food from increased wind-driven nutrient supplies

Human drivers on this ecosystem, represented by BC coastwide catch estimates for selected taxa, do not appear as significant drivers

Caveats

- ignored autocorrelation in calculations of significance values (most time series have a one year autocorrelation)

- large spatial scale (BC coastwide) of catch data

- annual anomalies of driver variables (rather than seasonal)

- time lag effects not yet examined

Conclusions

Since 1980, SW Vancouver Island marine ecosystem dominated by physical processes

- Variability is dominated by changes in SST
- Trend dominated by changes in NPGO, likely acting to increase wind-driven upwelling

- Importance of NPGO (and upwelling) may help to explain results of Kilduff et al 2015 (PNAS 112(35)):

  "…we show that both Coho and Chinook salmon survival rates along western North America indicate that the NPGO, rather than the PDO, explains salmon survival since the 1980s…. but the unknown mechanism underlying the ocean climate effect identified here is not directly subject to management actions."

- Management implications: since physical processes are not 'controllable', requires observations of drivers and ecosystem changes
  - time series are good: longer time series are better