In hot water: zooplankton now and in the future

Anthony J. Richardson

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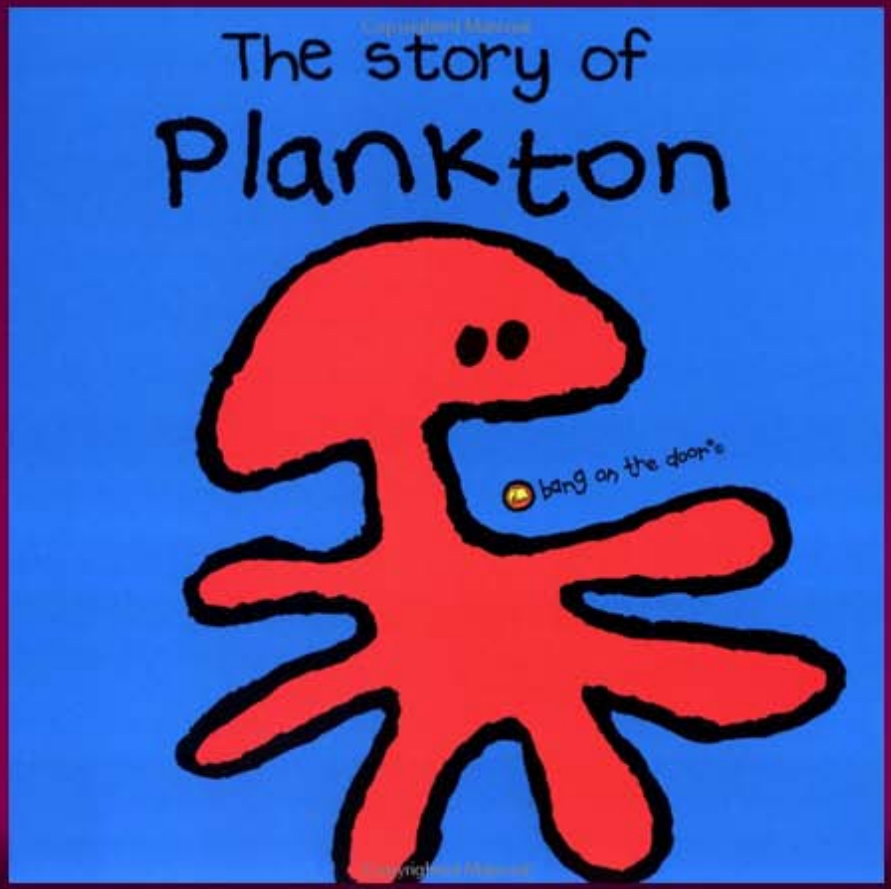
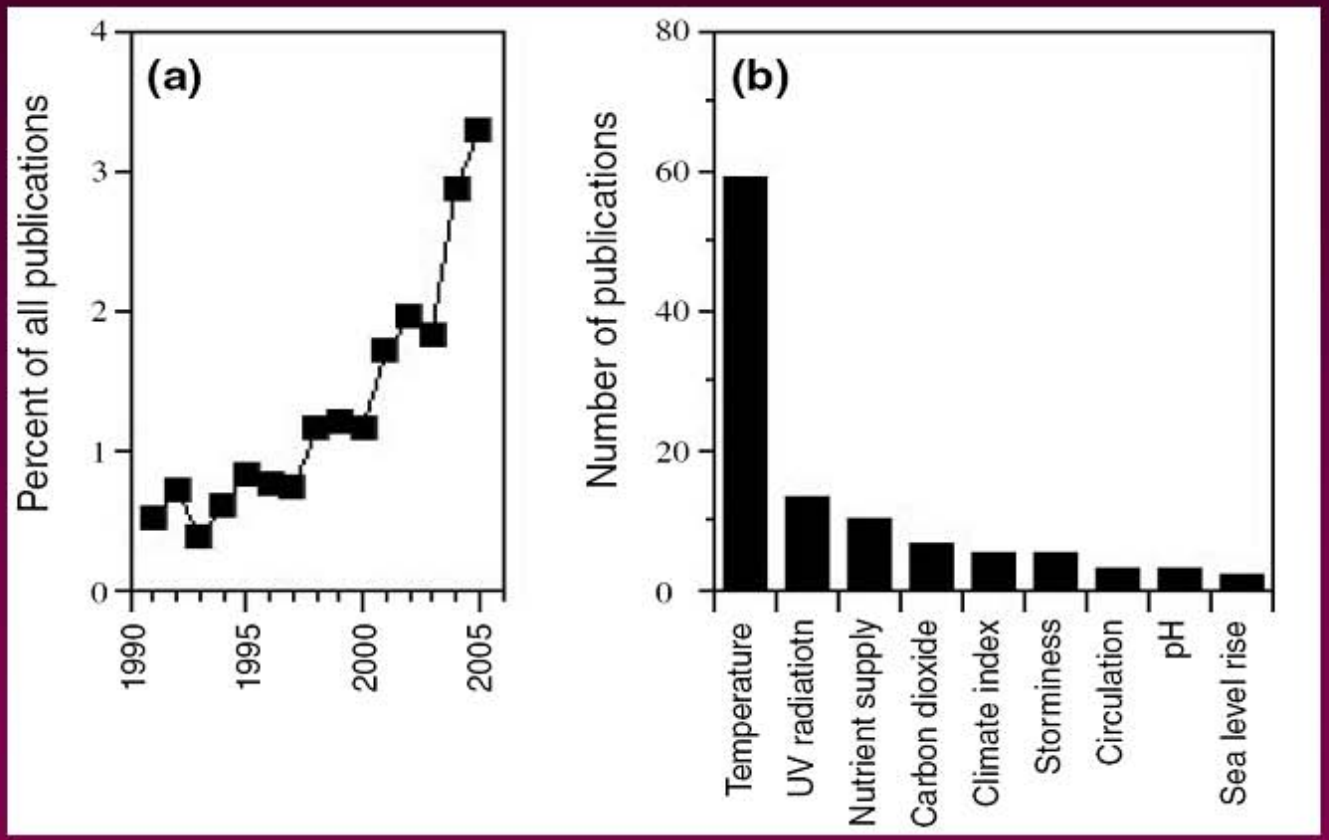


Increased Awareness of Climate Change

Climate Change Research: Marine Biology

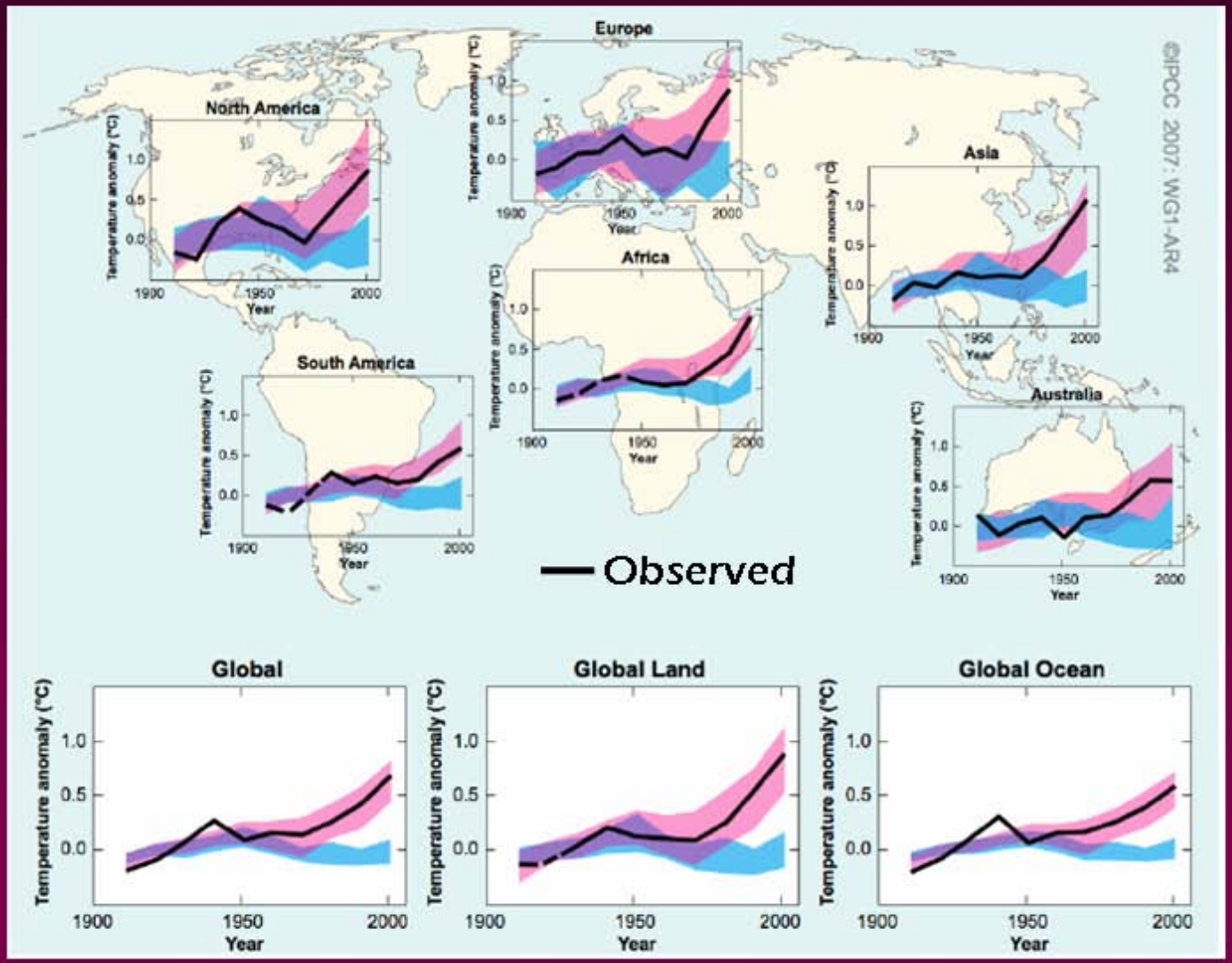


Harley et al (2006) Ecology Letters

Roadmap

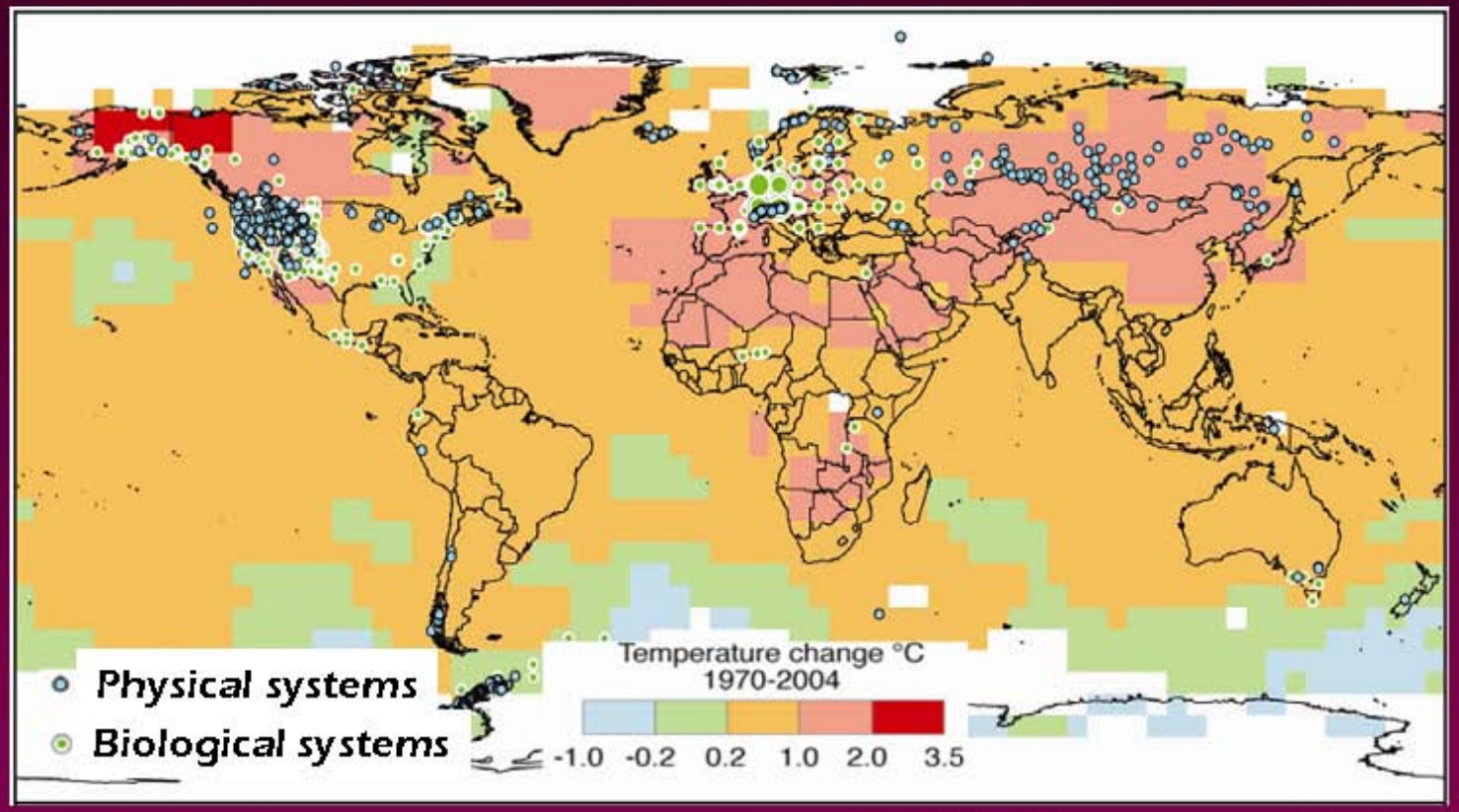
- The Present
  - Earth system changes
  - Plankton changes and ecosystem impacts
- The Future
  - Earth system changes
  - Modelling plankton changes
- Key Challenges

Earth System Changes
Temperature



The Present

Earth System Changes
Physics & Biology



Studies
- 1-30
- 31-100
- 101-800
- 801-1200
- 1201 -7500

	Terrestrial		Marine	
	Physical	Biological	Physical	Biological
# significant changes	764	28,586	1	85
% consistent with warming	94%	90%	100%	99%

IPCC WG1 AR4

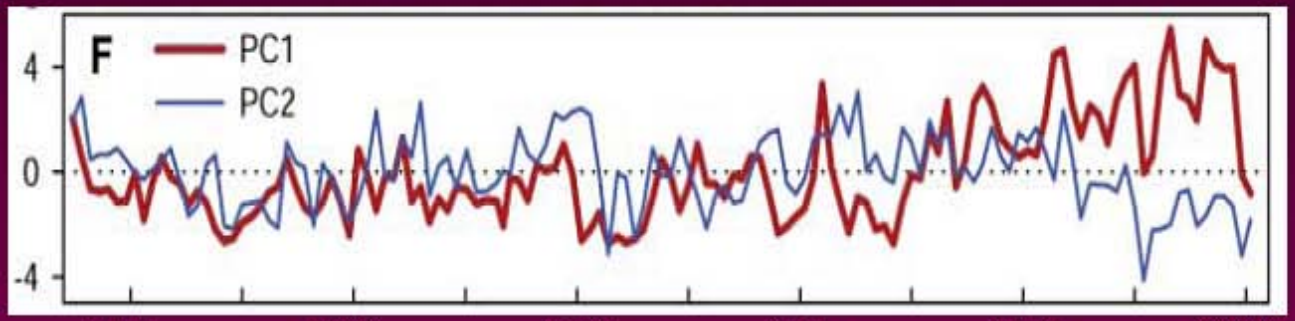
Plankton Changes

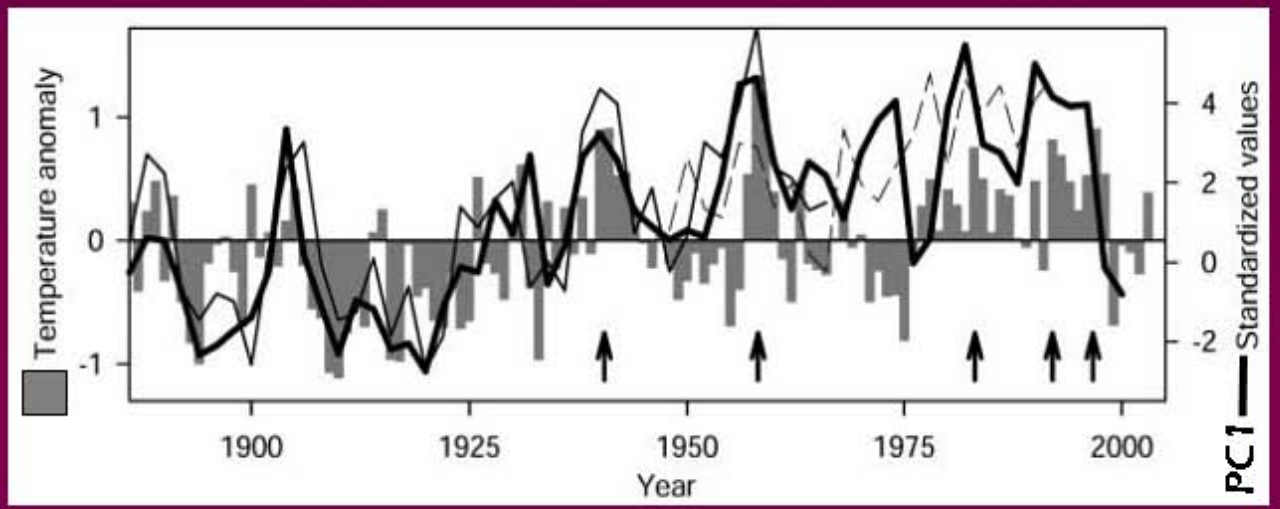
- Abundance
- Distribution
- Phenology
- Large-scale climate forcing

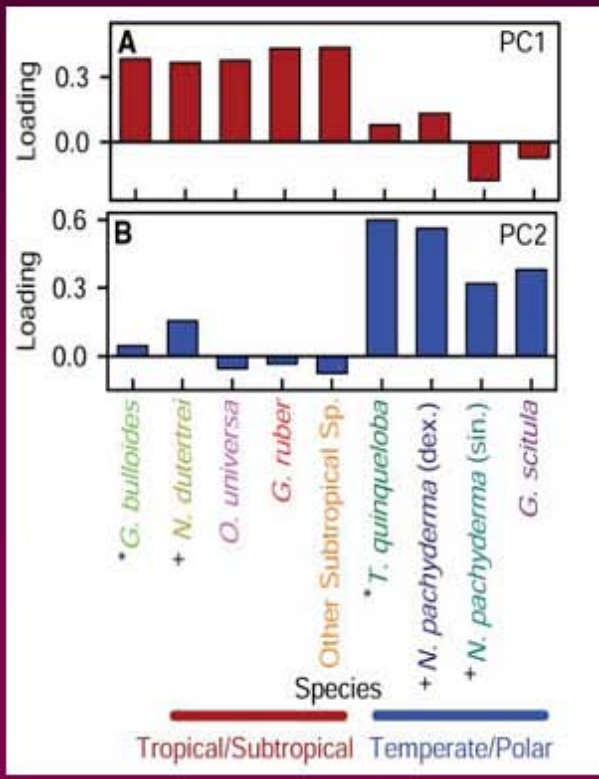
The Present

Plankton Changes

1. Abundance – Forams off California





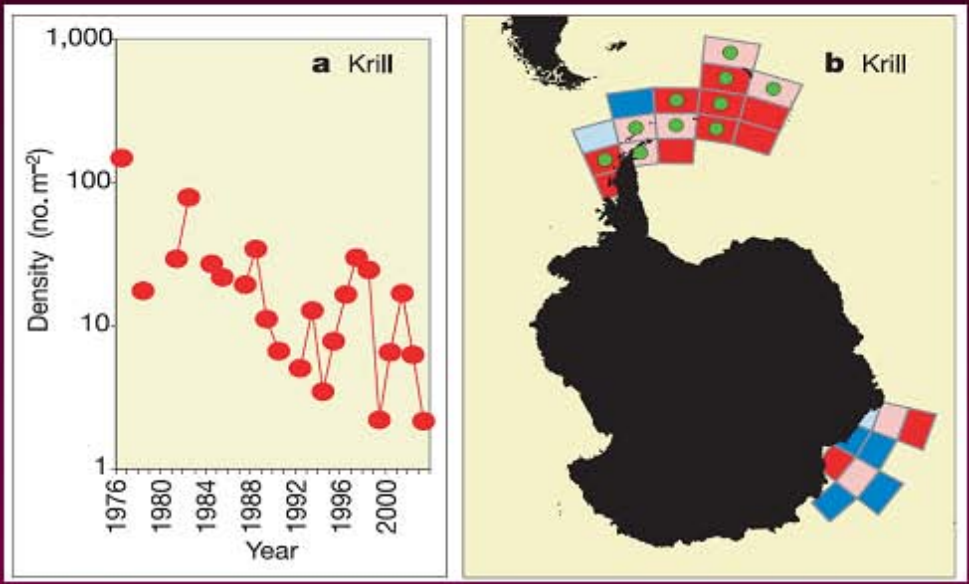


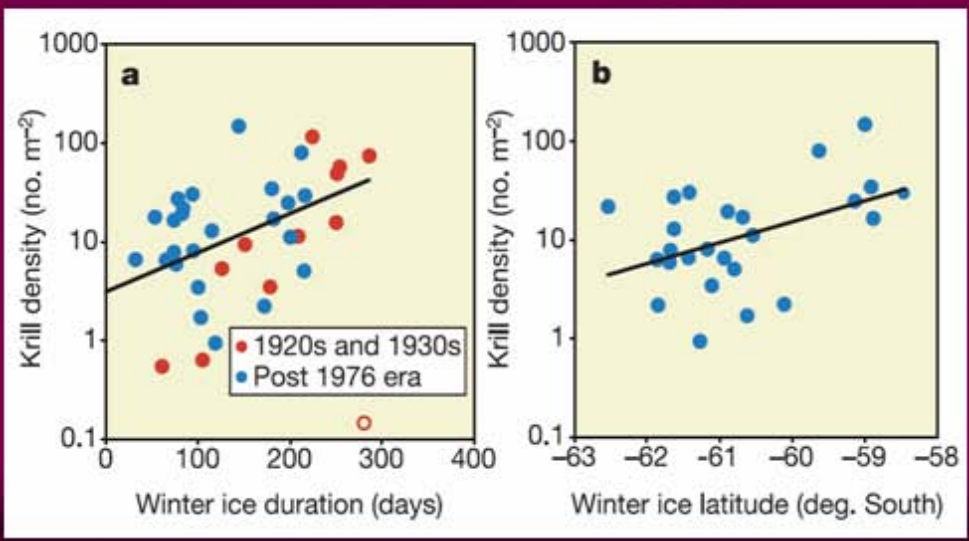
Field et al (2006) Science

The Present

Plankton Changes

1. Abundance – Southern Ocean



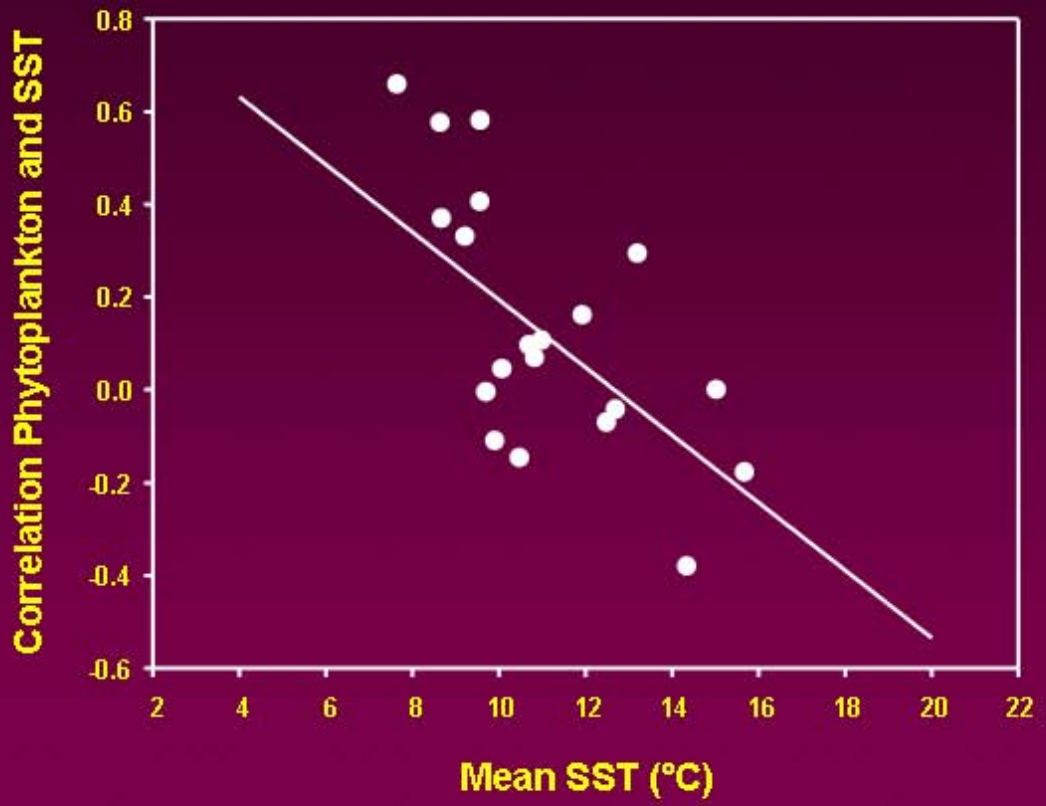


Atkinson et al (2004) Nature

The Present

Plankton Changes

1. Abundance – Northeast Atlantic



With warming: In Cold Areas Phyto ↑, Herb ↑, Carn ↑

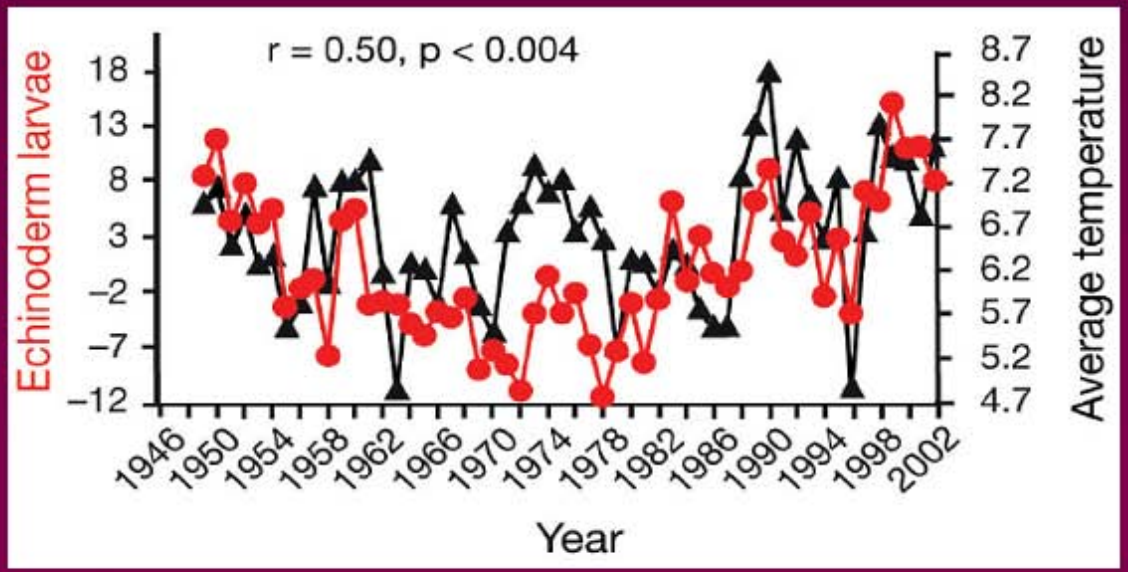
In Warm Areas Phyto ↓, Herb ↓, Carn ↓

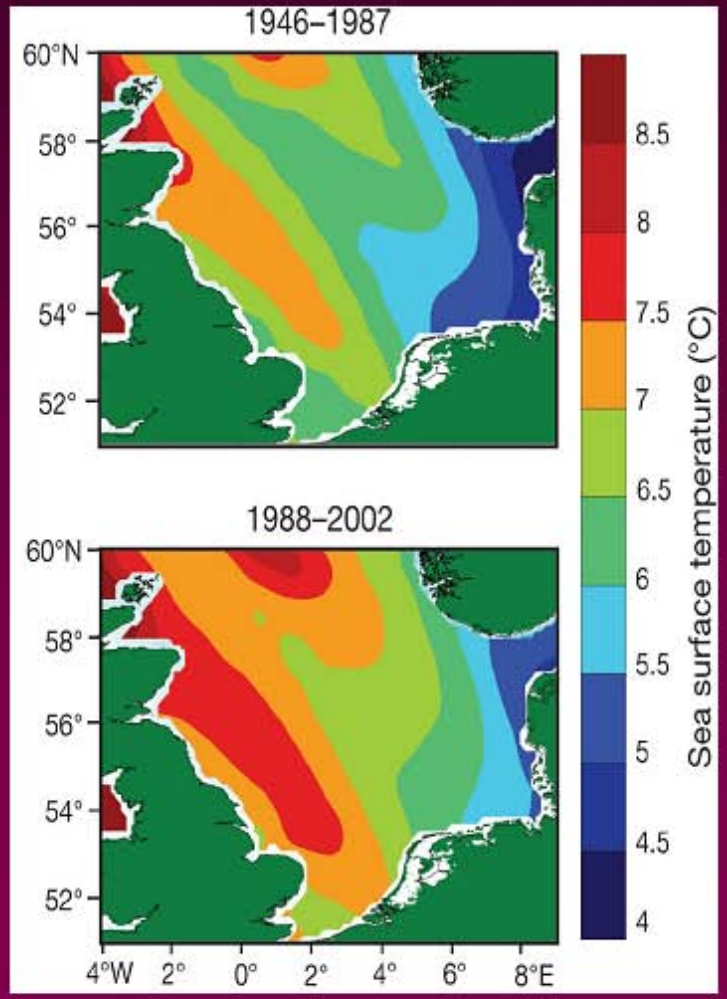
Richardson & Schoeman (2004) *Science*

The Present

Plankton Changes

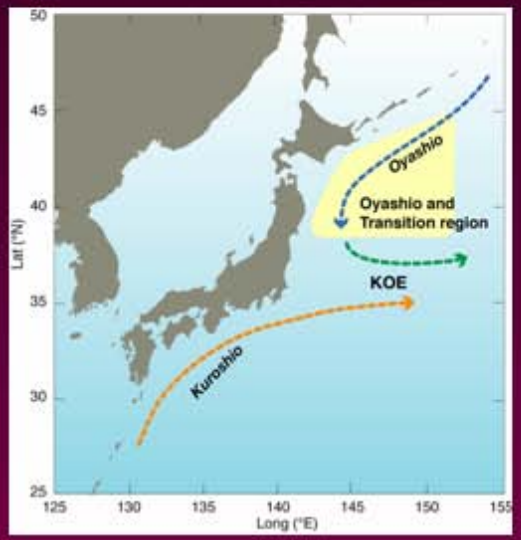
1. Abundance – North Sea



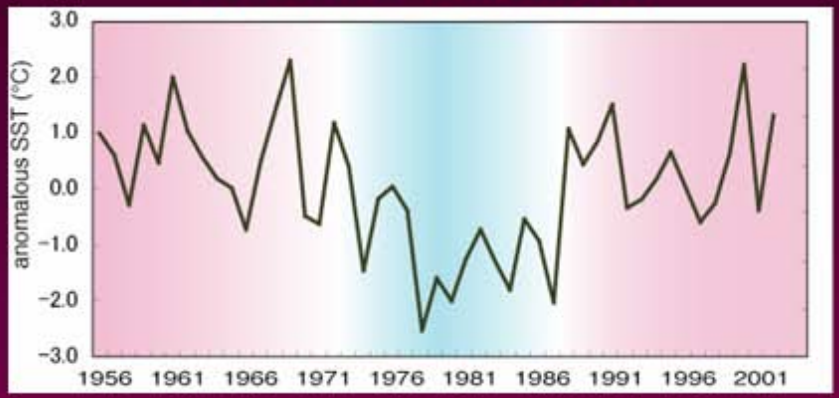


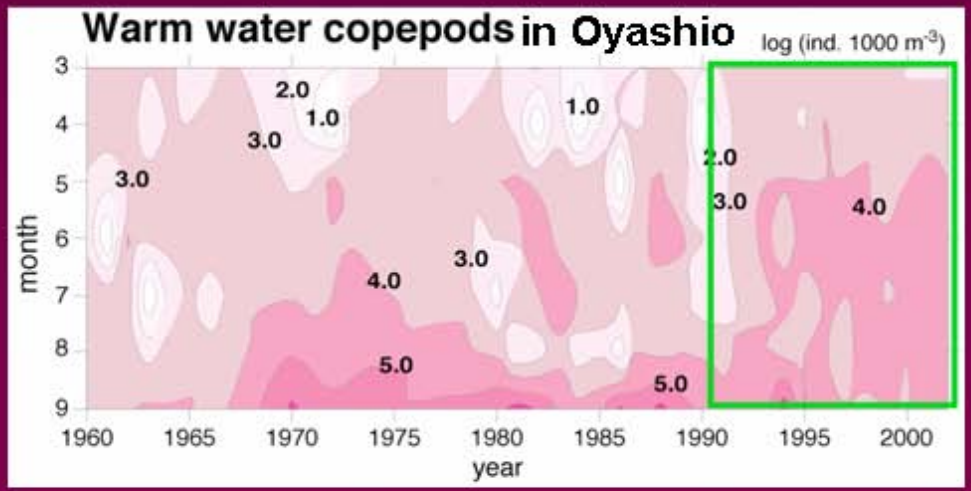
Kirby et al (2007) MEPS and see his oral for more info

Plankton Changes
2. Distribution – NW Pacific



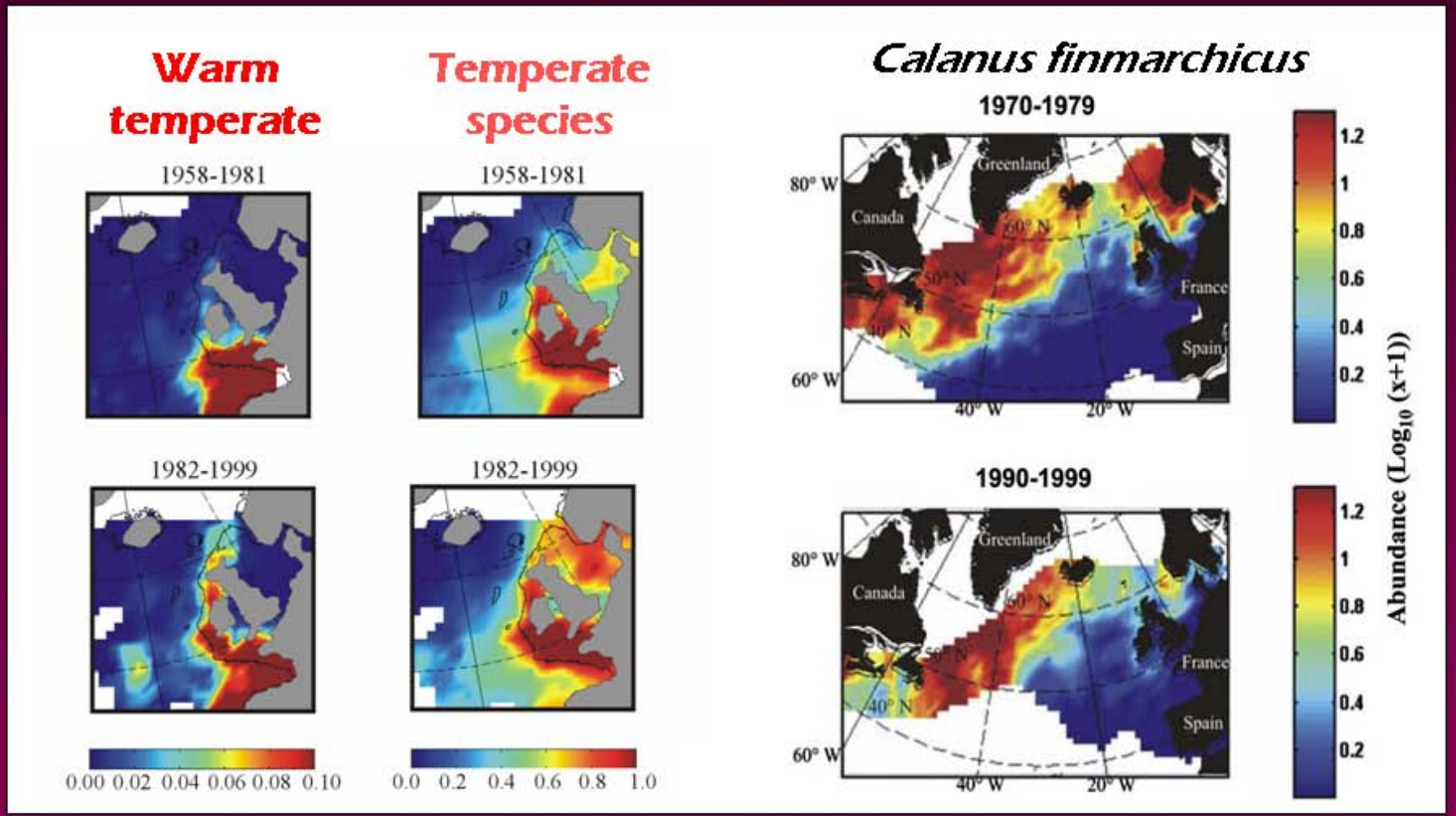
Western subarctic NP





Chiba (unpublished data) & see her oral for more info

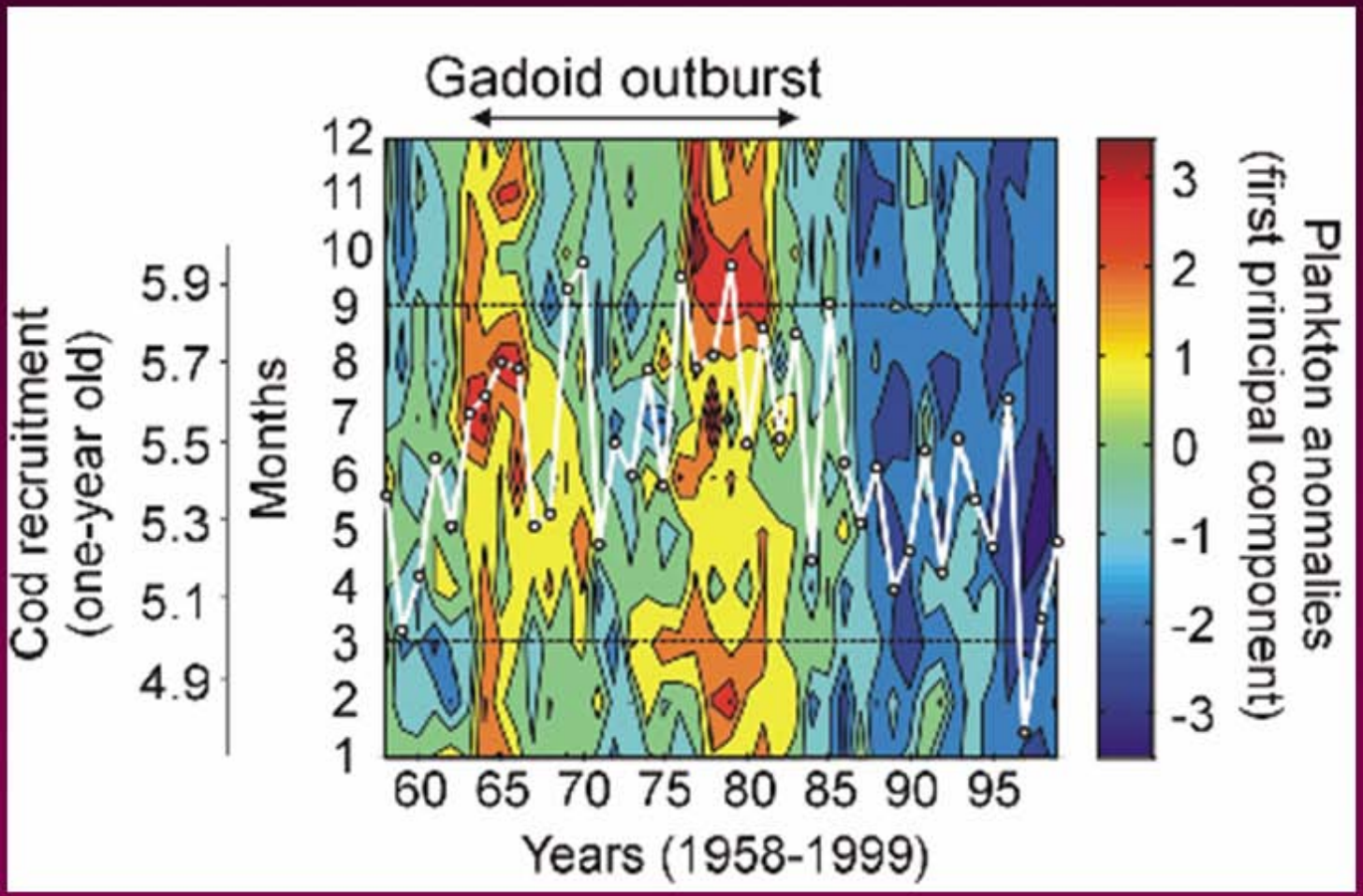
Plankton Changes
2. Distribution – Northeast Atlantic



Beaugrand et al (2002) *Science*

Bonnet et al (2005) PO

Plankton Changes
2. Distribution – Ecosystem Impacts



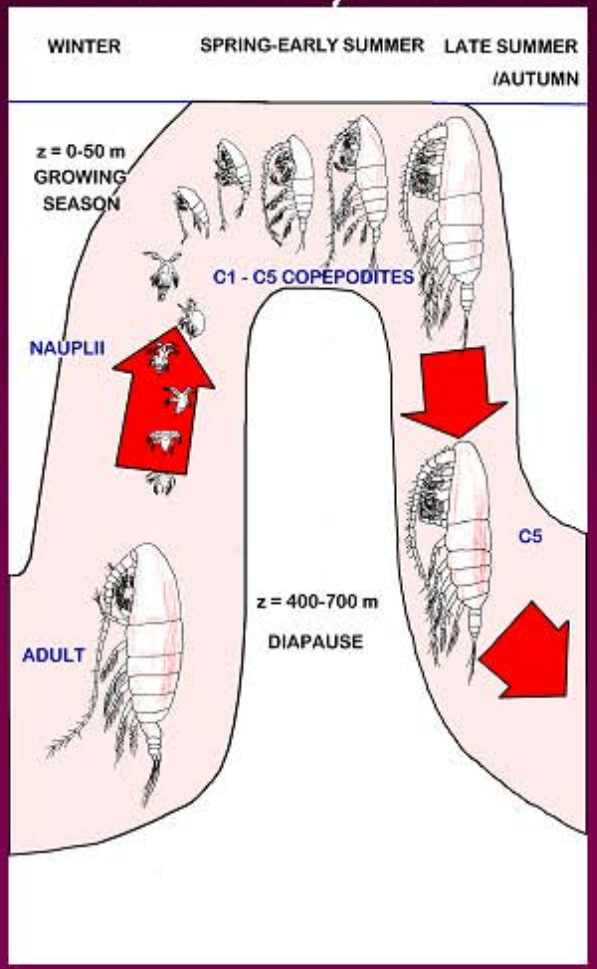
Beaugrand et al (2003) *Nature*

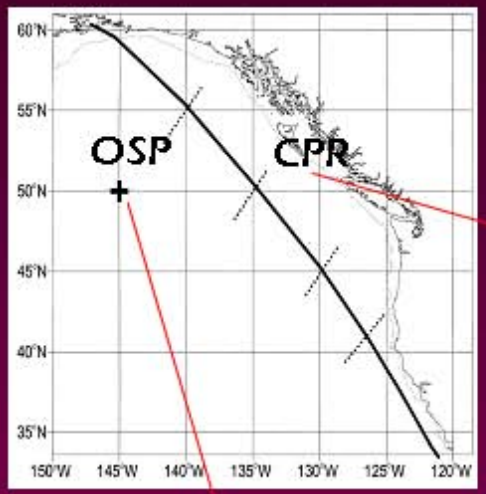
The Present

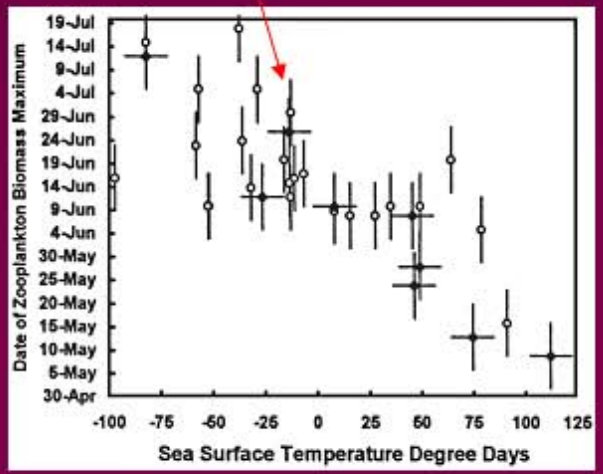
Plankton Changes

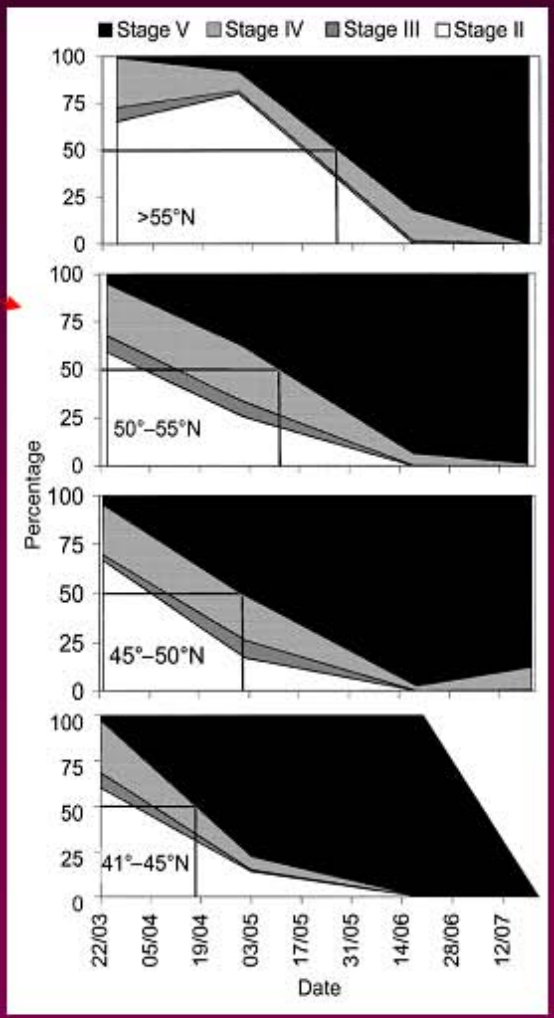
3. Phenology – Northeast Pacific

Neocalanus plumchrus









Mackas et al (1998) CJFAS

Mackas & Tsuda (1999) PO

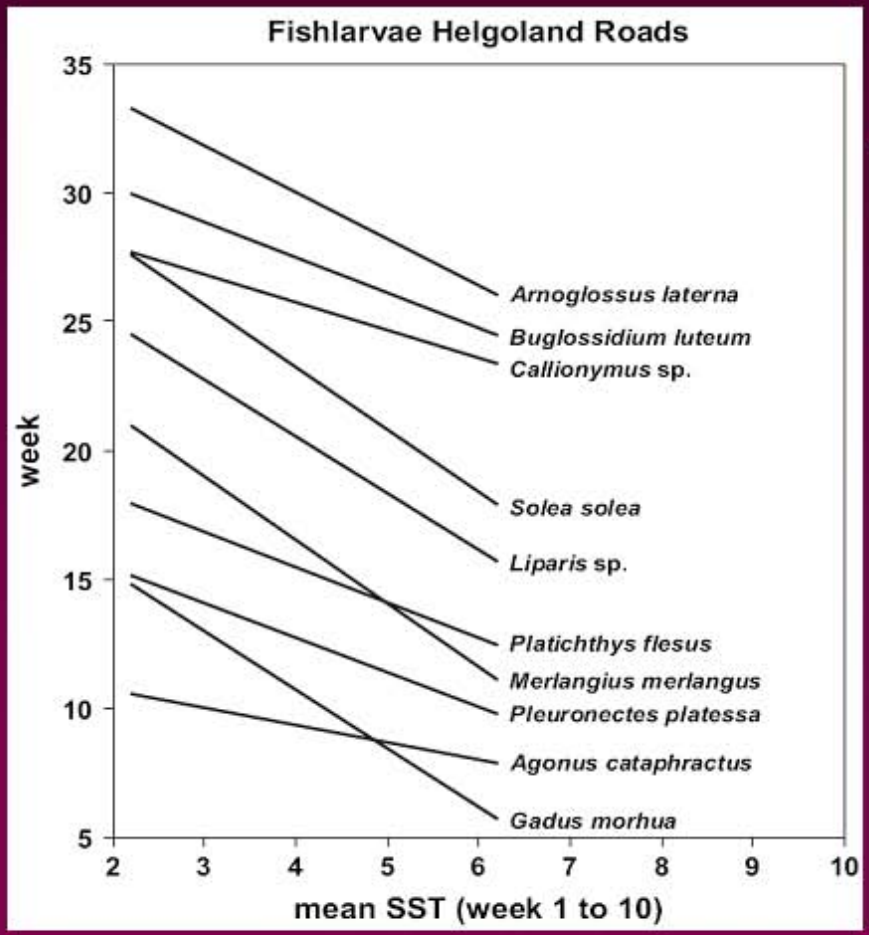
Batten et al (2003) FO

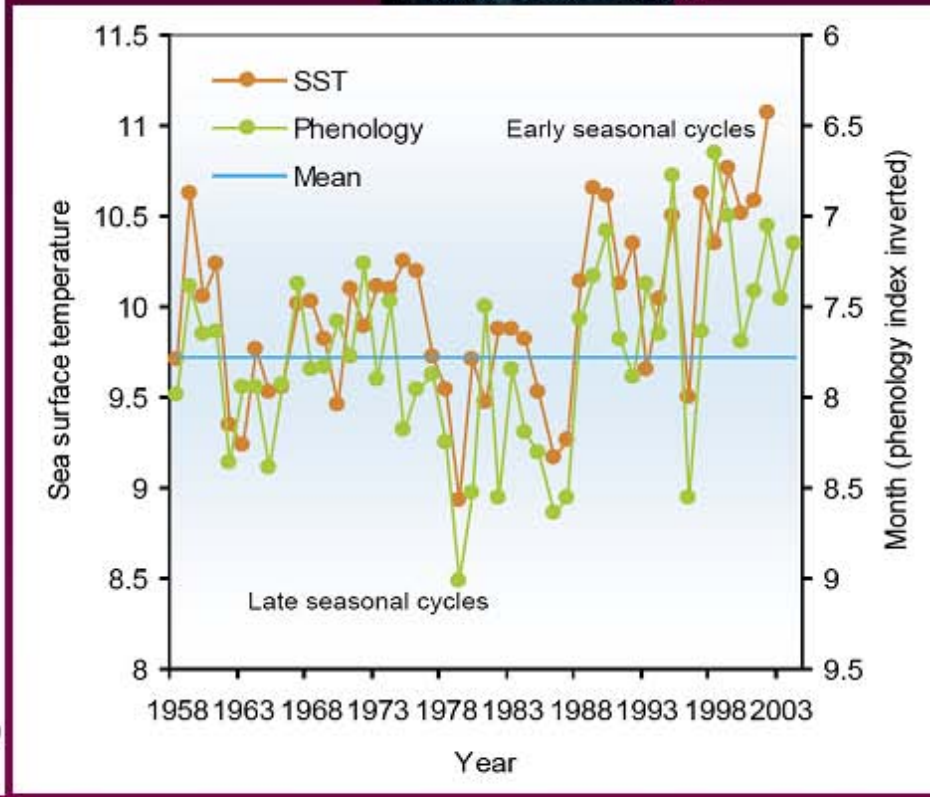
The Present

Plankton Changes

3. Phenology – North Sea Meroplankton

Image: Russ Hopcroft





Greve et al (2004) Helgol Mar Res

Edwards et al (2006) SAHFOS Tech Rep

Plankton Changes

3. Phenology – North Sea Ecosystem Impacts

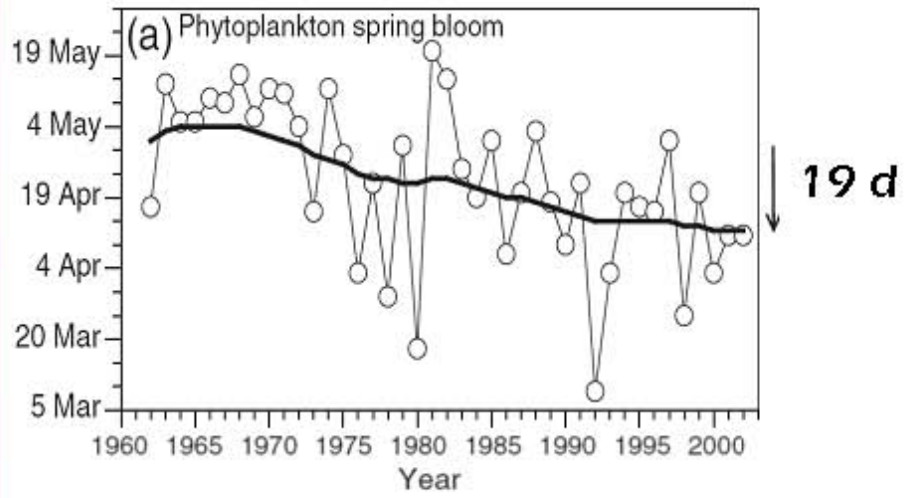
Season	Group	Days forward
Summer	Diatoms	22 d
	Dinoflagellates	23 d
	Copepods	10 d
	Other zooplankton	10 d
	Meroplankton	27 d

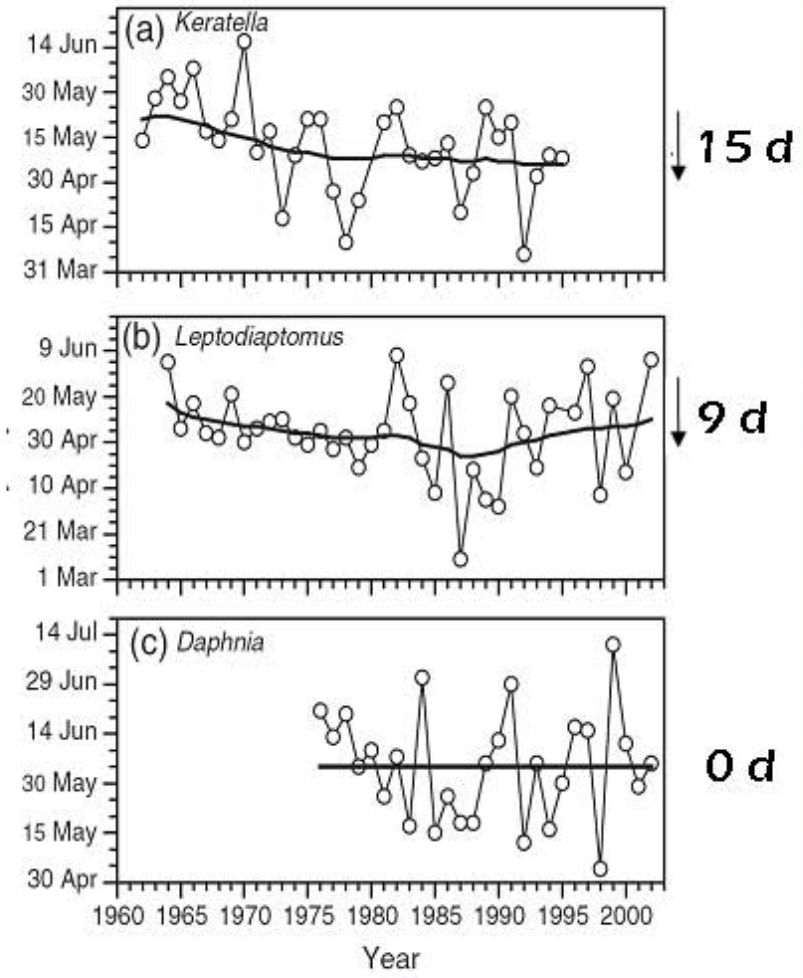
Edwards & Richardson (2004) Nature

Plankton Changes

3. Phenology – FW Ecosystem Impacts

Lake Washington (US)

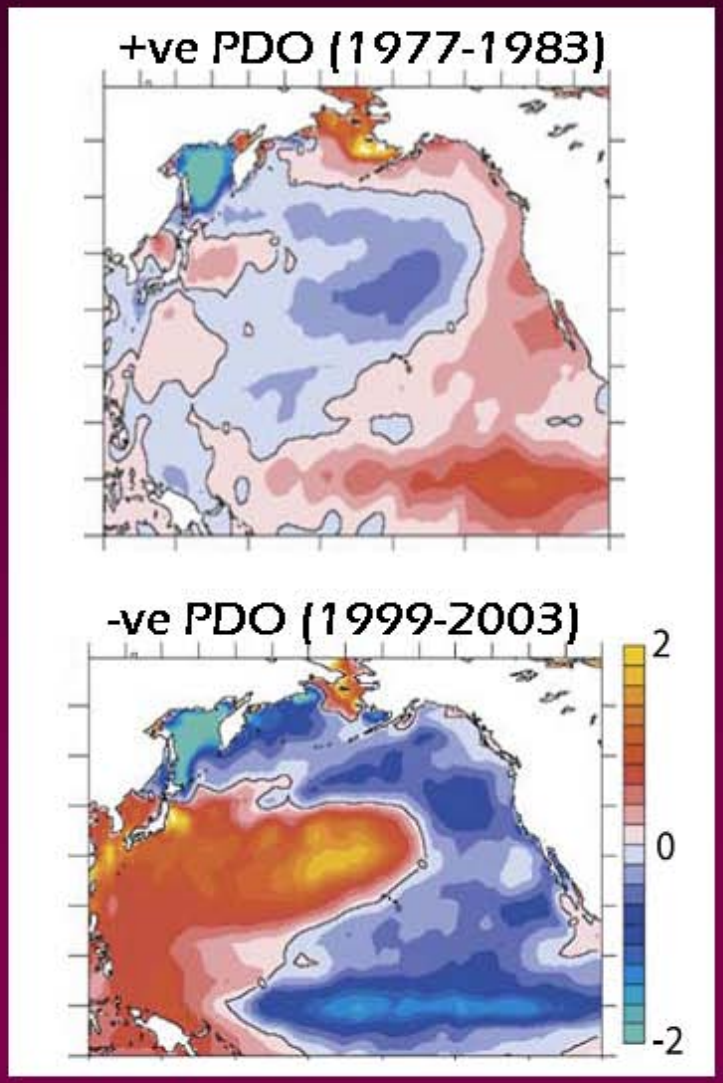


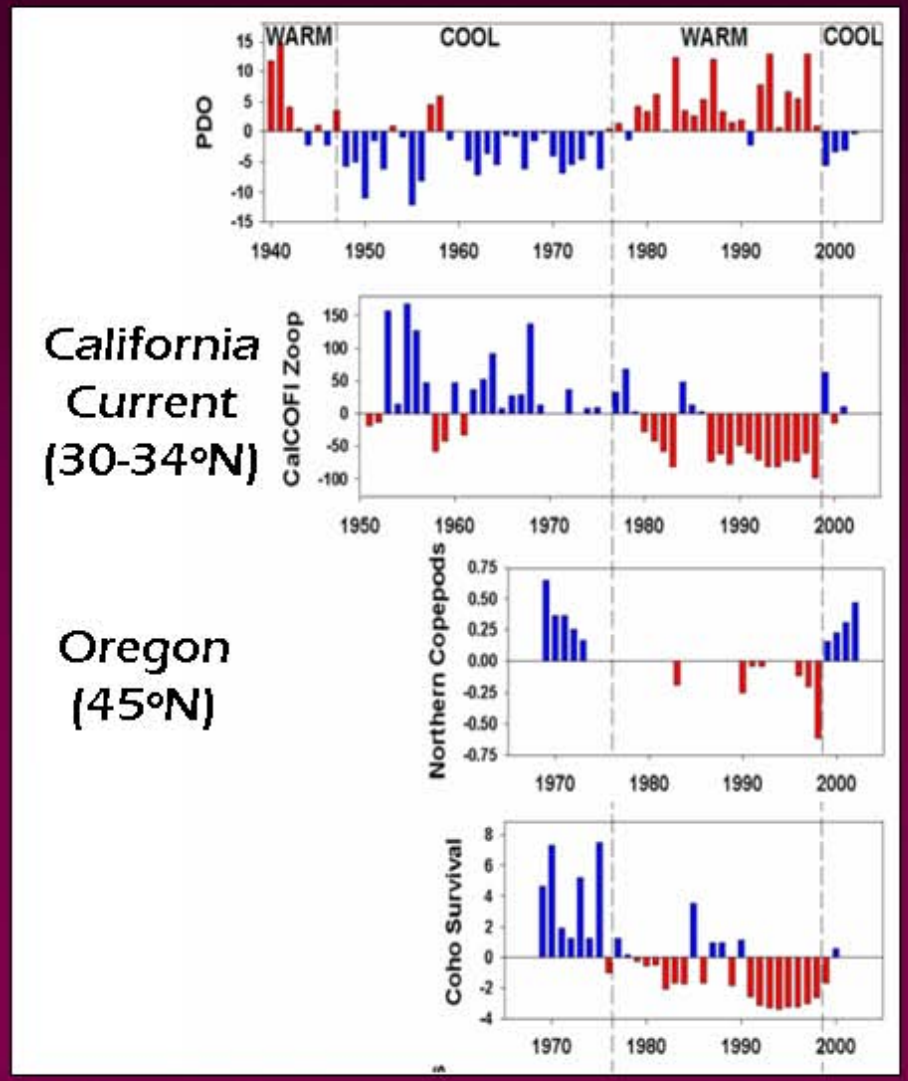


Winder & Schindler (2004) GCB

Plankton Changes

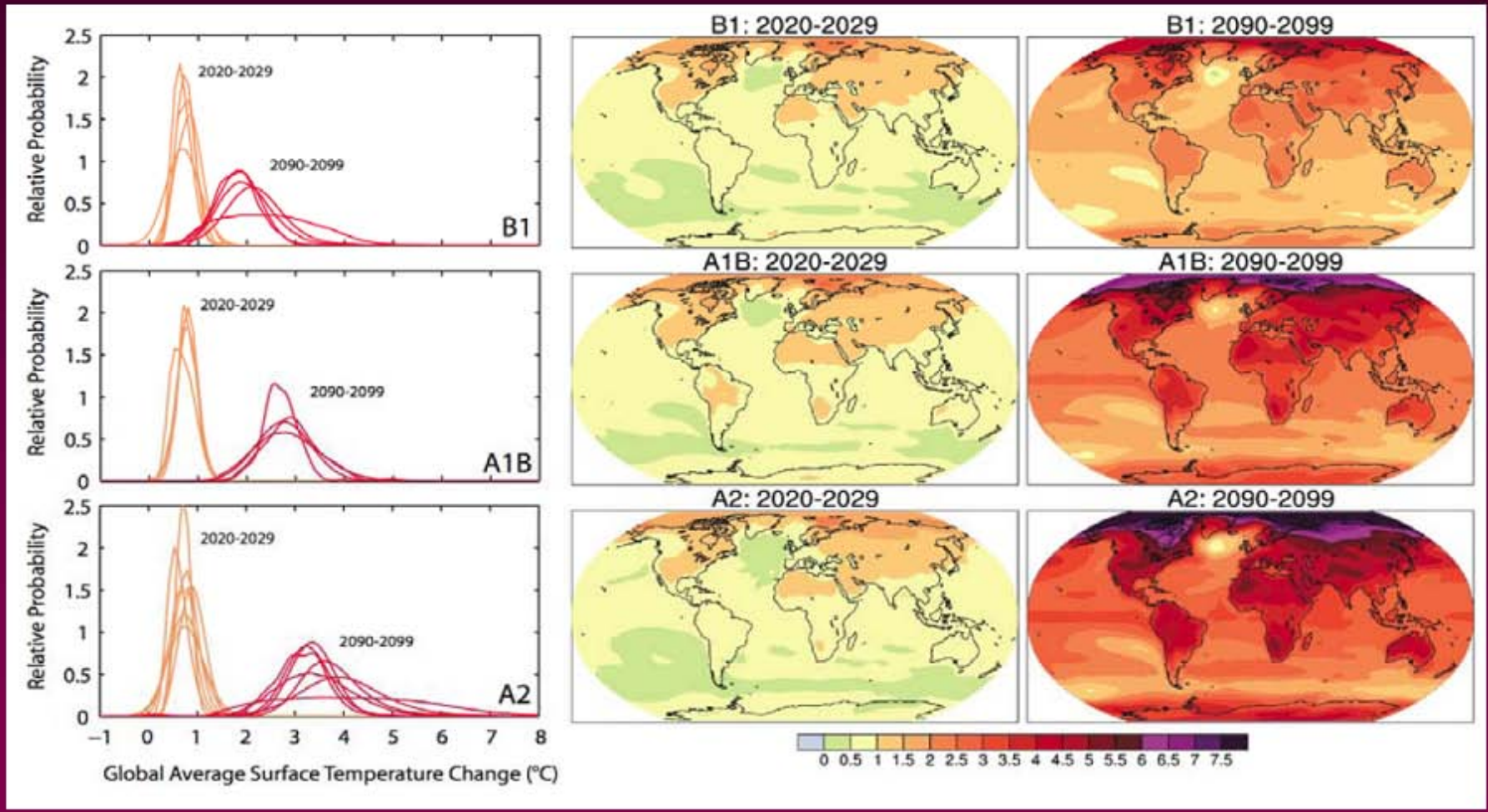
4. Large-scale Forcing – NE Pacific





e.g. SCOR WG125 Peterson & Schwing (2003) GRL

Earth Systems Changes
Temperatures

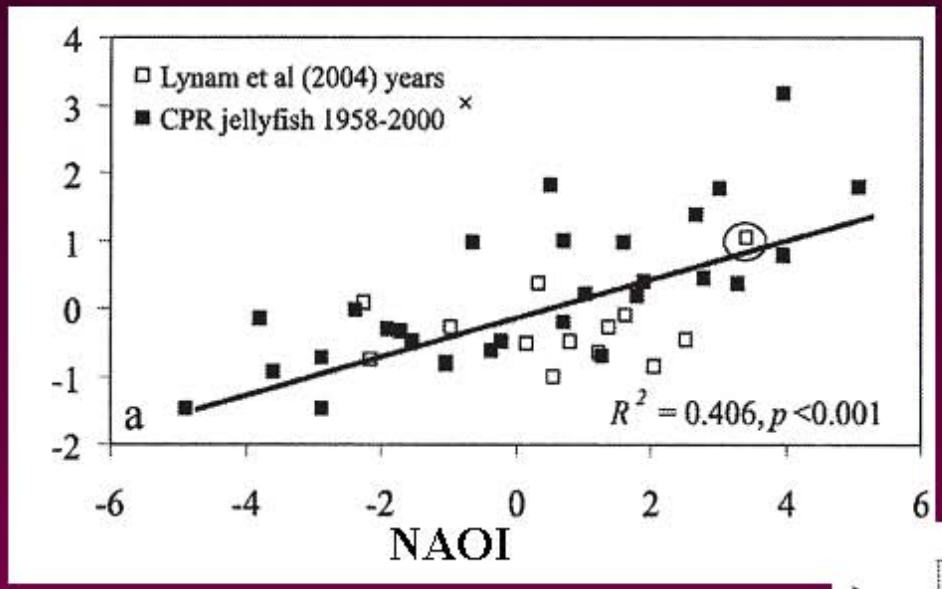


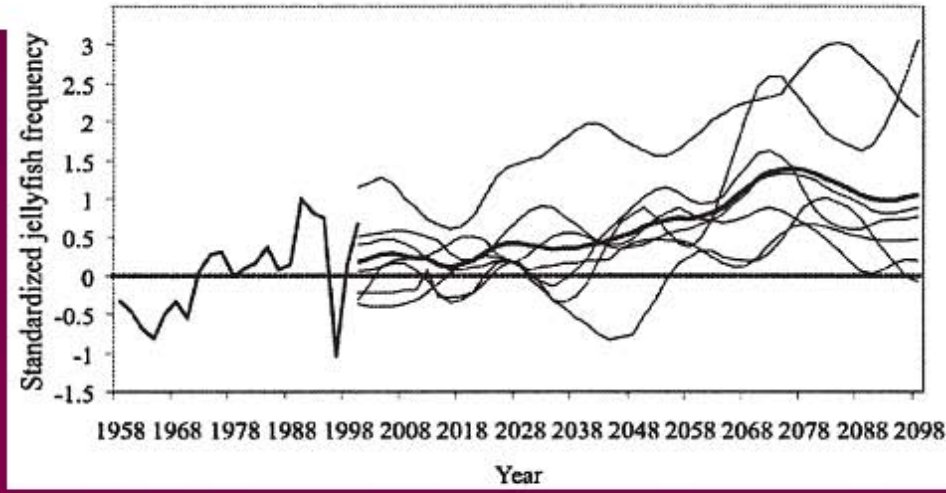
Plankton Changes

- Issues
  - Which groups do we think will be most sensitive?
  - Where do we have sufficient empirical or process-based understanding?
  - When is the scale of GCM output OK?
- Modelling
  - Empirical models
  - BGC and NPZ models
  - *Detailed population models (e.g. C. finmarchicus)*
  - *Ecosystem models*

Plankton Changes

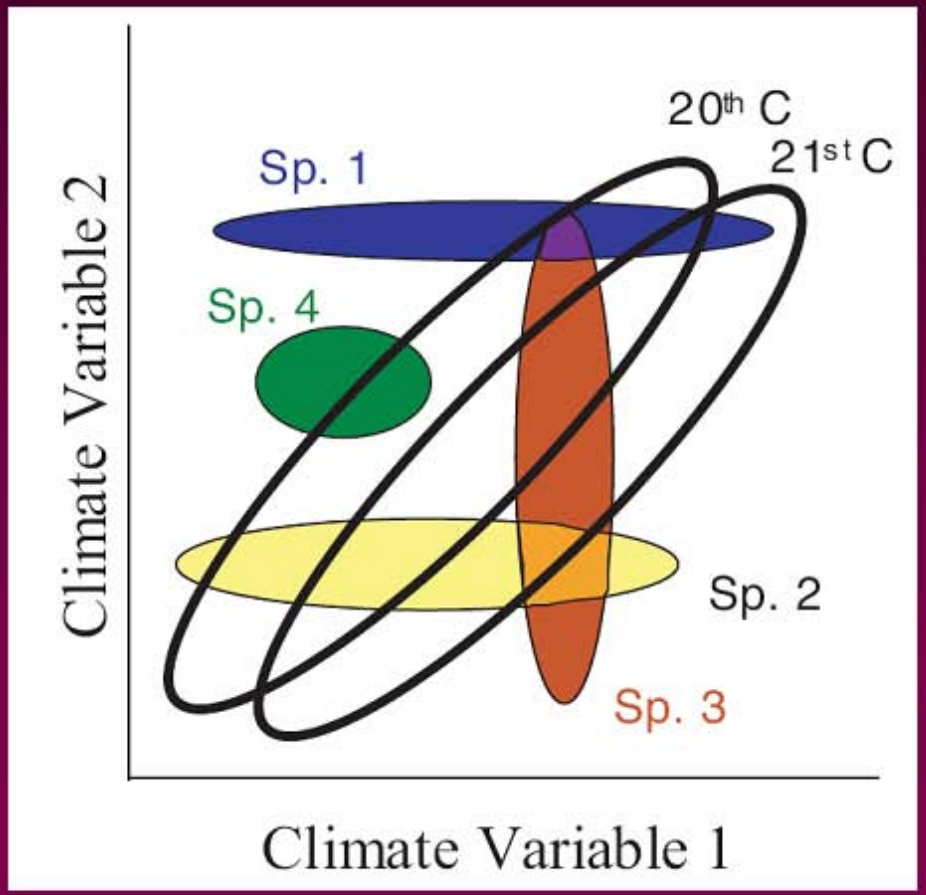
1. Empirical Models - North Sea





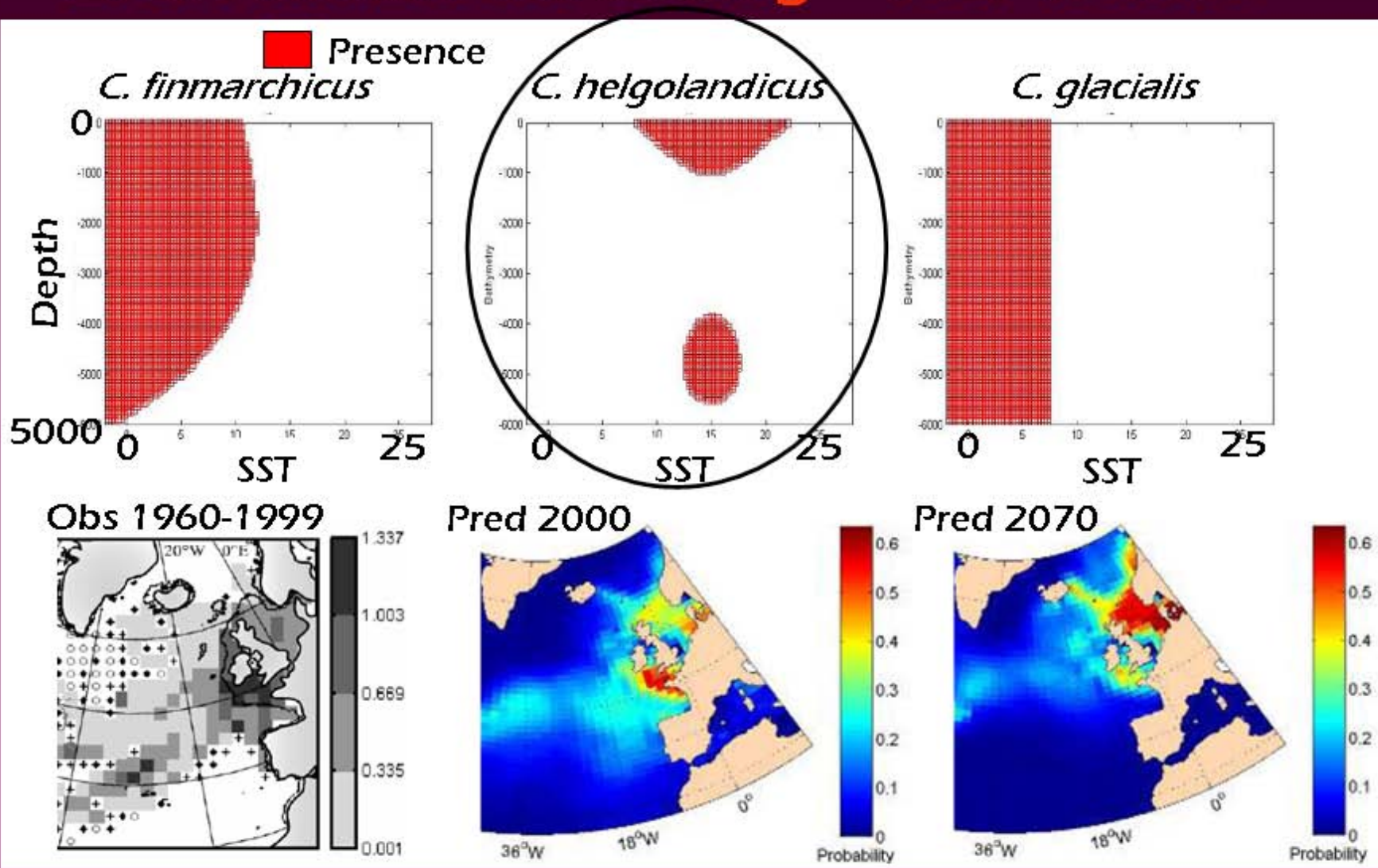
Attrill et al (2007) L&O

Plankton Changes
2. Bioclimate Modelling



Williams et al (2007) PNAS

Plankton Changes
2. Bioclimate Modelling – NE Atlantic

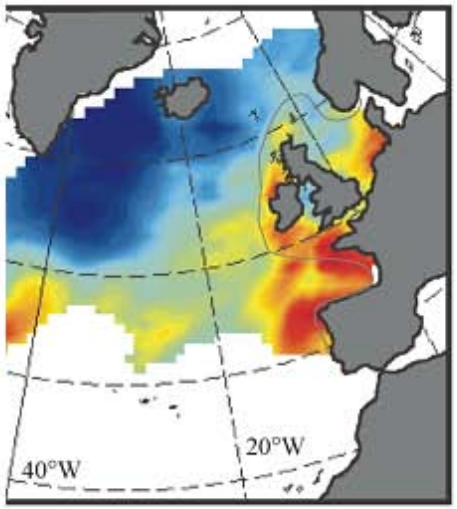


Richardson et al (unpublished)

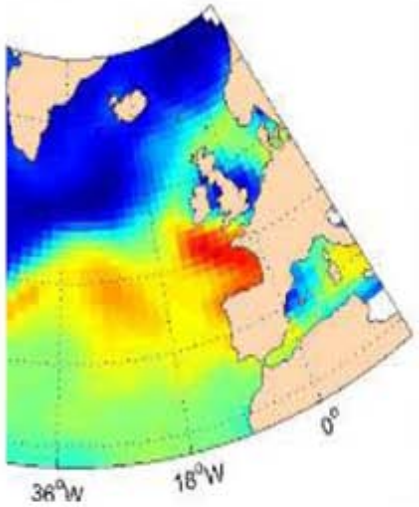
Plankton Changes
2. Bioclimate Modelling – NE Atlantic

- 111 phyto- and zooplankton spp for diversity

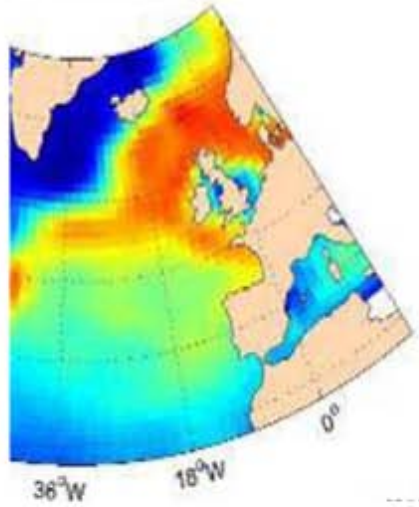
Obs 1960-1999



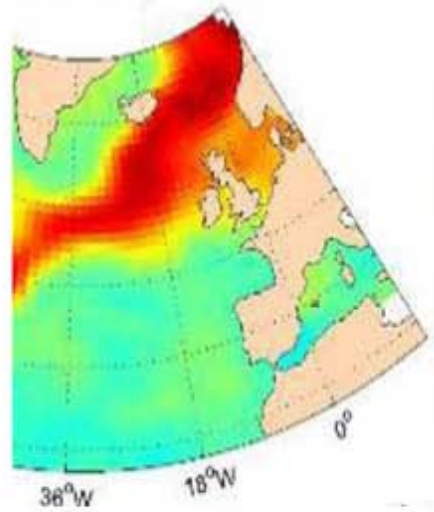
Pred 2000



Pred 2070



Pred 2070-2000



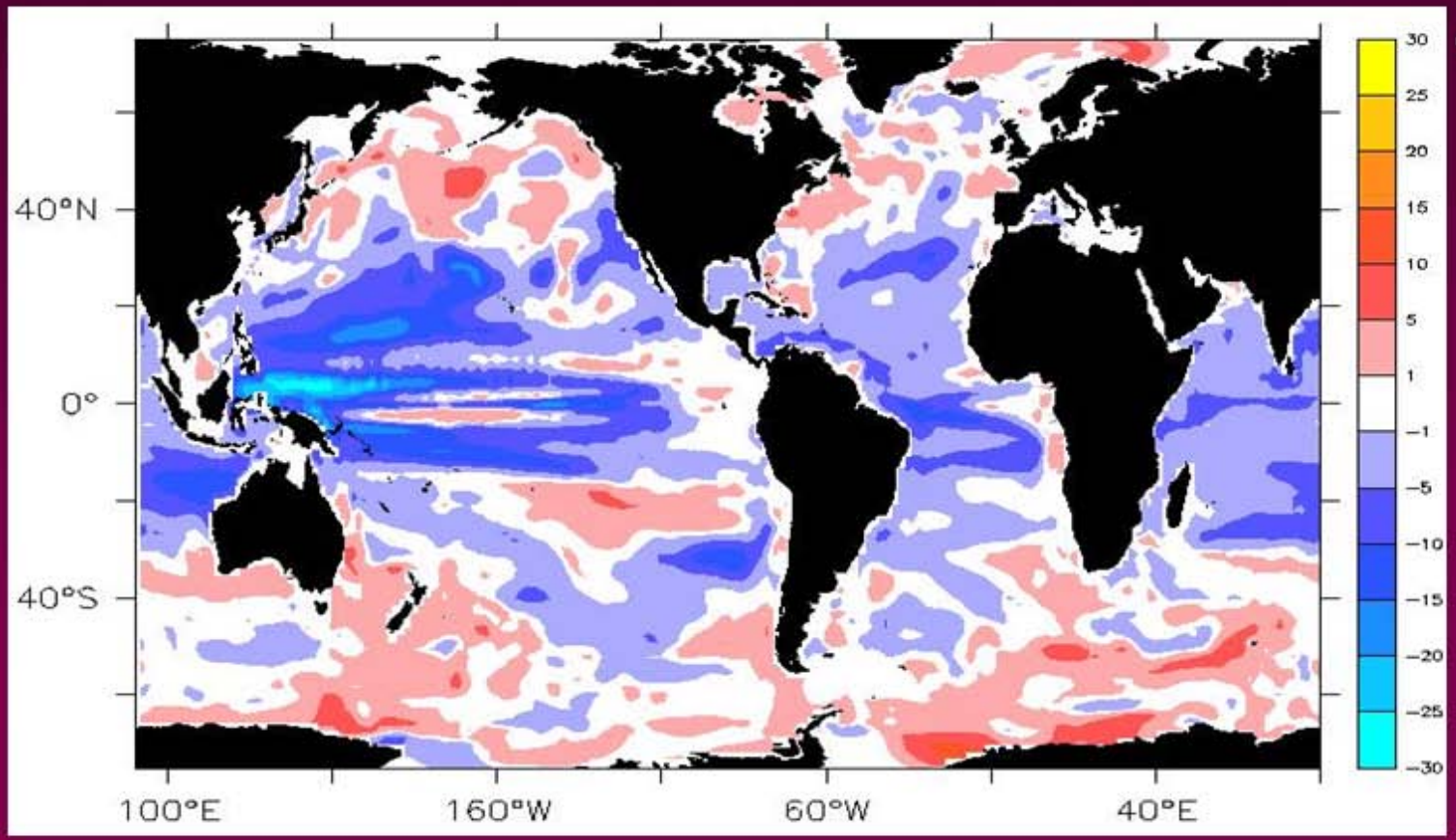
Taxonomic richness per sample

Beaugrand et al (2000) MEPS

Richardson et al (unpublished)

Plankton Changes
3. NPZ Modelling

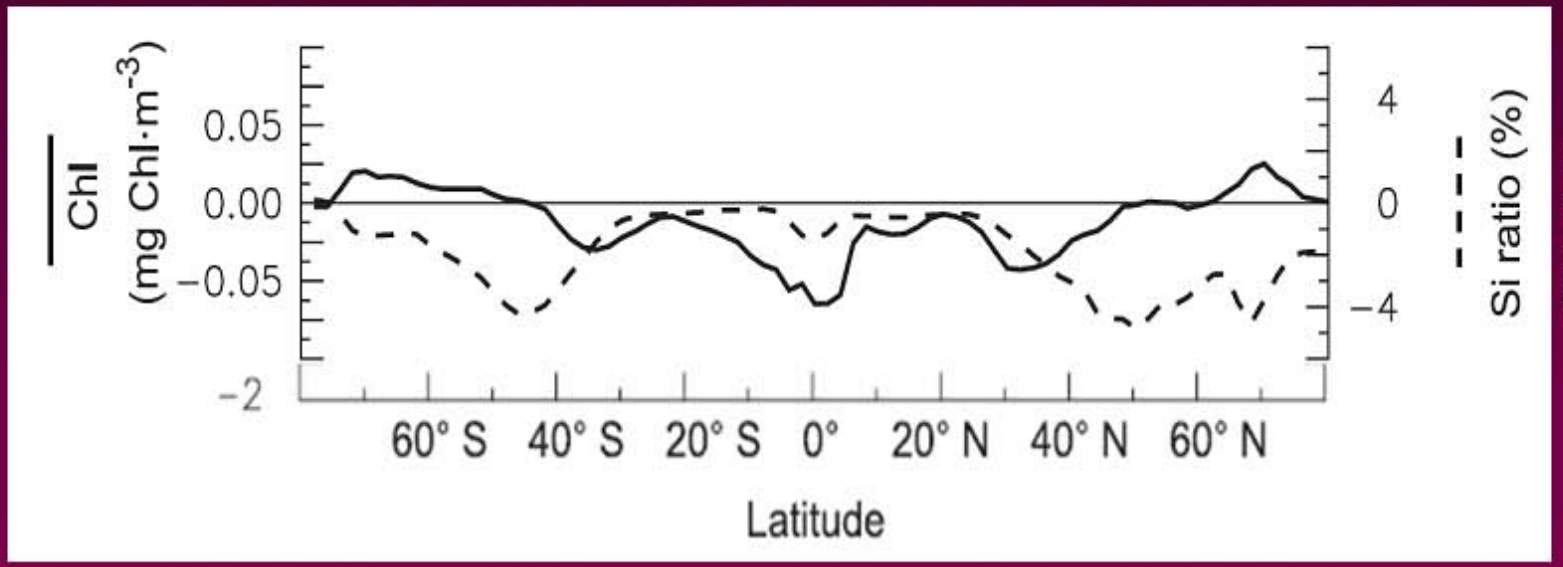
Primary Production, 2 x CO_2 – 1 x CO_2



Advantage of lower trophic levels

Bopp (2005)

Plankton Changes
3. NPZ Modelling



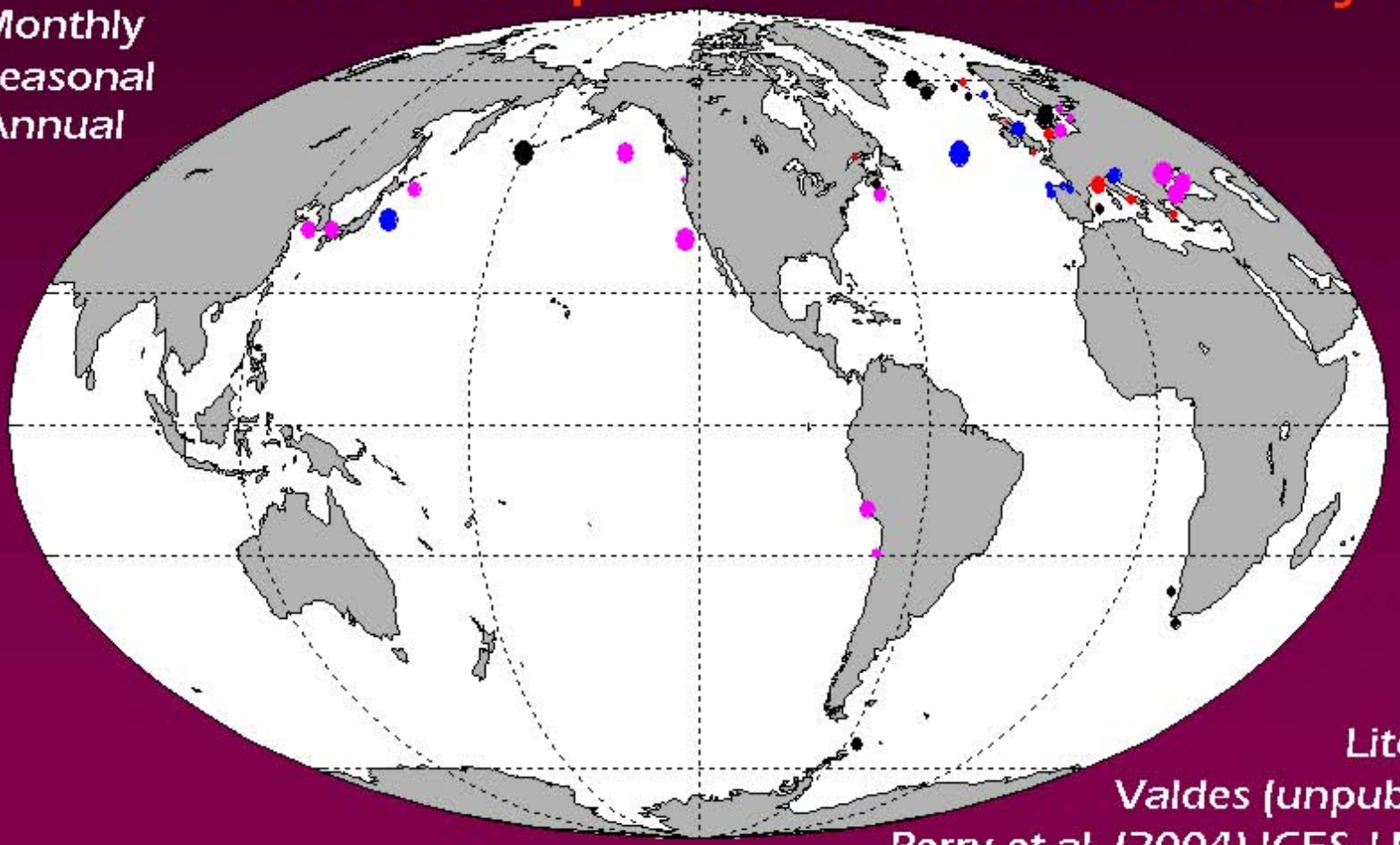
Need work incorporating zooplankton functional groups in NPZ models

Bopp et al (2004) CJFAS

Key Challenges

1. Response of tropical systems?

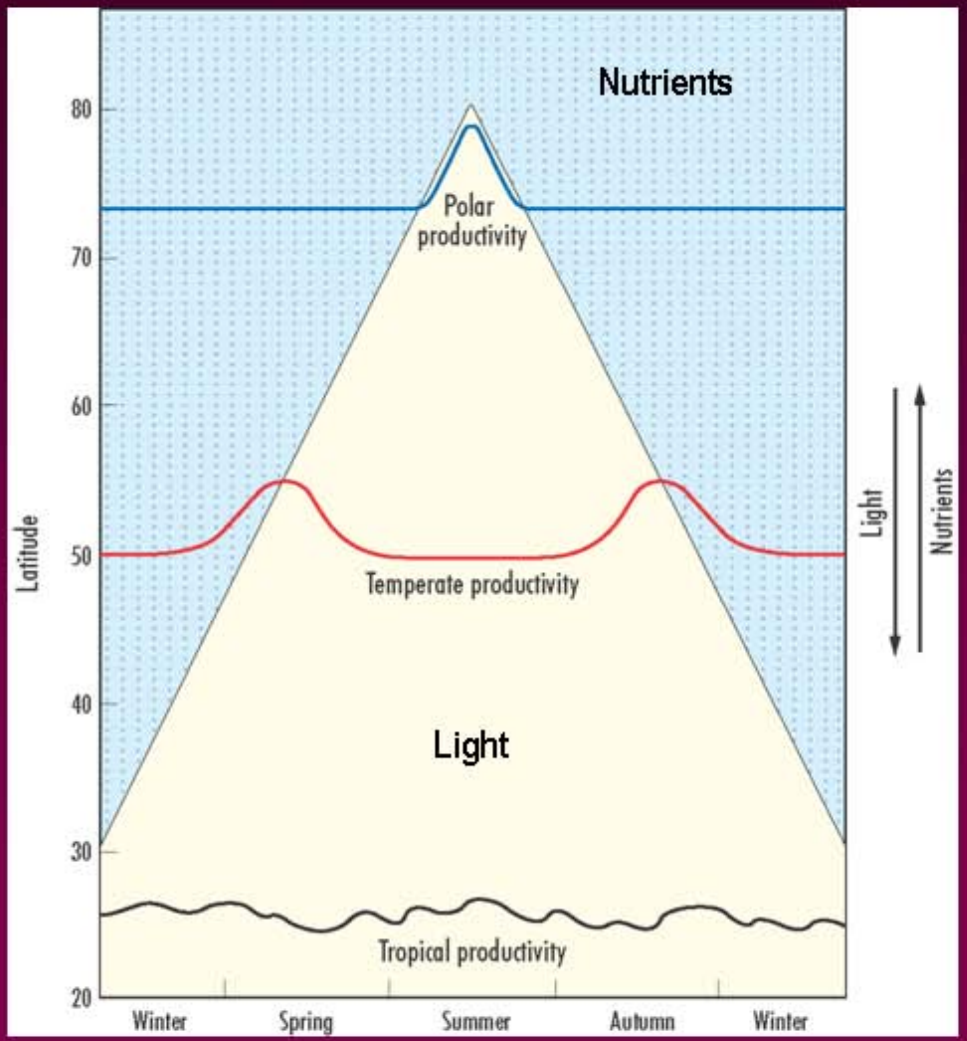
Extant Zooplankton Time Series Globally



Literature
Valdes (unpublished)
Perry et al. (2004) ICES J Mar Sci
COPEPOD Database (O'Brien 2005)

Key Challenges

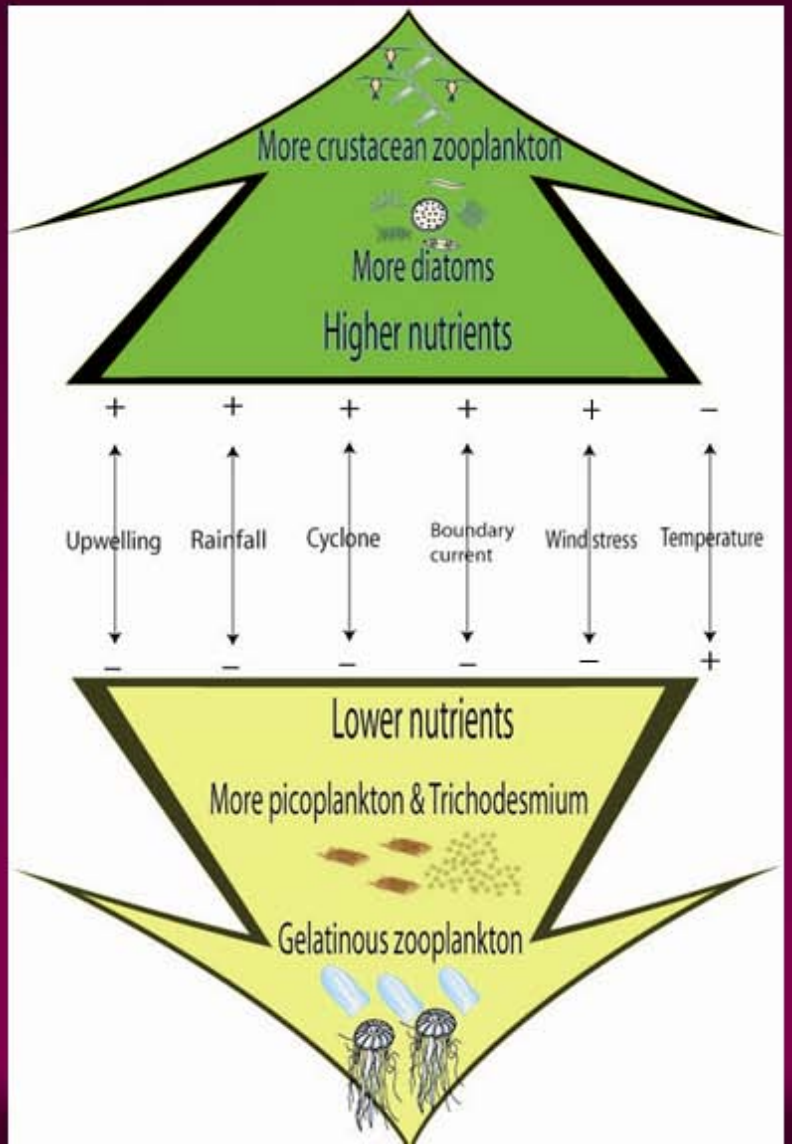
1. Response of tropical systems?



Mann & Lazier (1996)

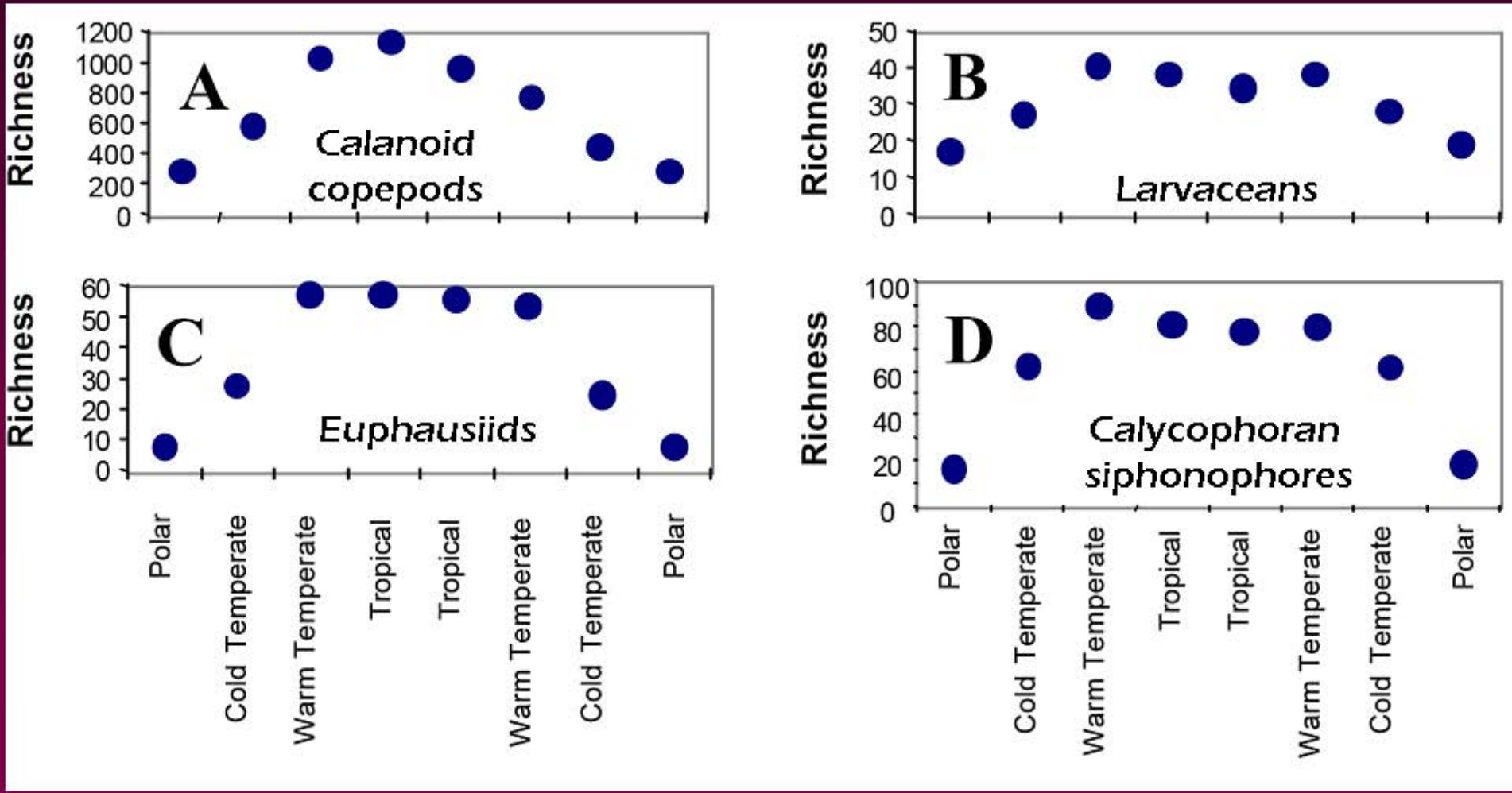
Key Challenges

1. Response of tropical systems?



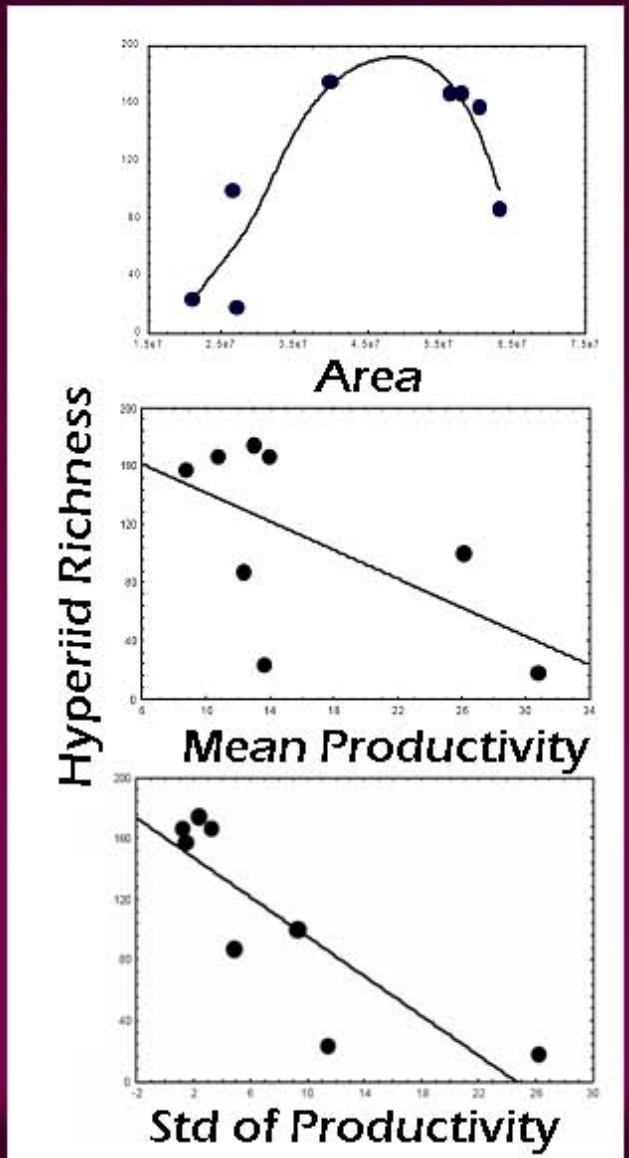
McKinnon et al (in press) GBR Book

Key Challenges
2. Understanding Drivers of Diversity



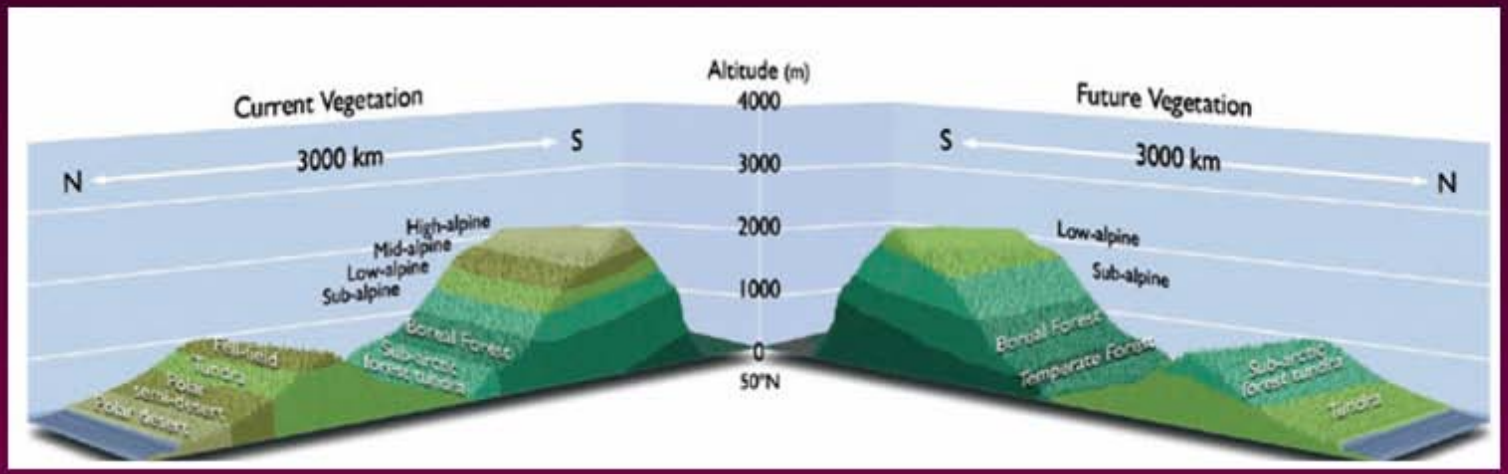
Gibbons et al (unpub data)

Key Challenges
2. Understanding Drivers of Diversity



Gibbons et al (unpub data)

Key Challenges
3. Vertical distribution

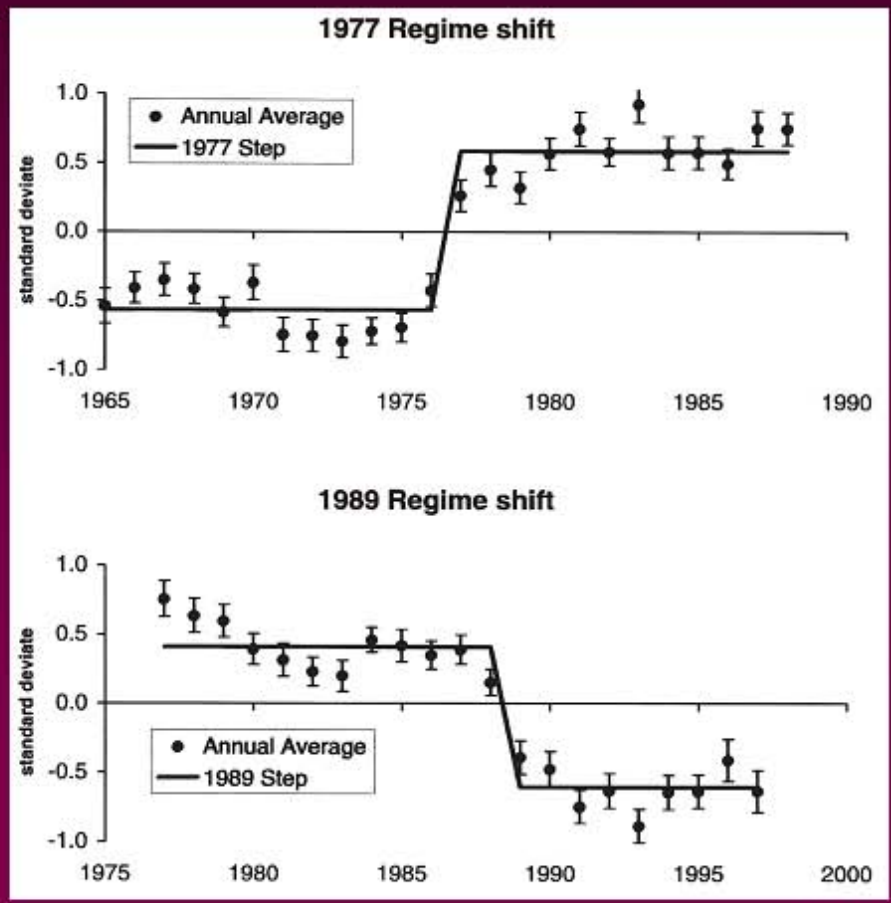


- Is there evidence for zooplankton going deeper in water column?

WWF (2006)

Key Challenges
4. Non-linear Dynamics

North Pacific



Hare & Mantua (2000) PinO

Scheffer & Carpenter (2003) TREE

Conclusions

- Dramatic impacts of climate change on zooplankton causing ecosystem-wide consequences
- Exciting time for long-term zooplankton research
- Increasing use of modelling approaches to peer into the future


WELCOME TO
AUSTRALIA!
NO FARTING
AUSTRALIA - LEADING FROM BEHIND ON GREENHOUSE EMISSIONS