Impacts of climate change on Antarctic marine ecosystems

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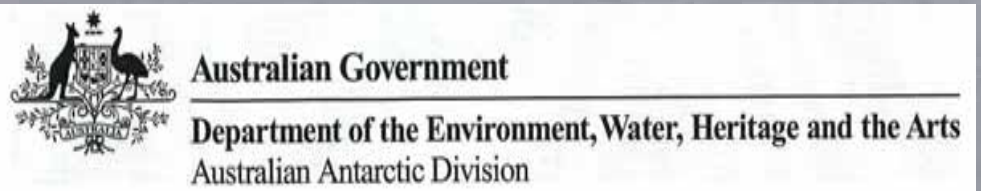
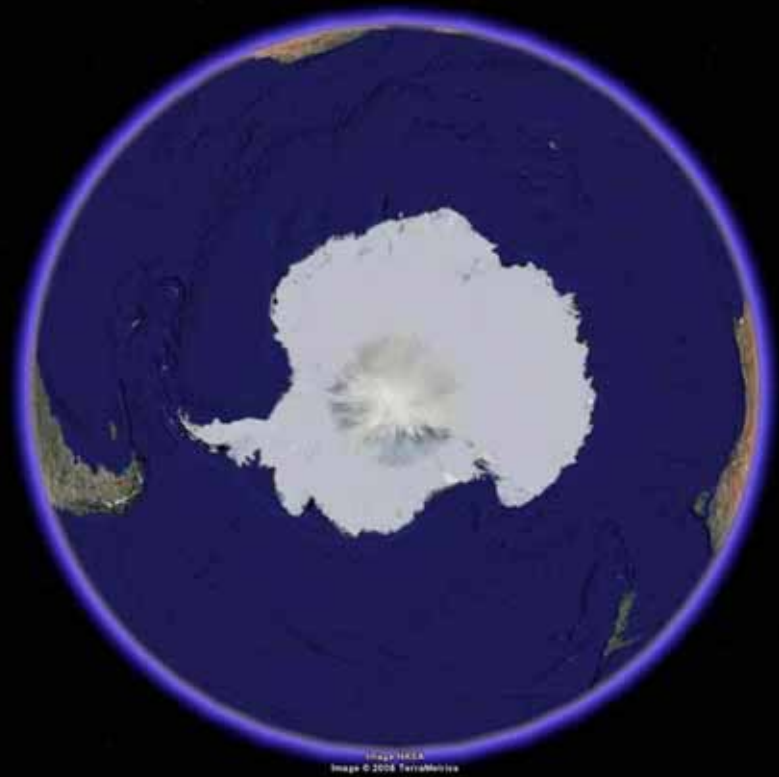
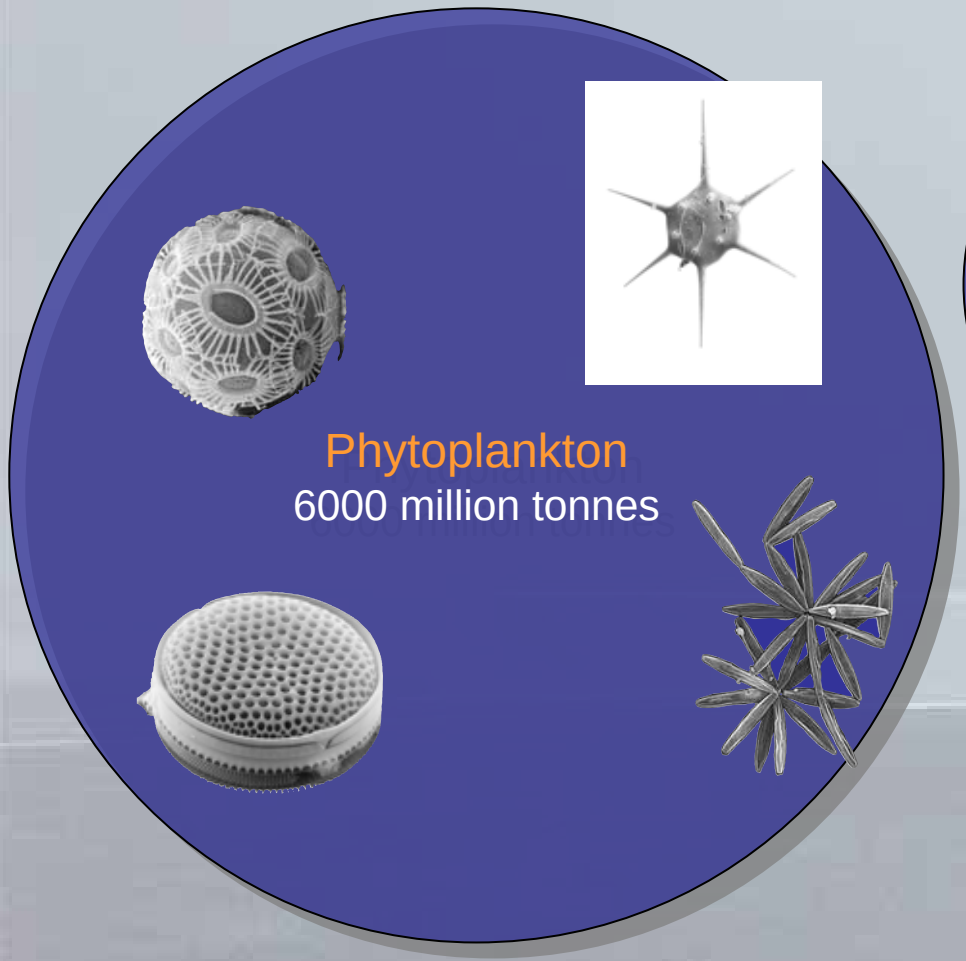


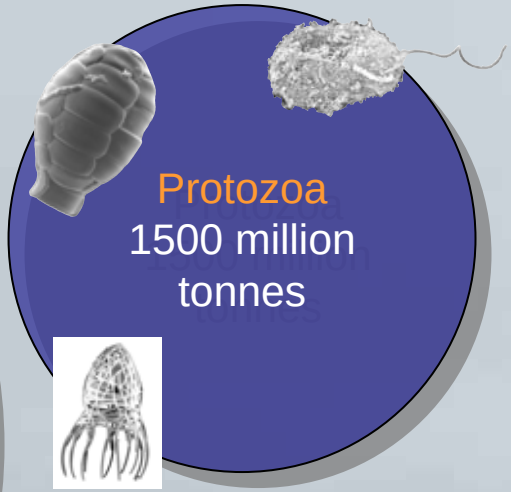
SCAR
Southern Ocean
Continuous Plankton Recorder
Survey

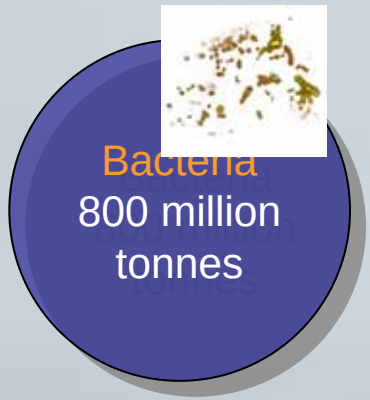
Polar regions probably more susceptible to climate change

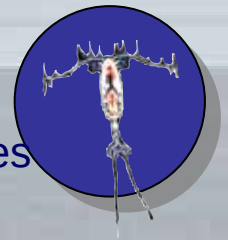


Census of Antarctic Marine Life (CAML) – www.caml.aq
2006/07 2007/08 2008/09

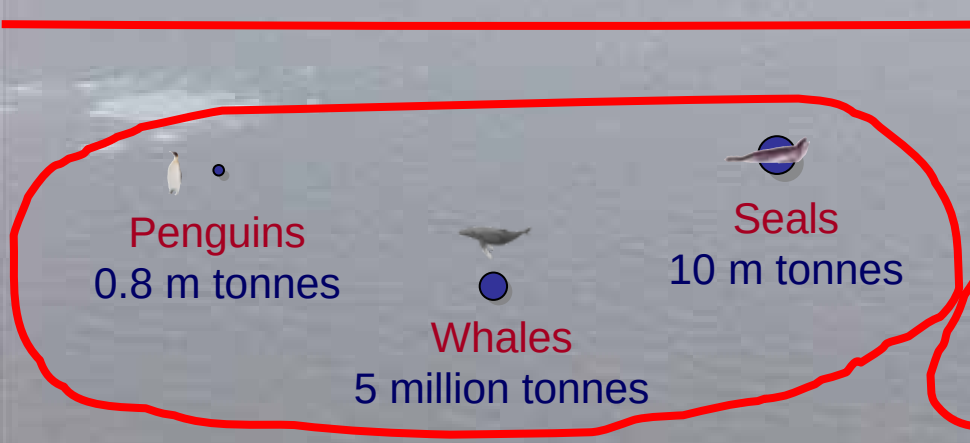

Phytoplankton
6000 million tonnes

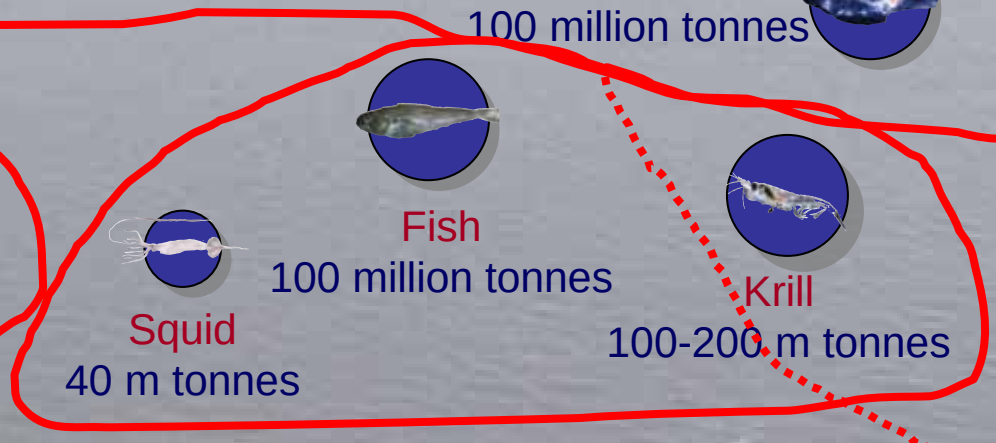

Protozoa
1500 million
tonnes

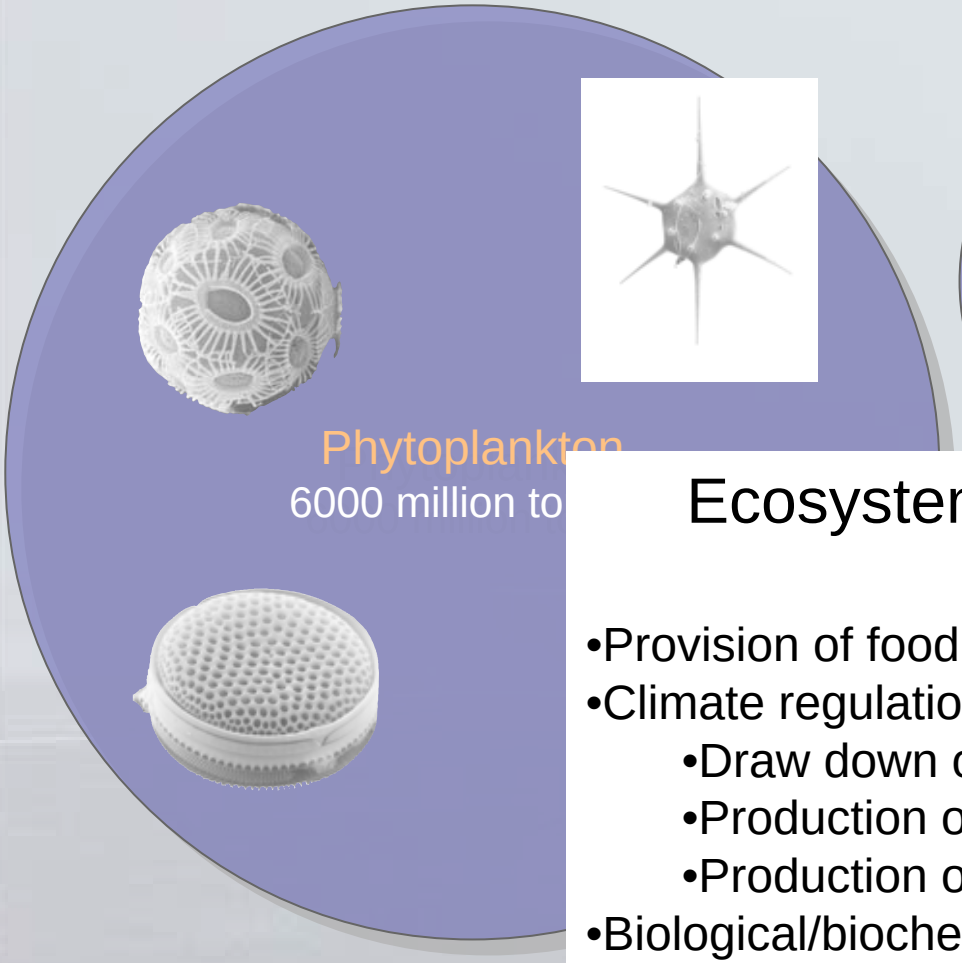

Bacteria
800 million
tonnes


Copepods
300+ million tonnes


Salps
100 million tonnes

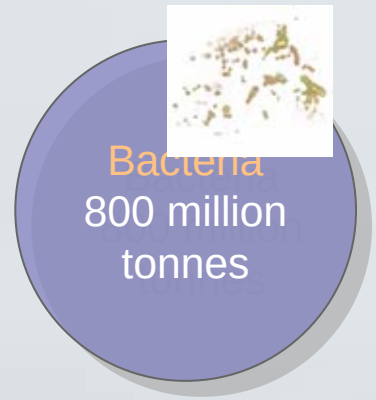

Penguins
0.8 m tonnes
Whales
5 million tonnes
Seals
10 m tonnes


Squid
40 m tonnes
Fish
100 million tonnes
Krill
100-200 m tonnes



Phytoplankton
6000 million to

Protozoa
1500 million
tonnes

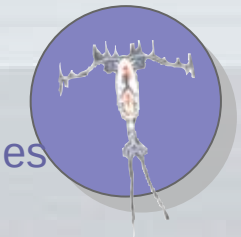


Bacteria
800 million
tonnes

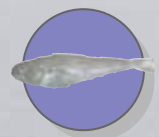
Ecosystem Services

- Provision of food
- Climate regulation
  - Draw down of carbon dioxide
  - Production of oxygen
  - Production of dimethyl sulphide
- Biological/biochemical products

opepods
million tonnes



Salps
100 million tonnes



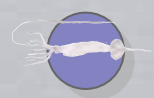
Fish
100 million tonnes

Krill
100-200 m tonnes

Penguins
0.8 m tonnes

Whales
5 million tonnes

Seals
10 m tonnes



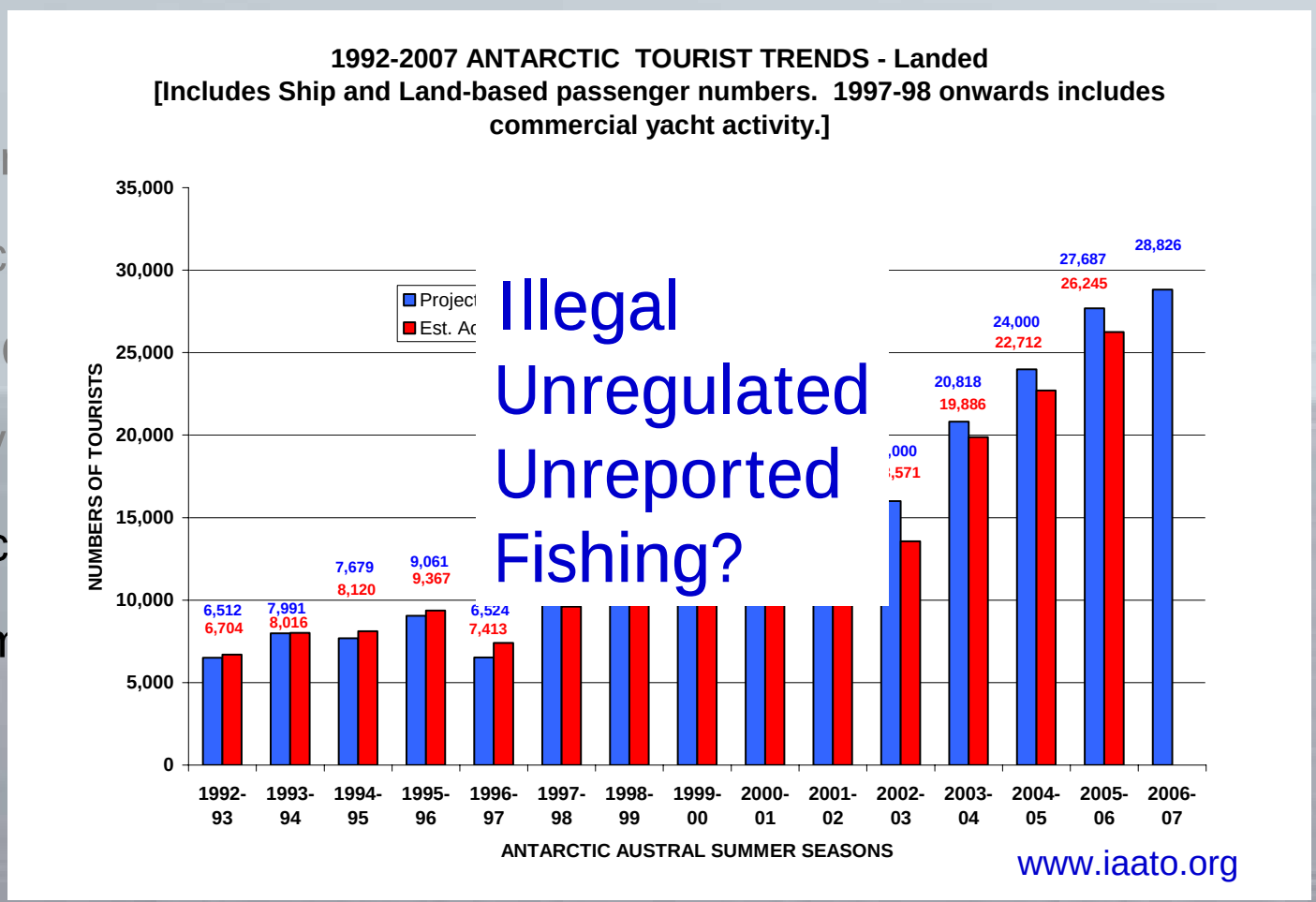
Squid
40 m tonnes

Threats

- Global warming
- Sea ice reduction
- Increase in CO_2 – ocean acidification - calcite and aragonite desaturation
- Increased UV exposure
- Invasive species
- Harvesting Impact – imbalance in species composition
- Increased shipping – IUU and Tourism

Threats

- Global warmi
- Sea ice reduc
- Increase in C
- Increased UV
- Invasive spec
- Harvesting Im
- **Shipping**



Threats

- Global warming – in favour of temperature tolerant species
- Sea ice reduc
- Increase in C
- Increased UV
- Invasive species
- **Harvesting Impact – imbalance in species composition**
- Shipping

Commission for the Conservation of Antarctic Marine Living Resources
CCAMLR

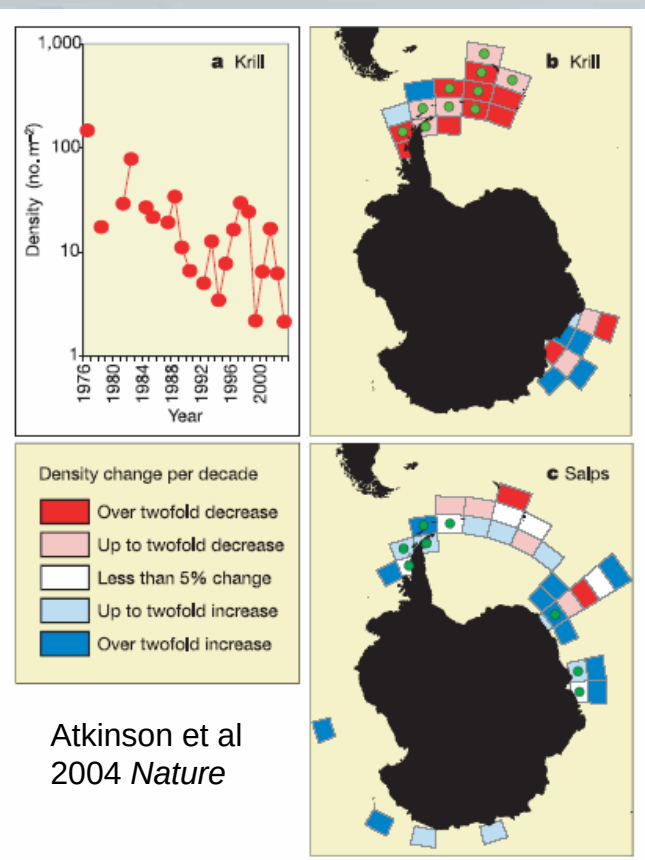
• Ecosystem management approach
• IUU

Threats

- Global warming – in favour of temperature tolerant species
- Sea ice reduction – decline in sea ice biota
- Increase in CO_2 – ocean acidification - calcite and aragonite desaturation
- Increased UV exposure
- **Invasive species** – change in species range, e.g. *Emiliania huxleyi*
- Harvesting Impact – imbalance in species composition
- Shipping

Global Warming & Sea Ice Reduction

- Southern Ocean warming
  - in favour of temperature tolerant species
  - Antarctic krill prefer <2°C
- Significant reduction in sea ice extent between 1960s and 1970s
  - reduction in habitat
  - reduction in ice algae production
  - decline in sea ice biota
- Decline in abundance of Antarctic
  - Increase in salp abundances



Atkinson et al 2004 *Nature*

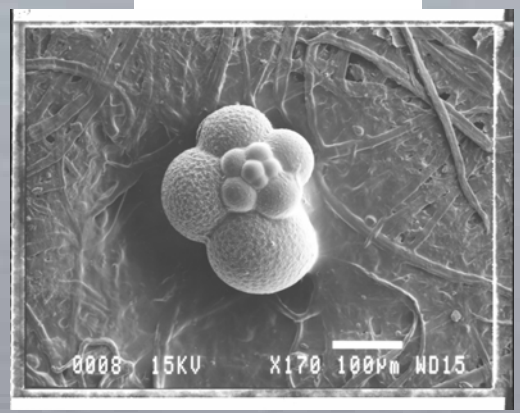
Ocean Acidification

- CO_2 increased 280 to 380 ppm in 200+ years, pH decreased by 0.1
- By 2100, pH projected to decrease 0.5, possibly 0.77 eventually

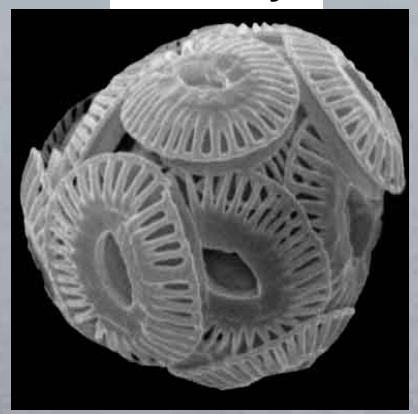
- Three main effects
  - Physiological, oxygen metabolism of animals – fish & squid ... krill?
  - Change in availability and chemical form of nutrients
  - Disruption of calcium carbonate formation and $CaCO_3$ flux

Pteropod

Foraminiferan

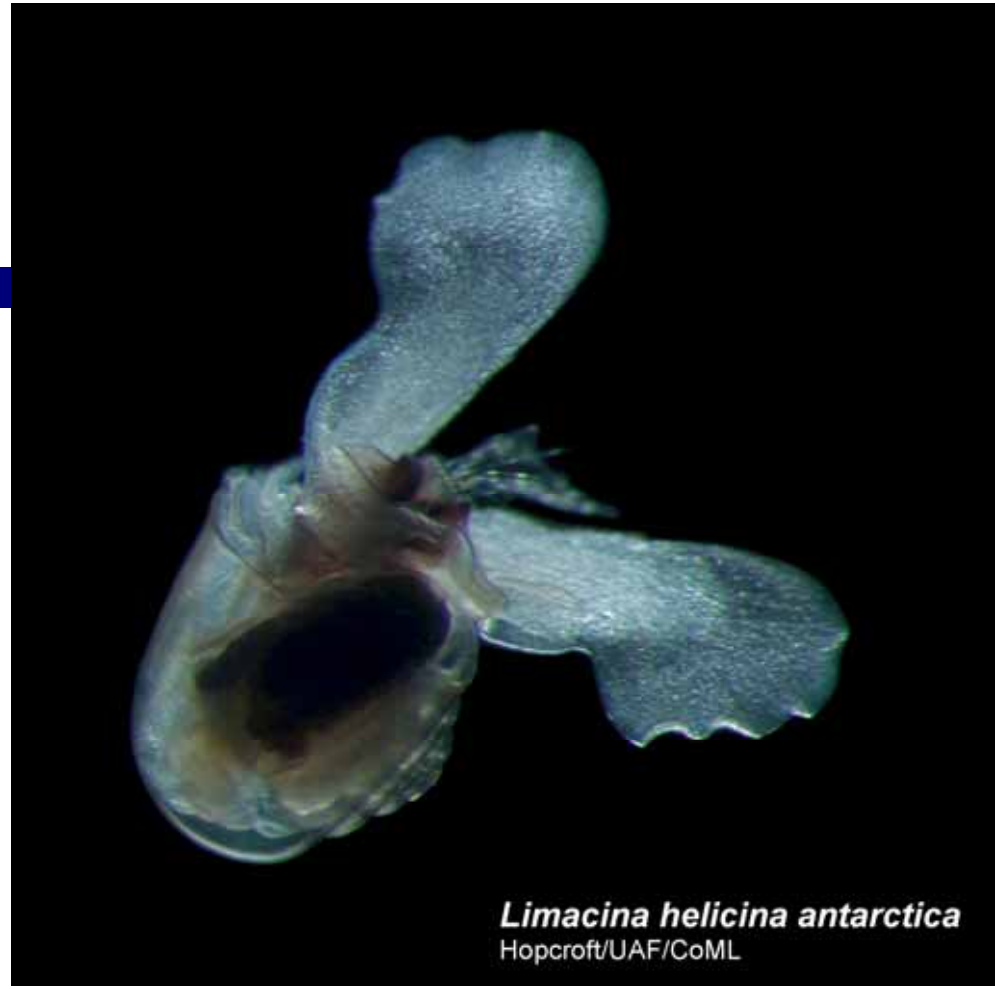


E. huxleyi



- Extinction of some plankton or change in composition

These may become extinct in Antarctic waters due to ocean acidification 2050 to 2100

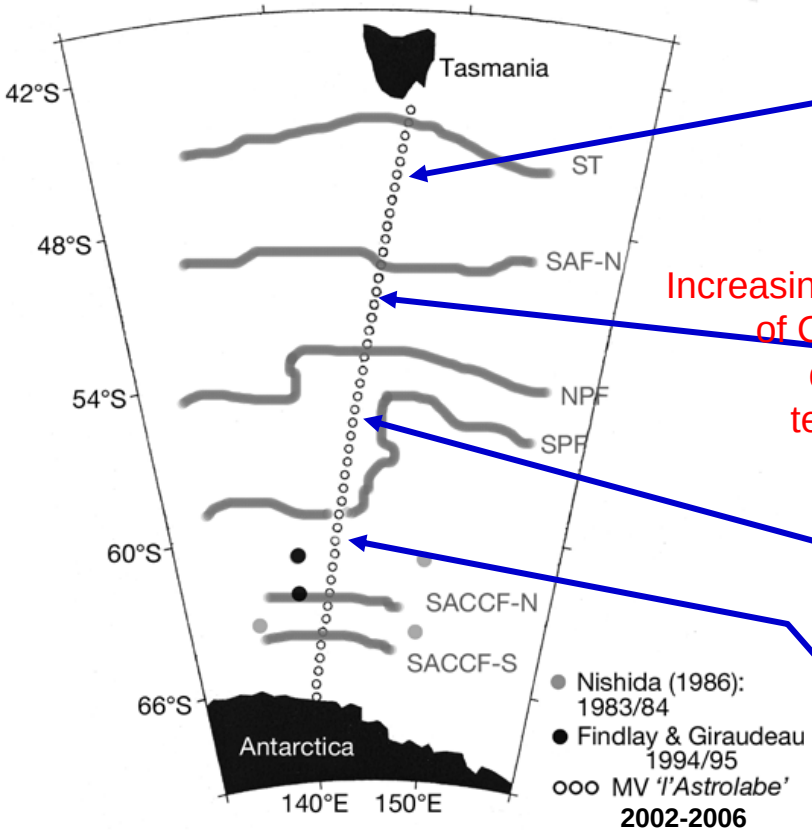


Pteropods:-

- Occur in upper 300 m
- Can be more abundant than krill
- Density $10^5 m^{-3}$ in Ross Sea
- Can account for large amount of the annual export flux of CO_3^{2-} and organic C
- South of the Polar Front can dominate the export flux of $CaCO_3$
- Food of carnivorous zooplankton, fish (myctophids & nototheniids) and other zooplankton, e.g. gymnosome pteropods

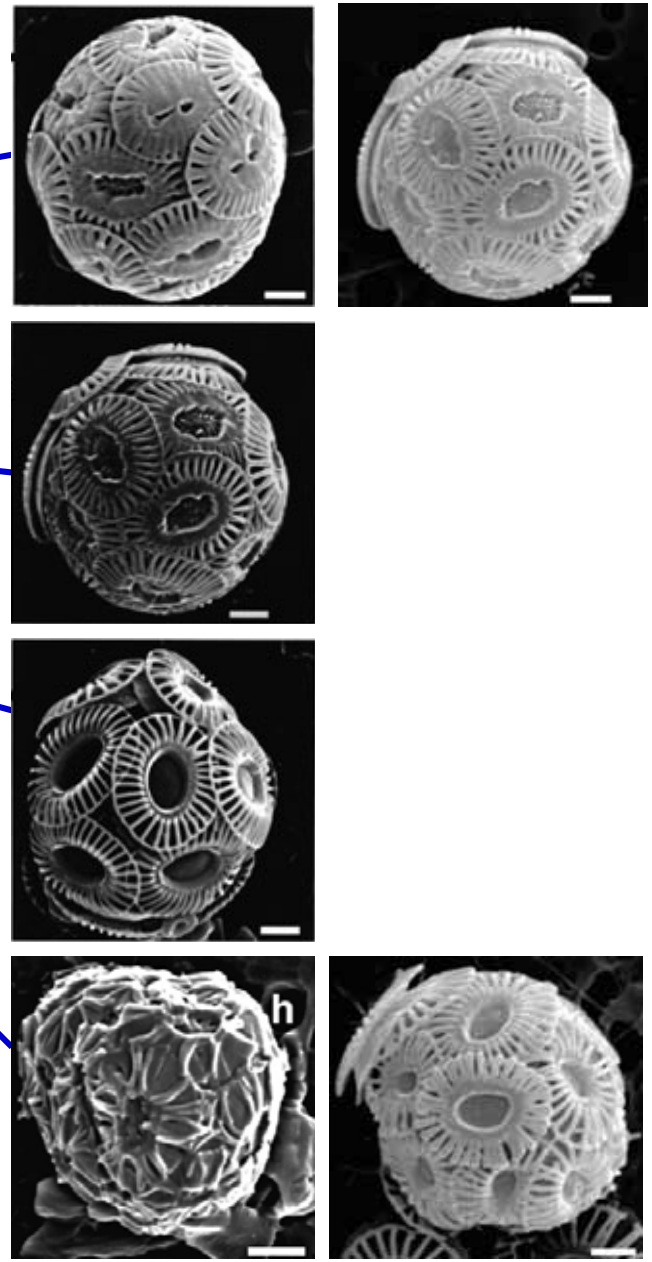
Emiliania huxleyi

Cubillos et al MEPS 2008



Increasing solubility of $CaCO_3$ with decreasing temperature

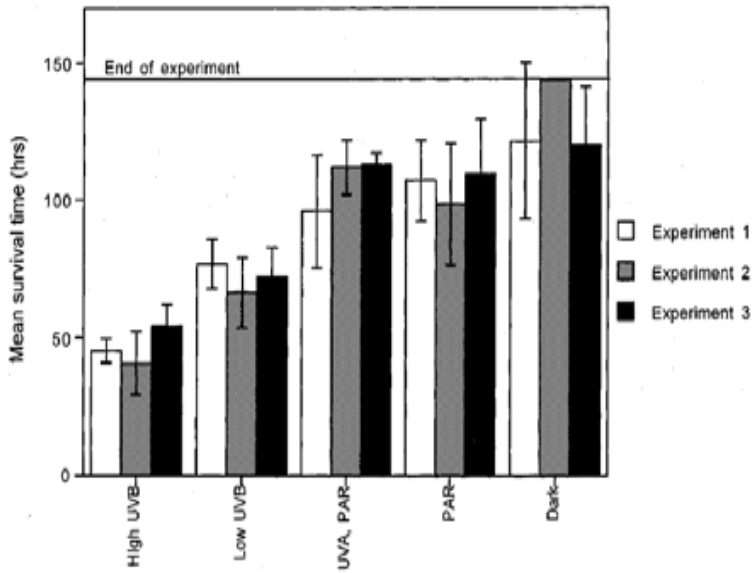
Morphotypes



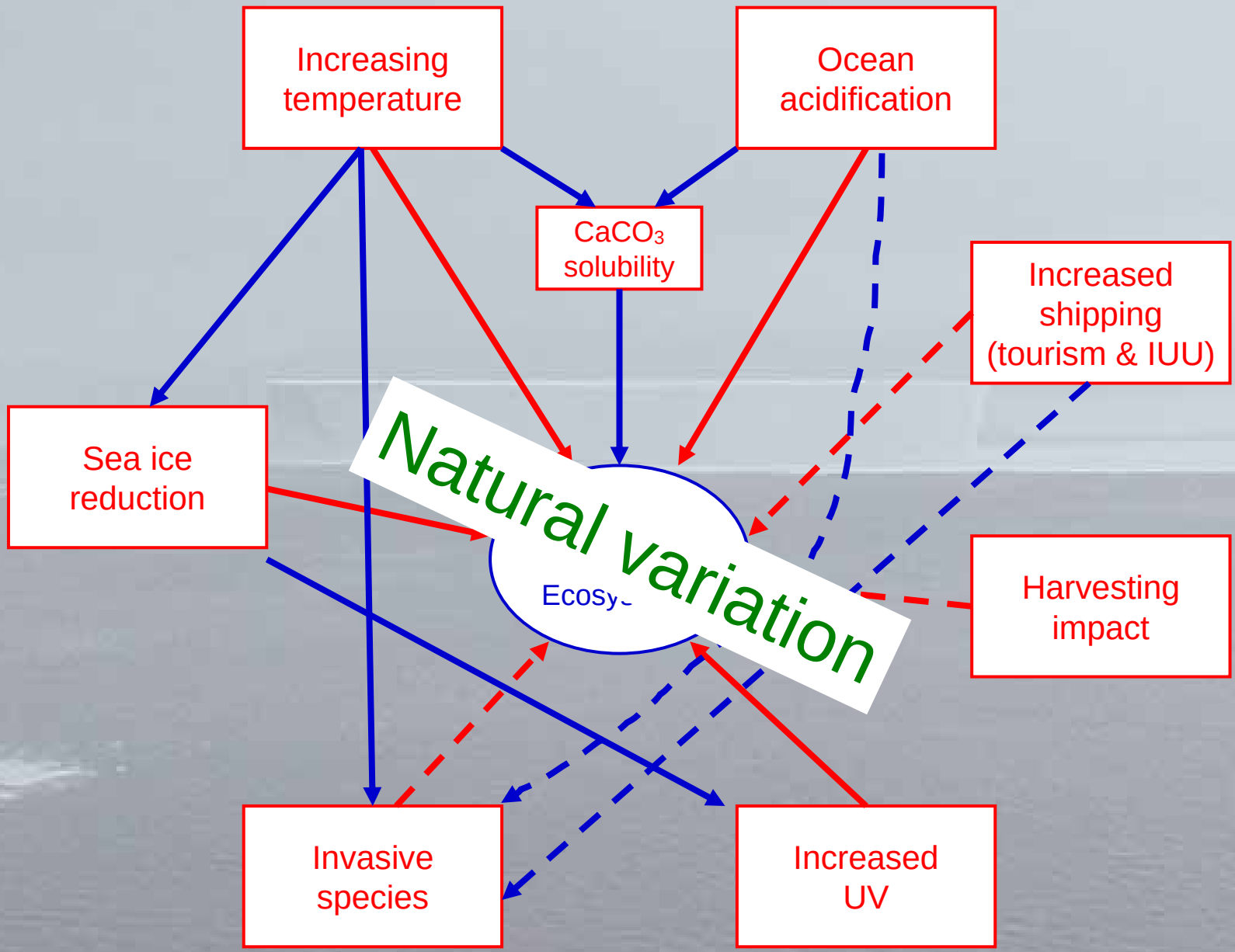
- Prior to 1995, *E. huxleyi* was absent or extremely rare south of 60°S
- 2002-2006 very abundant 100 cells ml^{-1}
- 2004 – same along 45°E (Mohan et al 2007)

UV Impact

- Phytoplankton Chl *a* production drops by 56% when UV is below 300 DU
- UV is usually > 300 DU in high summer – no ice cover
- UV drops to about 180 DU in spring
  - retreating ice from maximum to minimum extent
  - global warming reducing ice cover
- UVB levels equivalent to 10m depth can kill Antarctic krill
- Can damage DNA
- Also effects zooplankton and ice fish eggs



Newman et al 1999


Increasing temperature
Ocean acidification
$CaCO_3$ solubility
Increased shipping (tourism & IUU)
Sea ice reduction
Natural variation
Ecosy
Harvesting impact
Invasive species
Increased UV

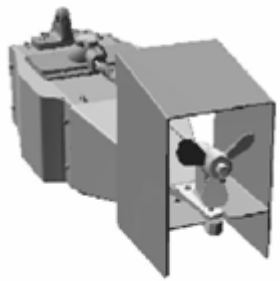
SCAR Southern Ocean CPR Survey

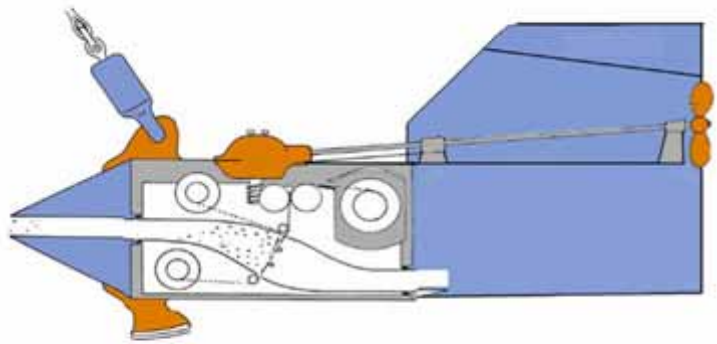
- Map the biodiversity and distribution of zooplankton, including euphausiid (krill) life stages, in the Southern Ocean.
- Use the sensitivity of plankton to environmental change as early warning indicators of the health of Southern Ocean.
- Serve as reference on the general status of the Southern Ocean for other monitoring programs
  - eg CCAMLR Ecosystem Monitoring Program (C-EMP)
  - Southern Ocean Observing System (SOOS)

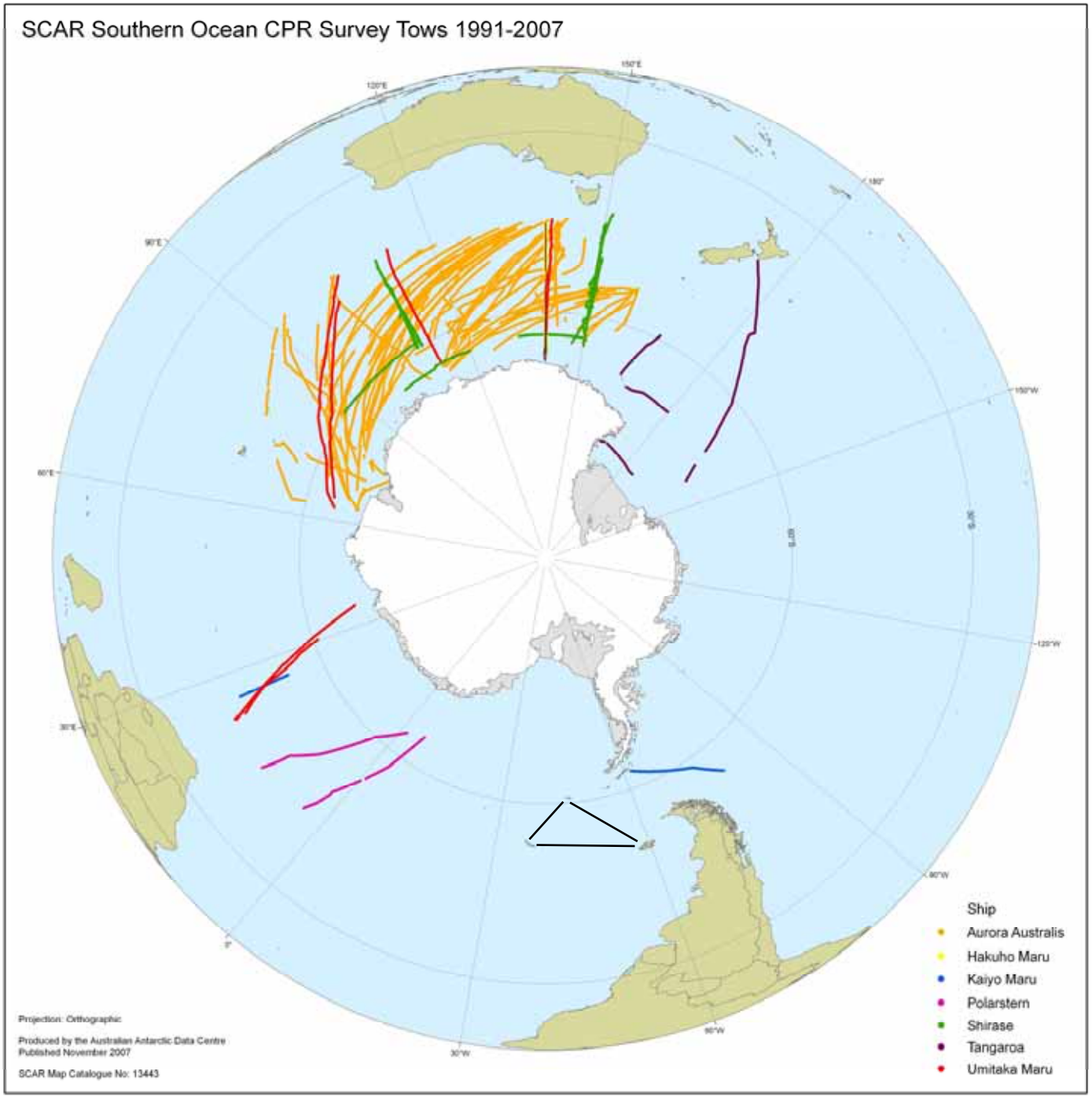
SCAR
Southern Ocean
Continuous Plankton Recorder
Survey

Sir Alister Hardy with Type II Mark I CPR 1931

AAD designed CPR
Type II – Mk V
1995







The Survey covers >50 % of the Southern Ocean October to April

Approximately 40-50 tows each year >4,000 samples p.a. 5 n-mile resolution

110,000 nautical miles of data have been collected since 1991

This represents more than 22,000 samples, 200+ taxa +environmental data

Australia, Japan, NZ, Germany, UK, USA, Russia

Zooplankton before 2000-2001

40ºS

Sub-Tropical Front

Hobart

Sub-Antarctic Front

Small zooplankton

50ºS

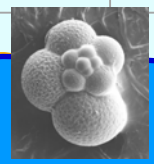
Small calanoid copepods

Oithona similis

Cyclopoid copepods

Foraminiferans

Neogloboquadrina pachyderma



Appendicularians

POOZ

Small euphausiids, e.g *Thysanoessa macrura*

Large calanoid copepods. e.g. *Calanoides acutus*

Euphausia superba

SIZ

Small euphausiids, e.g *Thysanoessa macrura*

Casey

Mawson

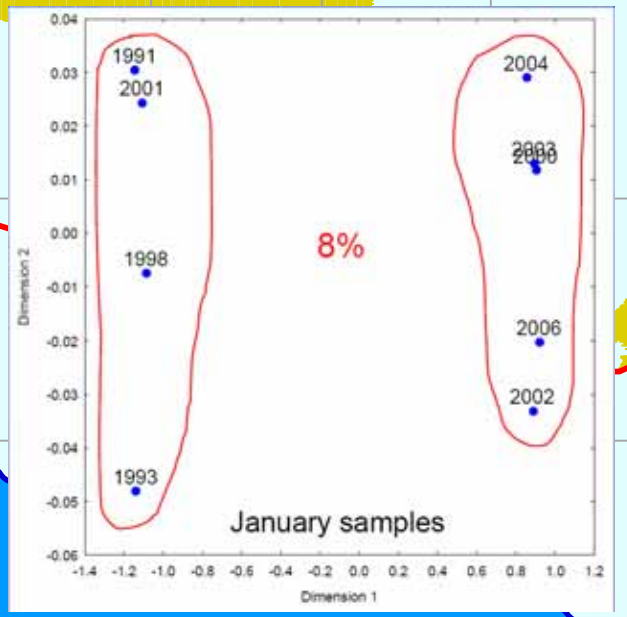
Davis

Large zooplankton

60ºE 70ºE 80ºE 90ºE 100ºE 110ºE 120ºE 130ºE 140ºE 150ºE 160ºE

G.W. Hosie AAD
SCAR Southern Ocean CPR Survey

Sea Ice Zone after 2000-2001



Sub-Tropical Front

Sub-Antarctic Front

POOZ

SIZ

Casey

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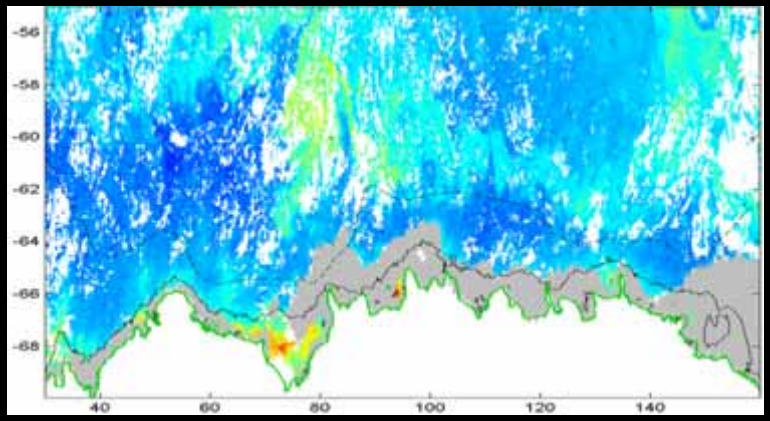
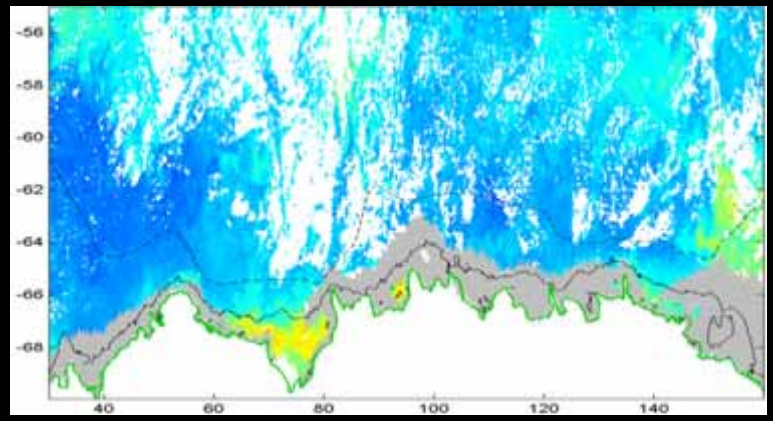
60°E 70°E 80°E 90°E 100°E 110°E 120°E 130°E 140°E 150°E 160°E

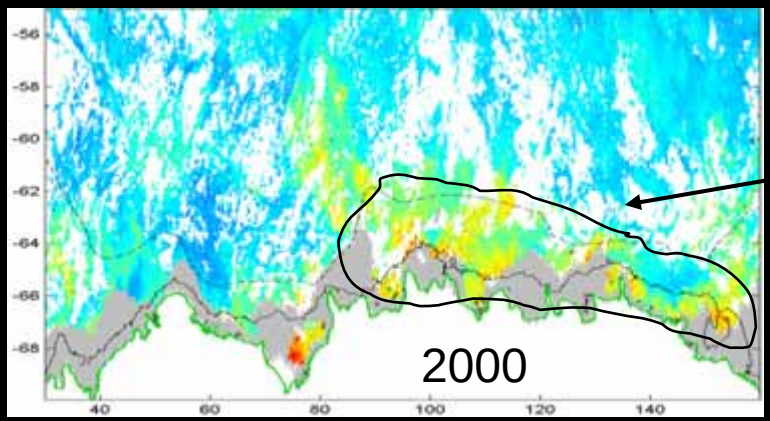
G.W. Hosie AAD
SCAR Southern Ocean CPR Survey

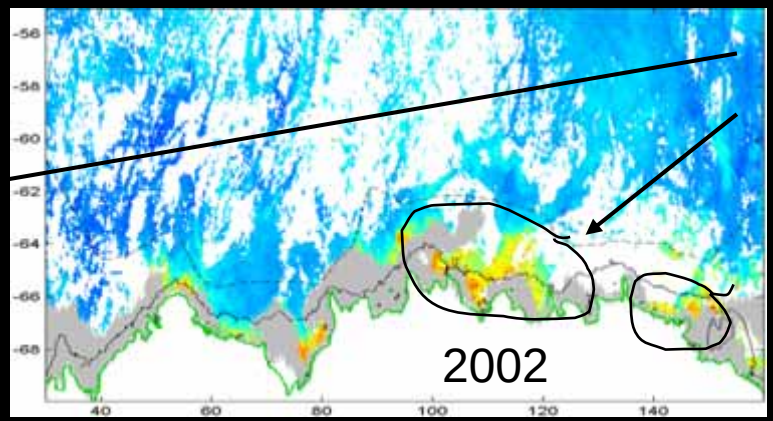




Group 1

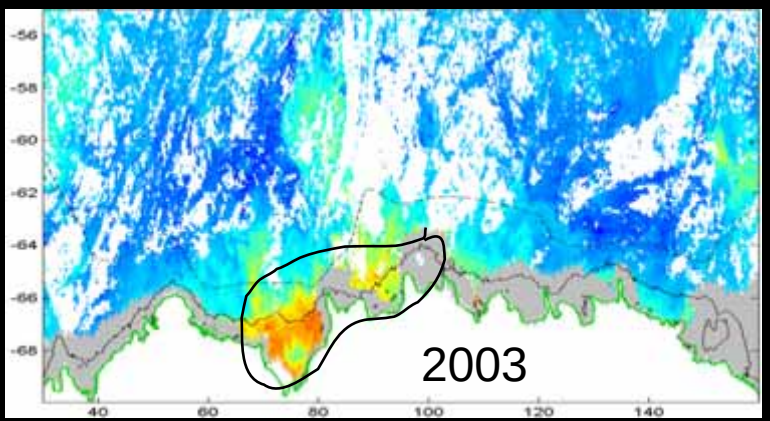
SeaWiFS
Chl *a* data
averaged for
mid-January

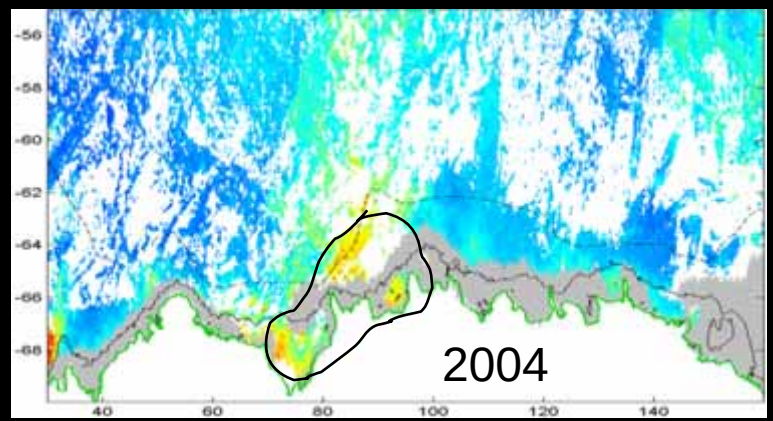


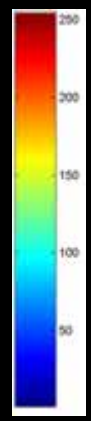


Higher
phytoplankton
abundance –

normally SIZ
spp or
a change?







Group 2

Permanent Open Ocean Zone 2004/05

40ºS

Sub-Tropical Front

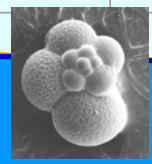
Hobart

Sub-Antarctic Front

50ºS

Oithona similis

50 to <20%



POOZ

2 to >50%

SIZ

Casey

Mawson

Davis

60ºE 70ºE 80ºE 90ºE 100ºE 110ºE 120ºE 130ºE 140ºE 150ºE 160ºE

K. Takahashi AAD-NIPR
SCAR Southern Ocean CPR Survey

SO-CPR Survey – Repeat survey of Drakes Passage

- 1927 transect - high abundances of large copepods, chaetognaths, *Limacina*
- 2000 transect – cyclopoids, small calanoids, very few chaetognaths

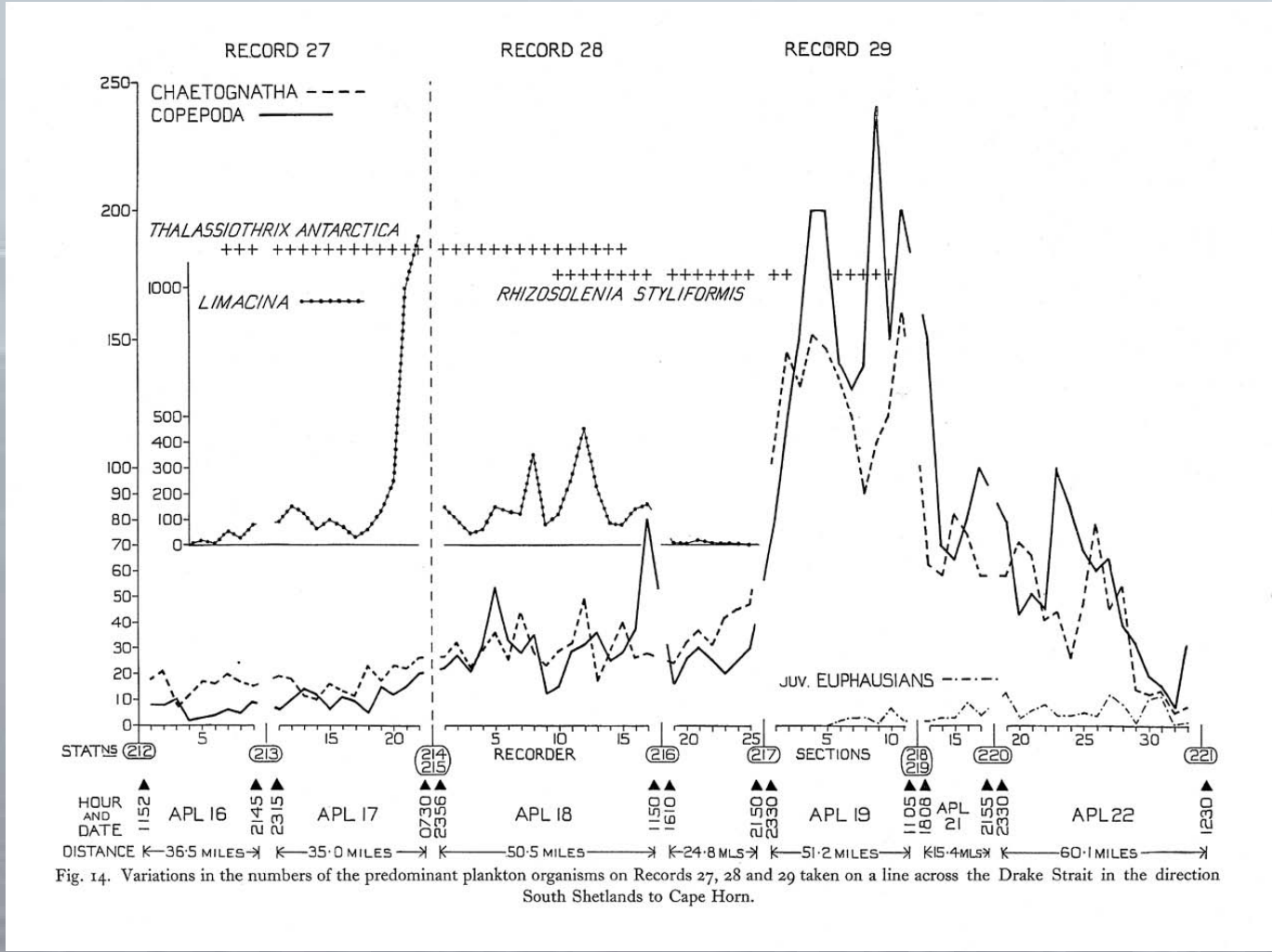


Fig. 14. Variations in the numbers of the predominant plankton organisms on Records 27, 28 and 29 taken on a line across the Drake Strait in the direction South Shetlands to Cape Horn.

Hardy 1936 Discovery Reports 11, 511-538

Take Home Message

- Climate change should not be considered in isolation
  - need to consider all potential stress factors and interactions
  - combination of relatively minor changes may trigger an effect

- Plankton are very sensitive to changes in their environment
  - they can synthesize and amplify signals

SCAR
Southern Ocean
Continuous Plankton Recorder
Survey

“Plankton know more about climate change than we do!”

Prof. Robin Pingree
SAHFOS Workshop, Plymouth, May 2008