Marine Life and Change in the Southern Ocean

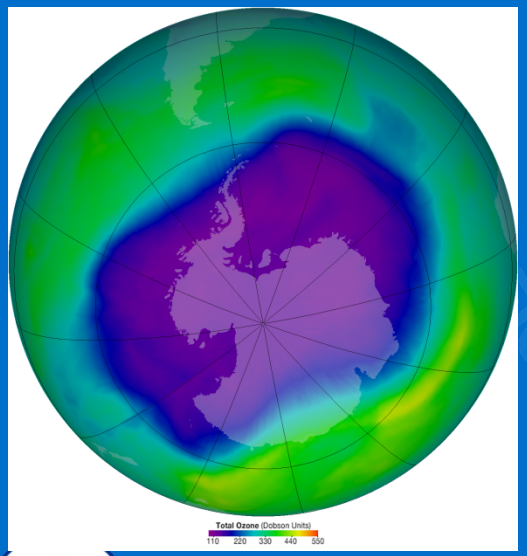
Prof. Dr. Karin Lochte

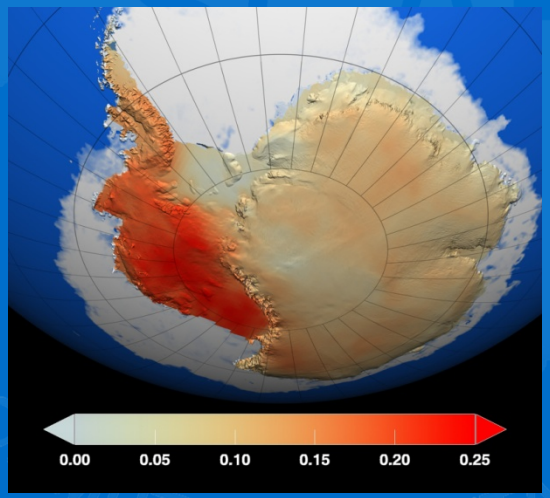
Antarctica in Changing World

Antarctica a symbol of the great wilderness and pristine environment ?

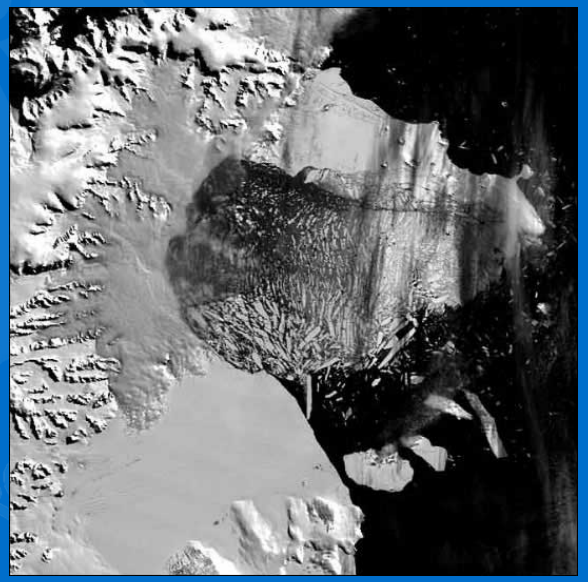
Antarctica is inextricably linked to global atmospheric, oceanographic and climatic processes

... and therefore exposed to the impact of human activities in the rest of the world.





Credit: NASA Earth Observatory



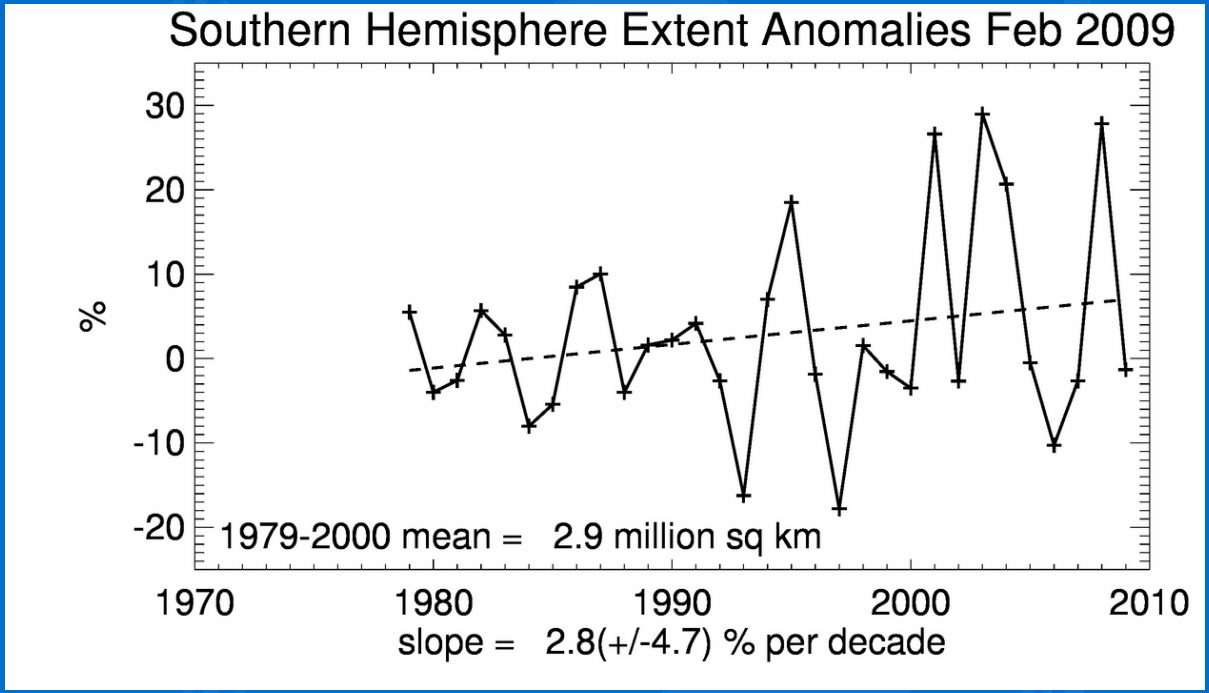
Particularities of Antarctic Marine Ecosystems

- Antarctic organisms have adapted their seasonal cycles to the dynamic interface between ice and water. This interface ranges from the micrometre-sized brine channels within sea ice to the planetary-scale advance and retreat of sea ice.
- Antarctic marine ecosystems are particularly sensitive to climate change because small temperature differences can have large effects on the extent and thickness of sea ice

Threats

- Global warming and sea ice reduction
- Ocean acidification
- Invasive species

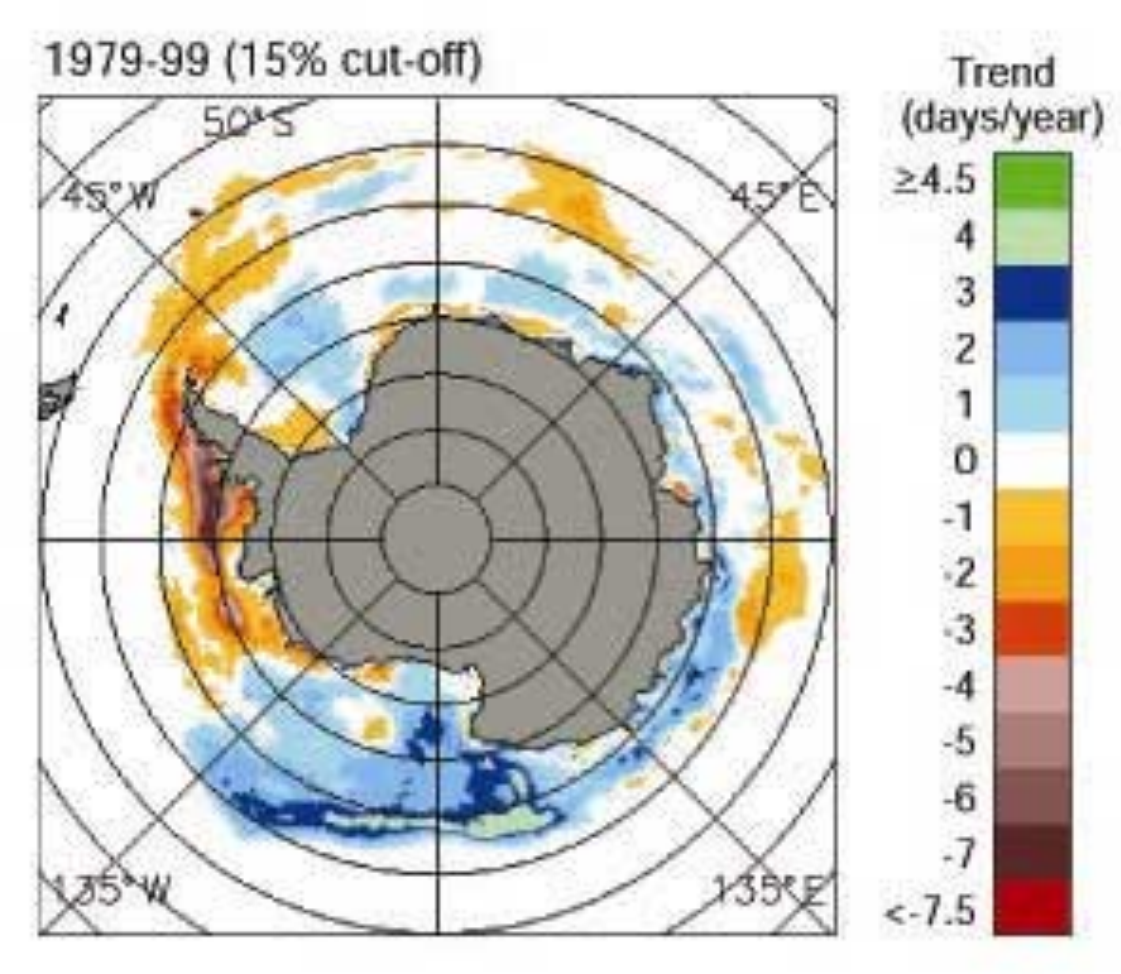
Antarctic sea ice trends



The National Snow and Ice Data Center, Boulder, Co

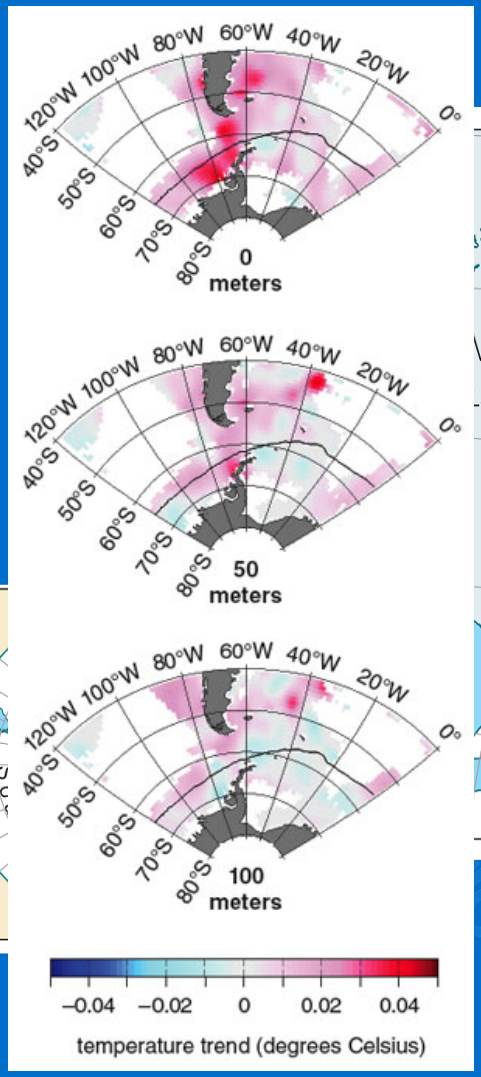
Sea ice changes

- The length of the sea ice season has shortened over past couple of decades
- Sea ice in Bellingshausen Sea has retreated since 1950s



(Parkinson, 2002)

Temperature hotspot at the Antarctic Penisula



	Station	Period / years	Trend (°C / century)	Significance
Long-records on the Antarctic Peninsula	Faraday (renamed Vernadsky in 1996)	50	+5.6 ± 4.3	99 %
	Esperanza	50	+3.3 ± 2.8	95%
	Bellingshausen	32	+3.5 ± 4.6	90%
Short-records on the Antarctic Peninsula	Marambio	26	+5.7	Unknown
	Rothera	23	+11 ± 13	95%
	Butler Is. Automatic Weather Station	9	+20 ± 16	Not significant
Other Antarctic records	Halley	44	0.0 ± 4.6	Not significant
	Orcadas	96	+2.0 ± 1.0	99%
	Amundsen-Scott	43	-2.0 ± 2.1 (cooling)	95%

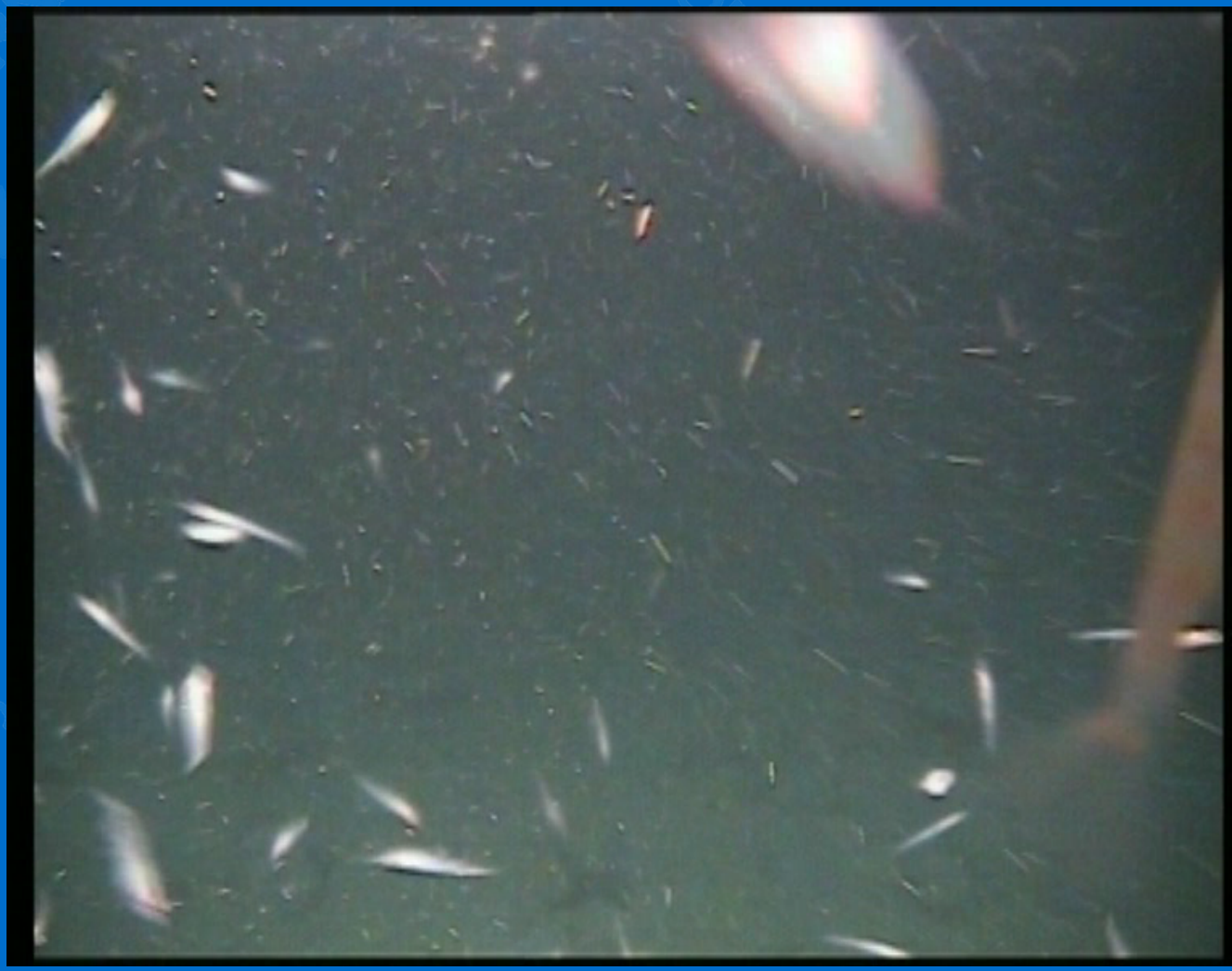
David G. Vaughan et al., 2001,
CLIMATE CHANGE: Devil in the Detail

Michael P. Meredith and John King 2005

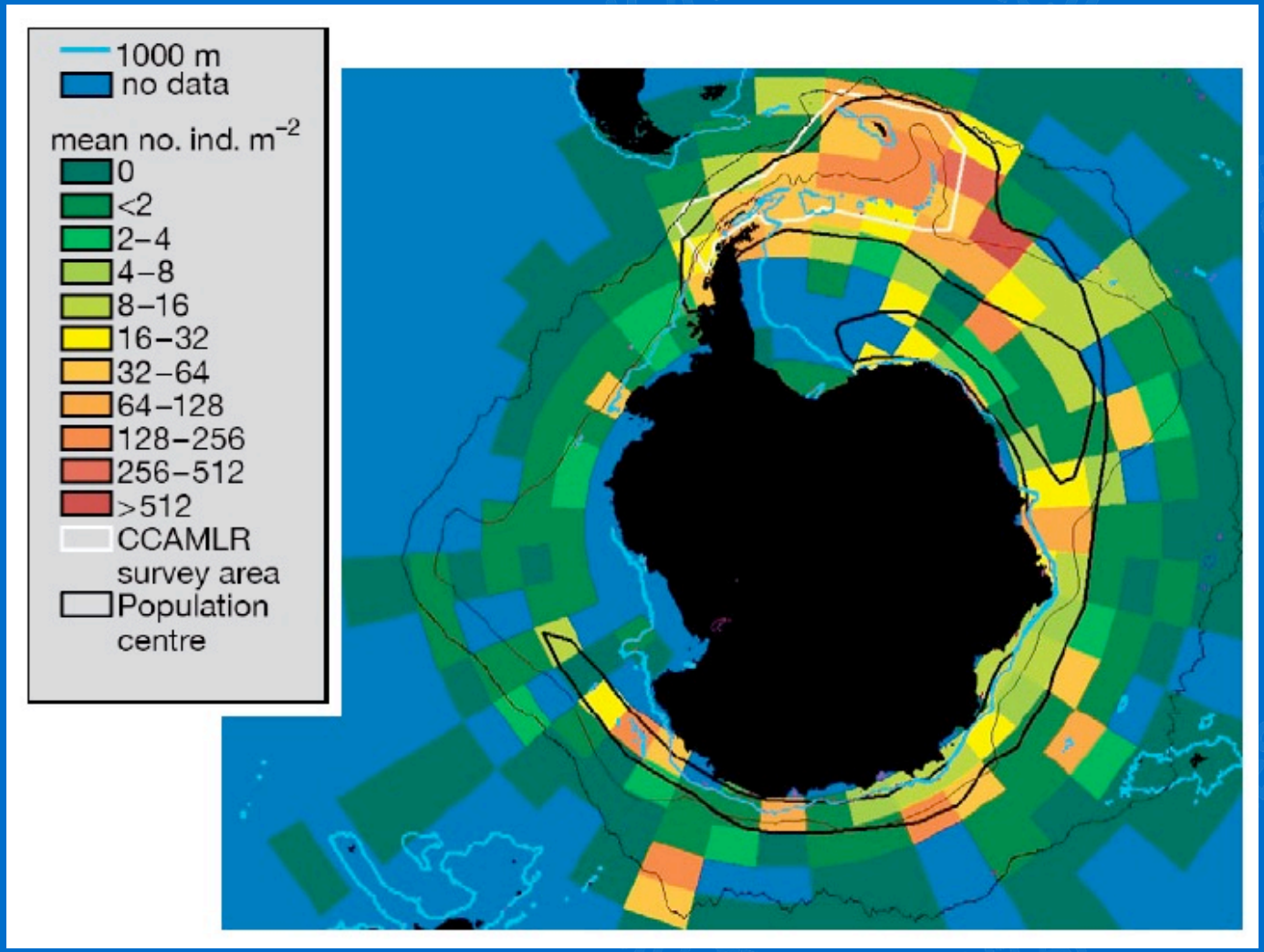
How do Southern Ocean ecosystems operate?

The pelagic ecosystem in the Southern Ocean focuses on Krill

Their spatial and temporal occurance is important

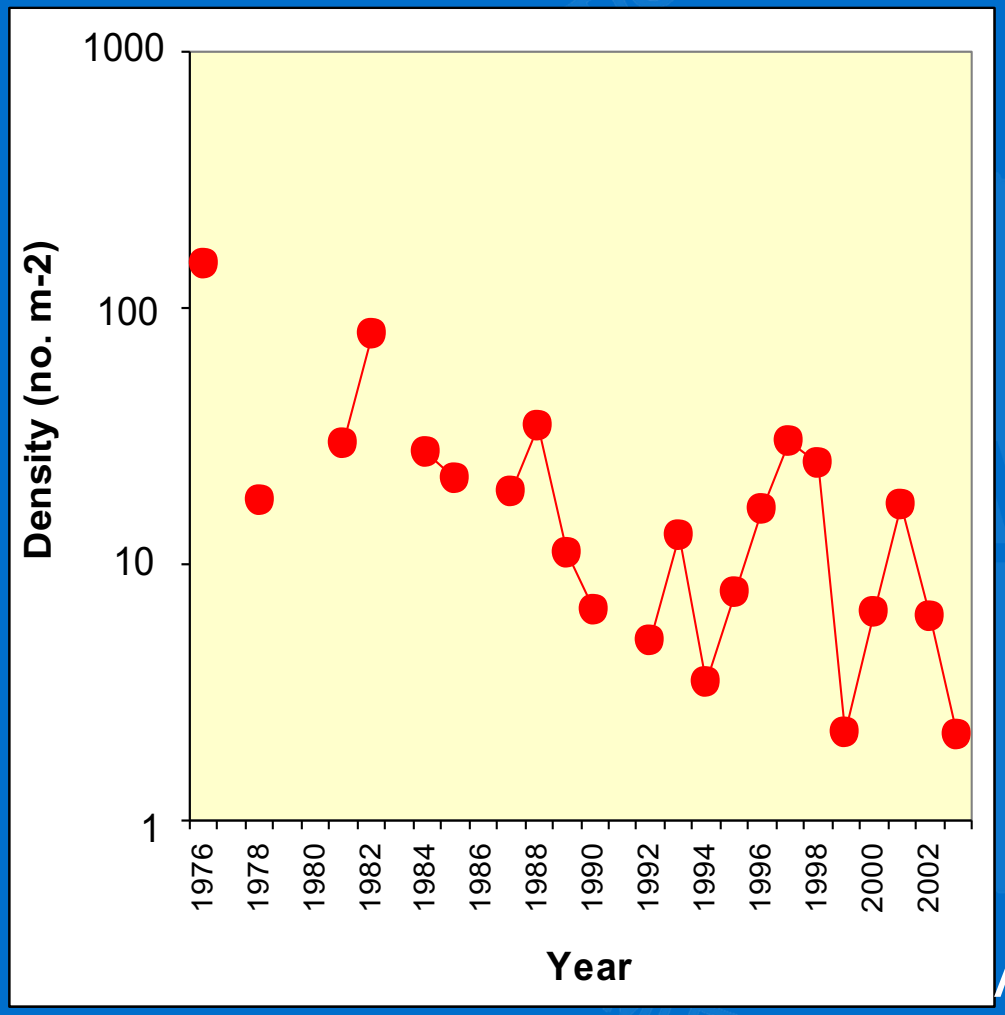


Circumpolar distribution of Antarctic Krill

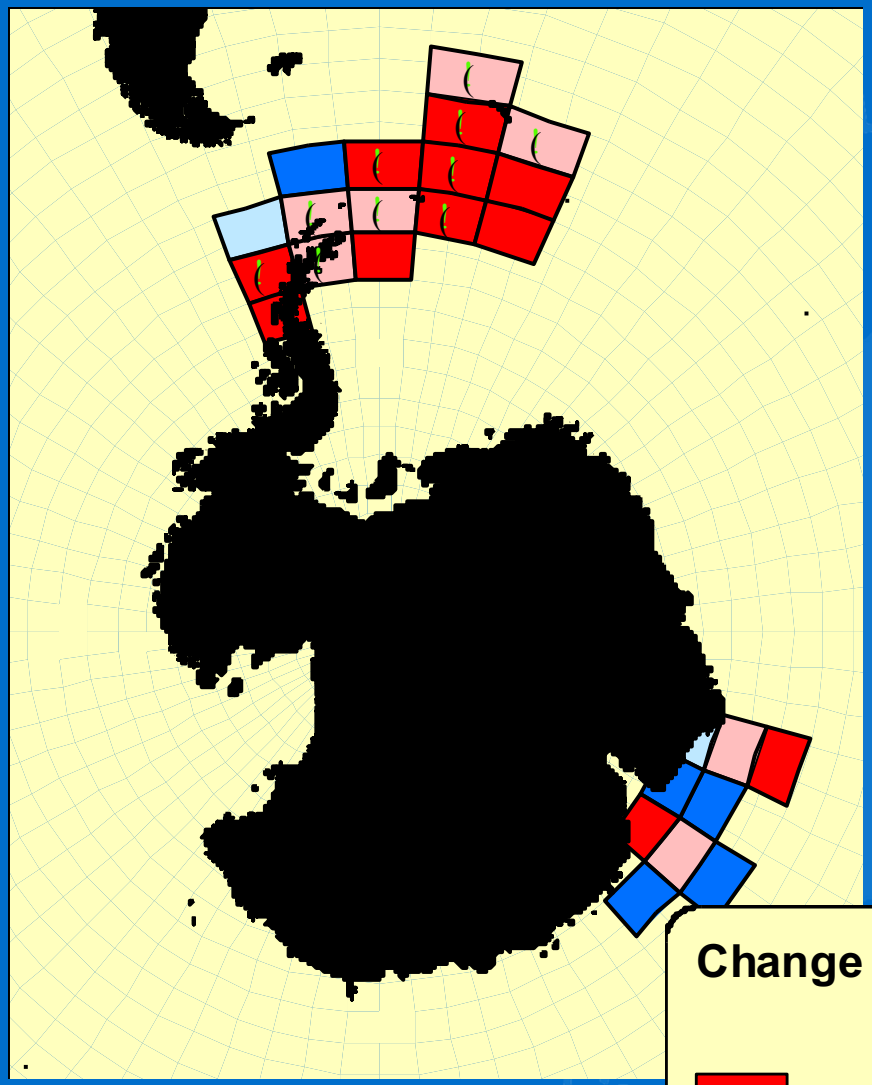


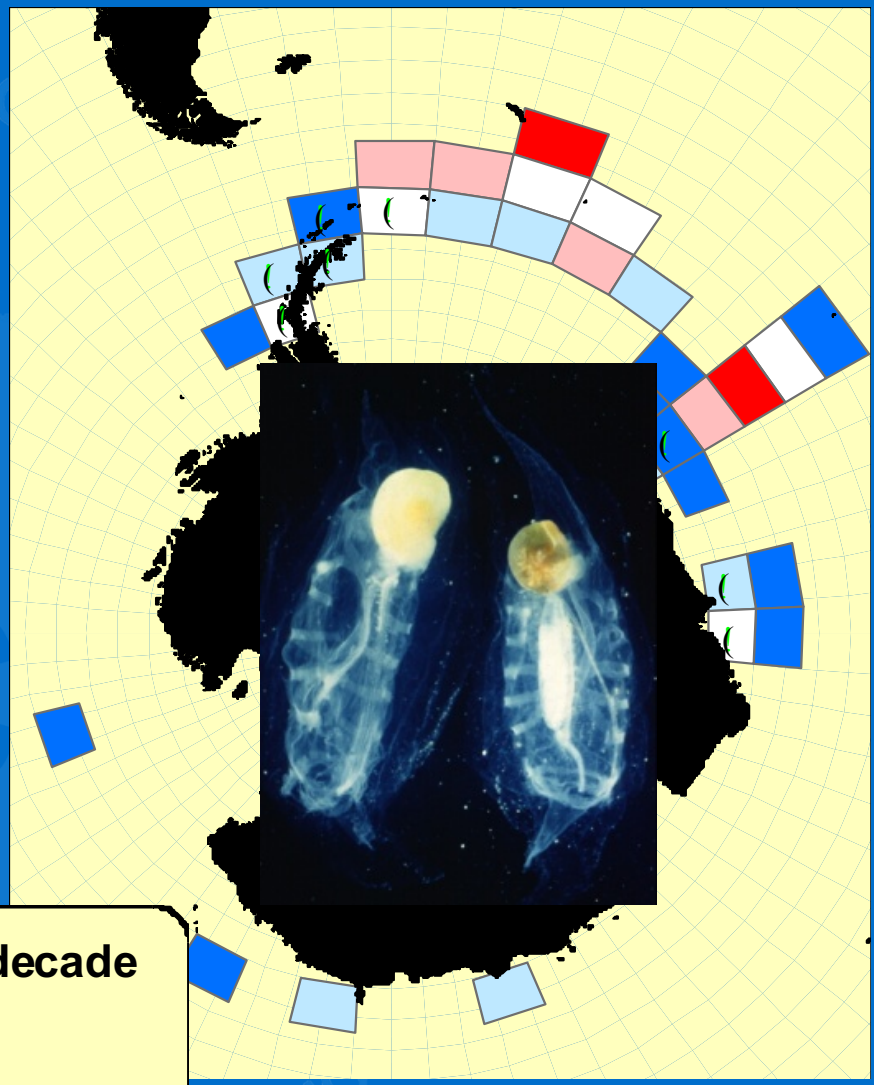
Atkins et al. 2008, Data from KRILLBASE (8789 stations including those north of the Antarctic Polar Front)

Responses of Southern Ocean Ecosystems to Change



Atkinson et al, 2004, Nature





Change per decade

- over twofold decrease
- up to twofold decrease
- less than 5% change
- up to twofold increase
- over twofold increase

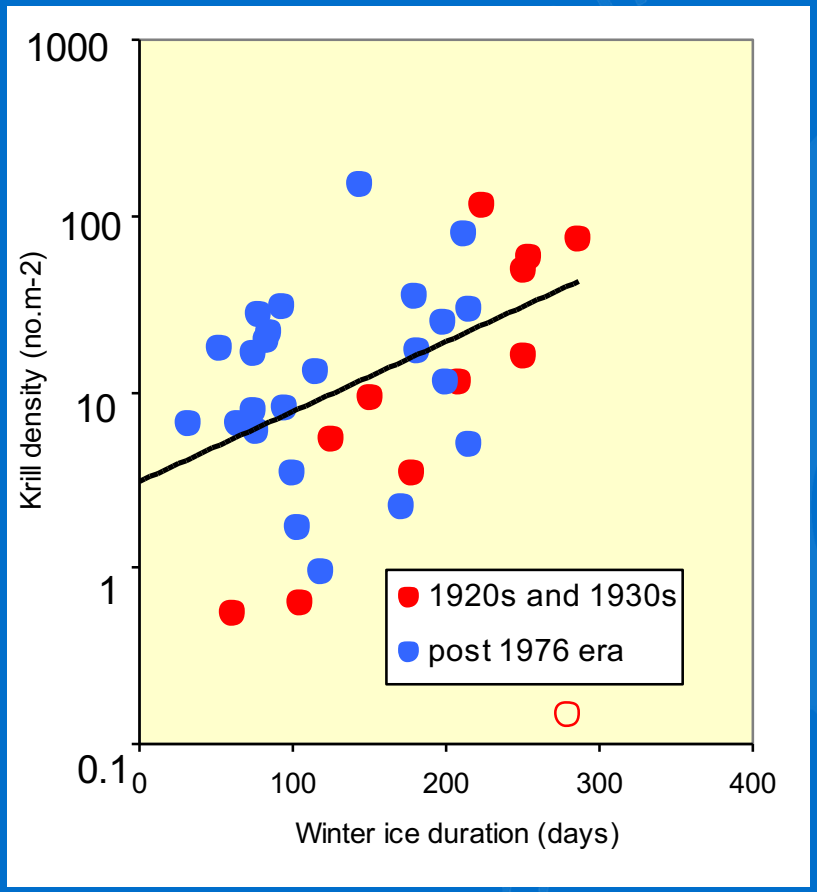
Krill decrease

Salp increase

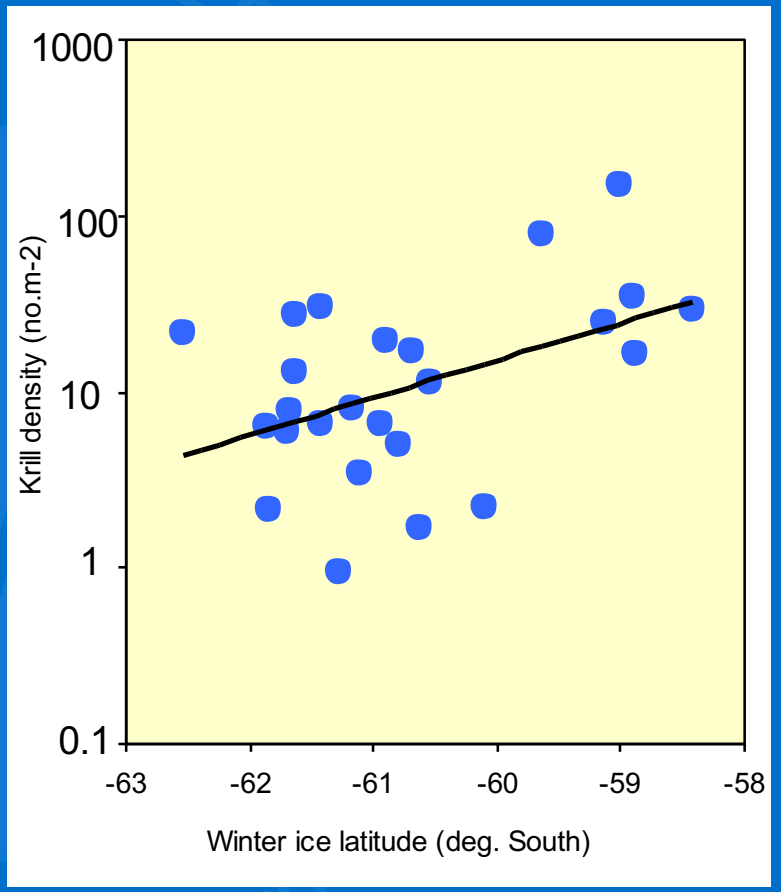
Scientific Committee on Ant

April 2009 SCAR

Summer krill abundance versus ice cover the previous winter



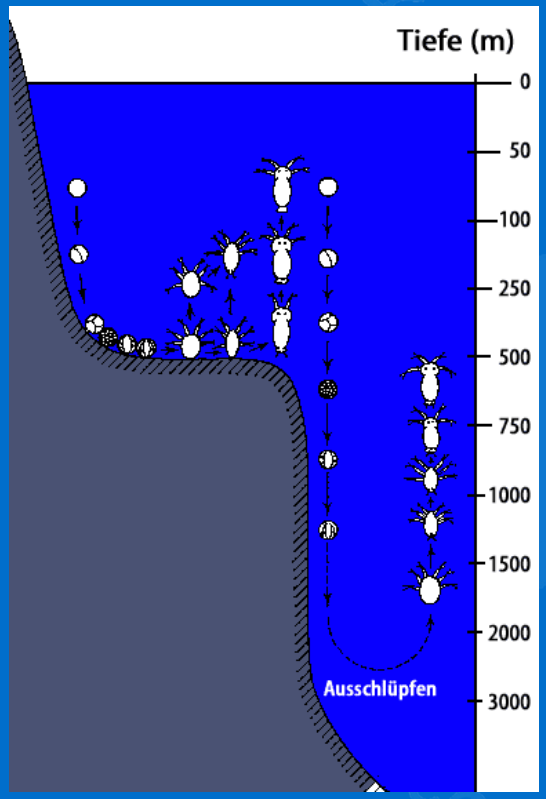
Ice duration at the South Orkneys



Ice extension across Scotia Sea (satellite observations in Sep)

(Atkinson et al 2004)

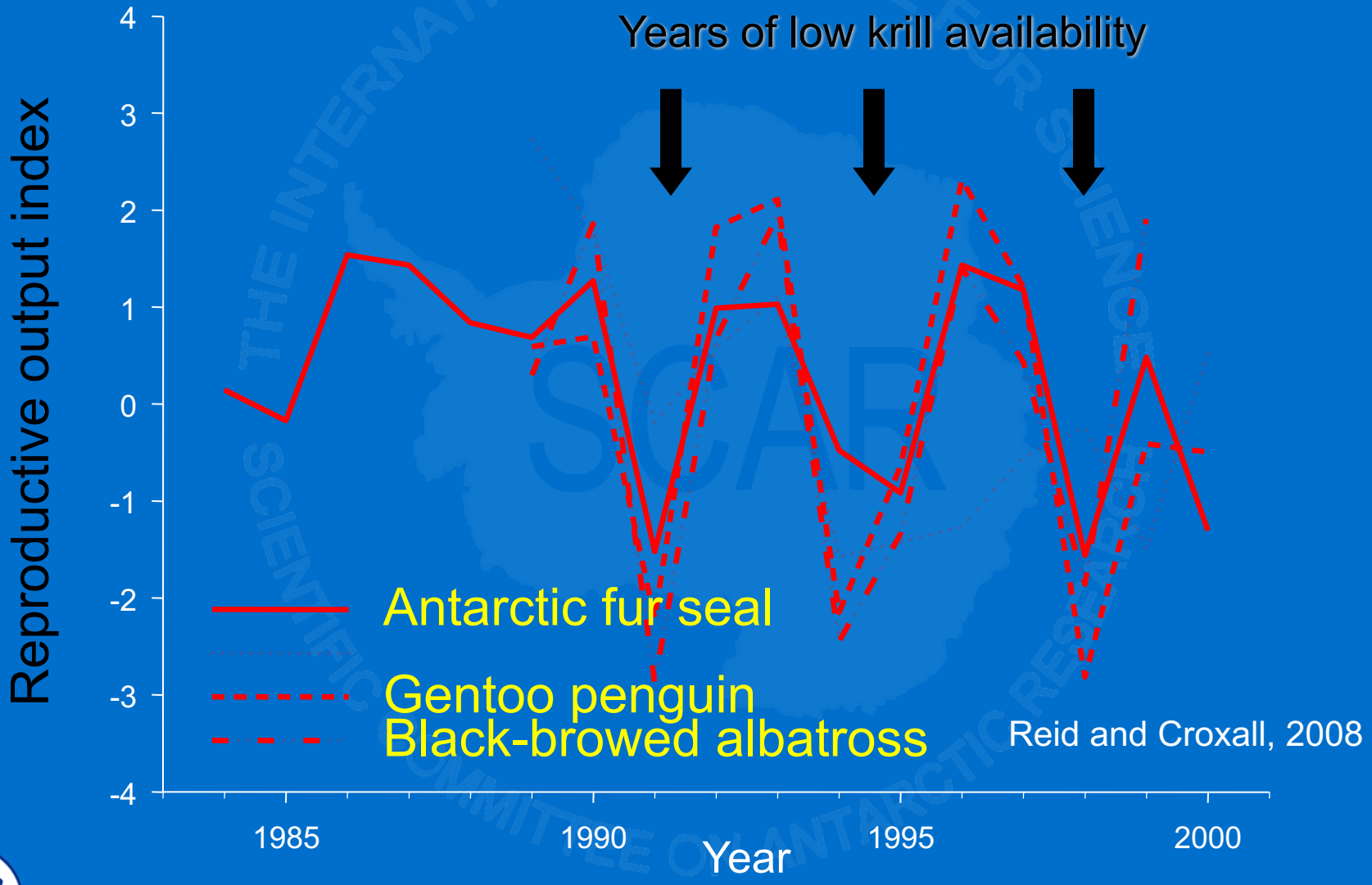
Development of the Antarctic Krill



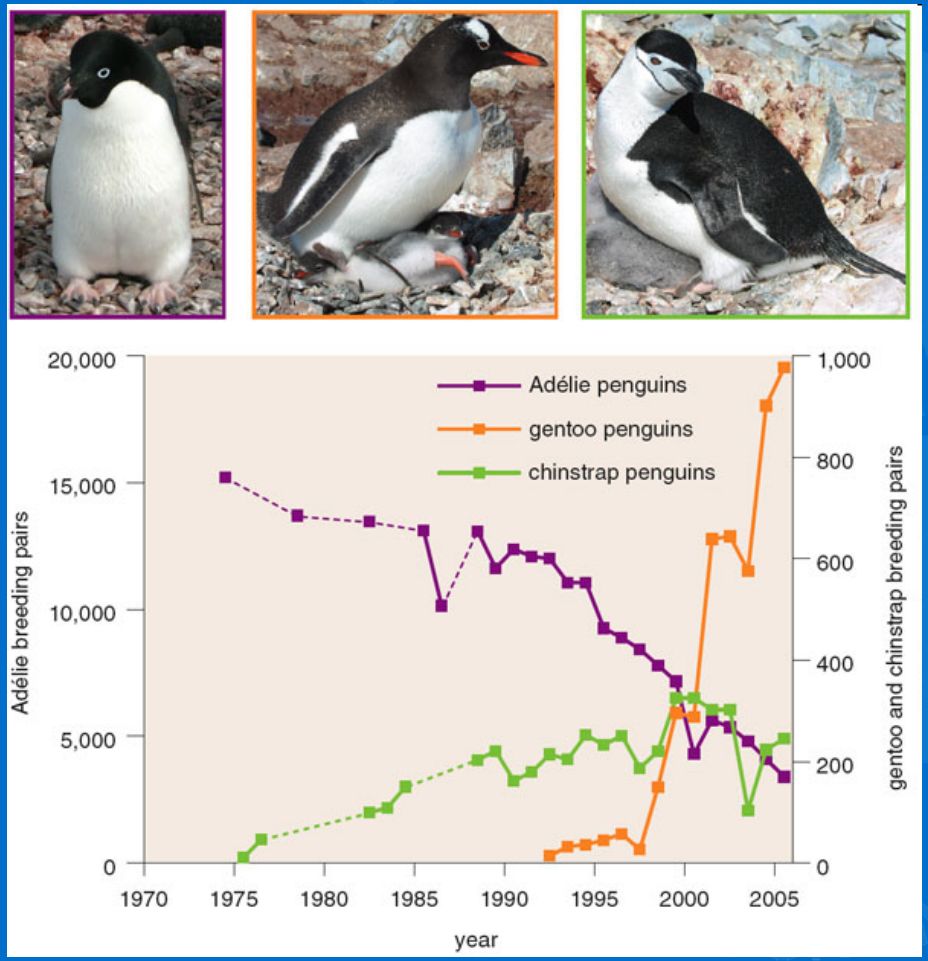
- January – March spawning season
- Sinking to the shelf bottom or down to 2000 m
- *Developmental ascent* of the larvae (Nauplius)
- 2 years as fragile juvenile Krill, surviving under the sea ice
- Maturity after 3 year
- Lifespan 5-7 years

Uwe Kils after Marr, 1962

Interannual variability



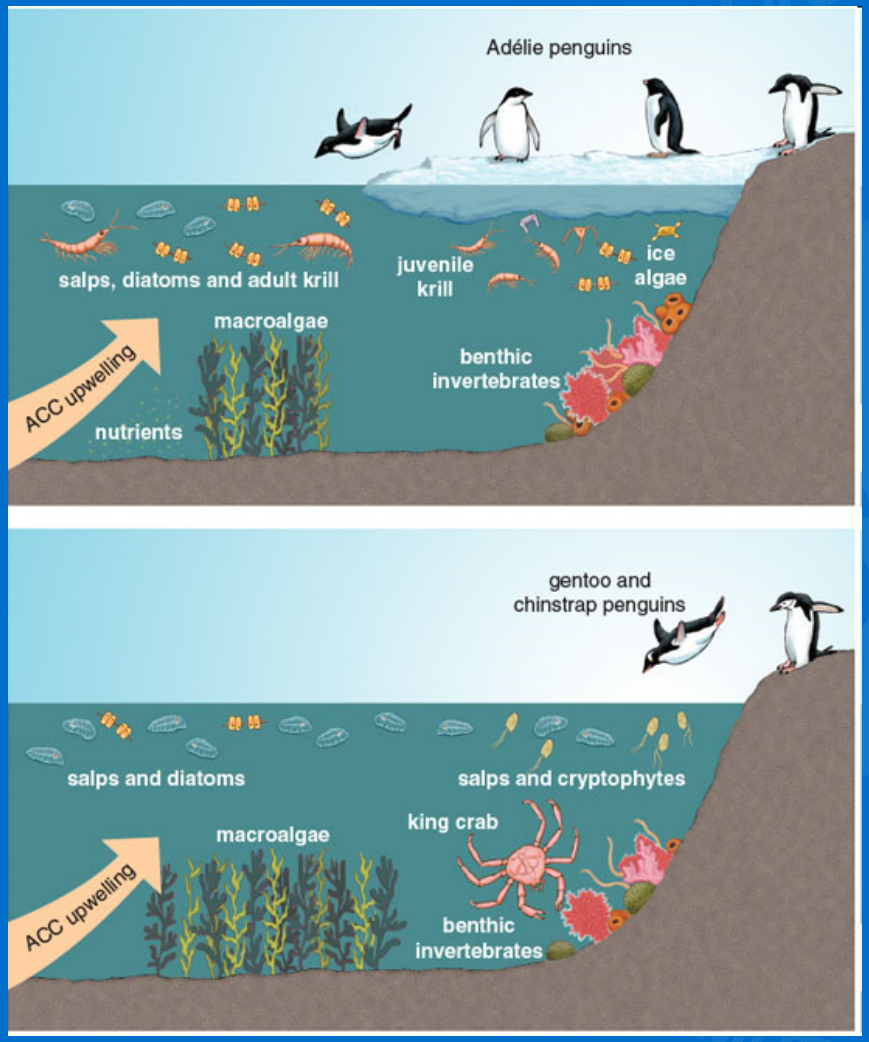
Breeding success and ecological response



Shifts in the penguin population on the western Antarctic Peninsula are attributed to changes in precipitation patterns and sea ice.

McClintock, 2008

Ecosystem response

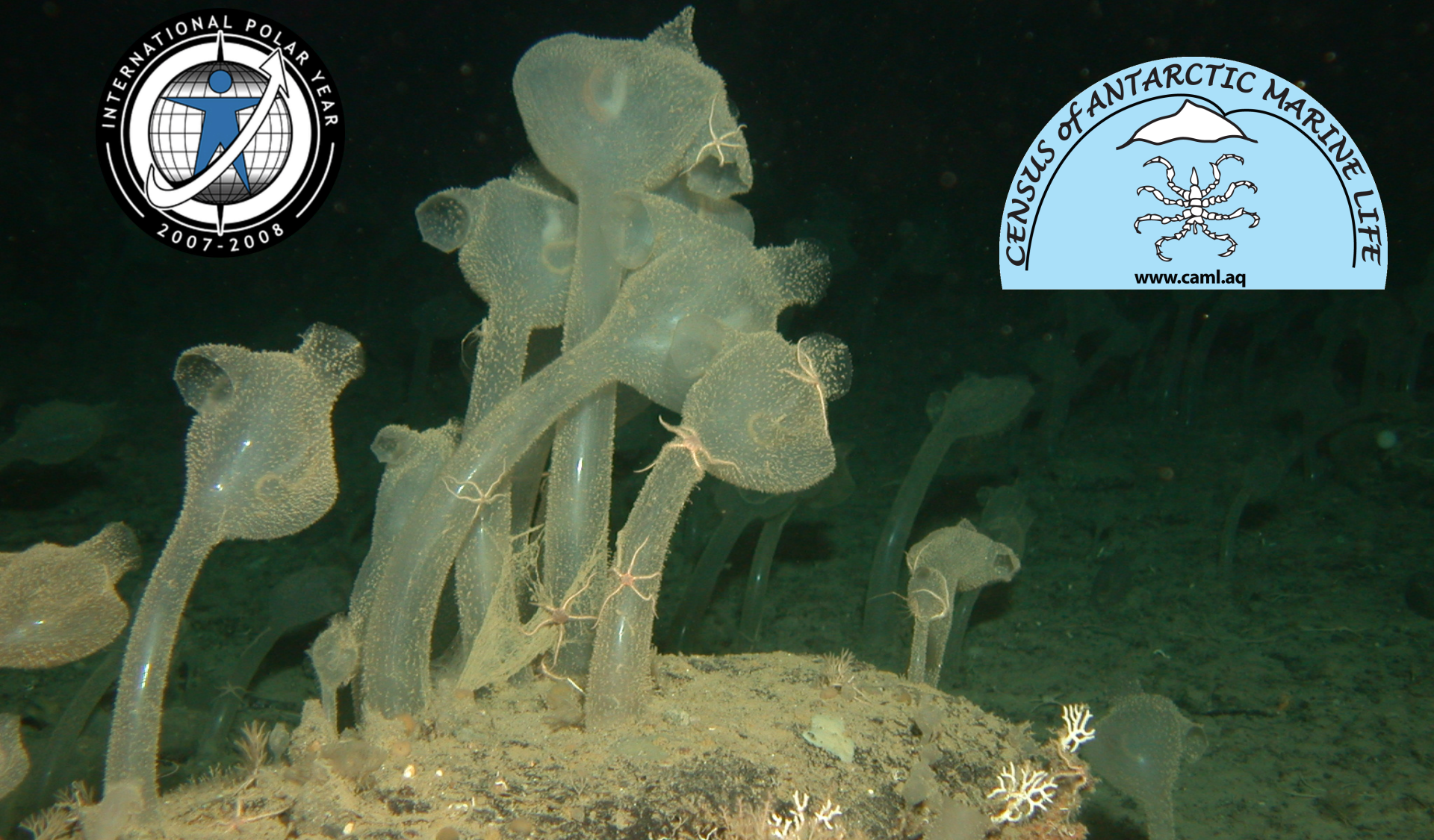


The ice shelters diatoms and other "ice algae" as well as the juvenile krill that feed on these primary producers.

Ice cover is also essential to Adélie penguins, which use it as a thoroughfare to reach isolated feeding "hot spots" nourished by upwellings of the Antarctic Circumpolar Current

McClintock, 2008

Climate Effects on Benthos
Reactions on the collapse of the Larson Ice Shelf



Census of Antarctic Marine Life

Understanding Past (Evolution) & Presence (Ecology)

↓

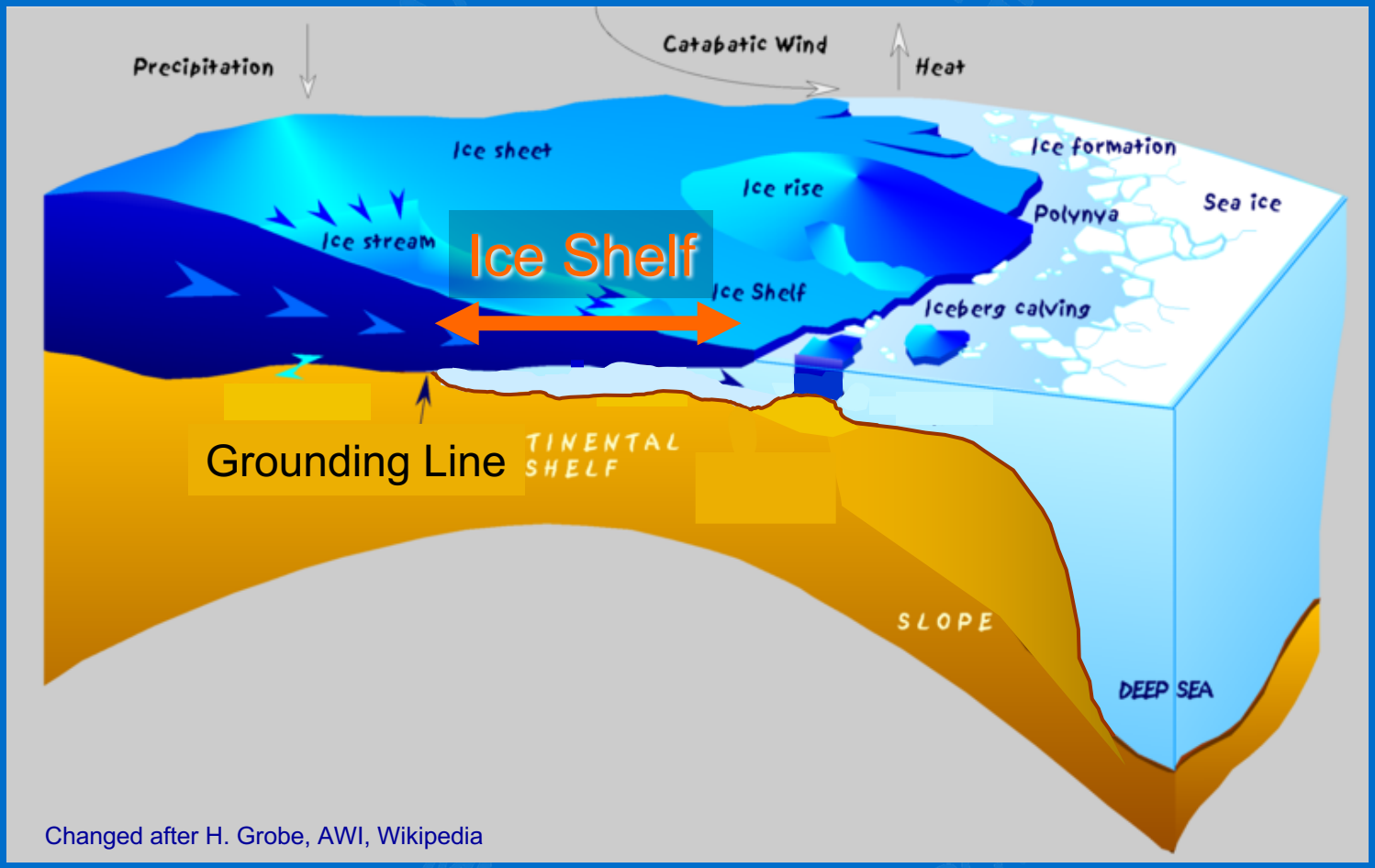
Predicting the Future

Credits: J. Gutt, W. Dimmler; © AWI/MARUM, University Bremen. Others: M. Scheidat, L. Lehnert, E. Nötig, J. Gutt, G. Chapelle, S. Langner



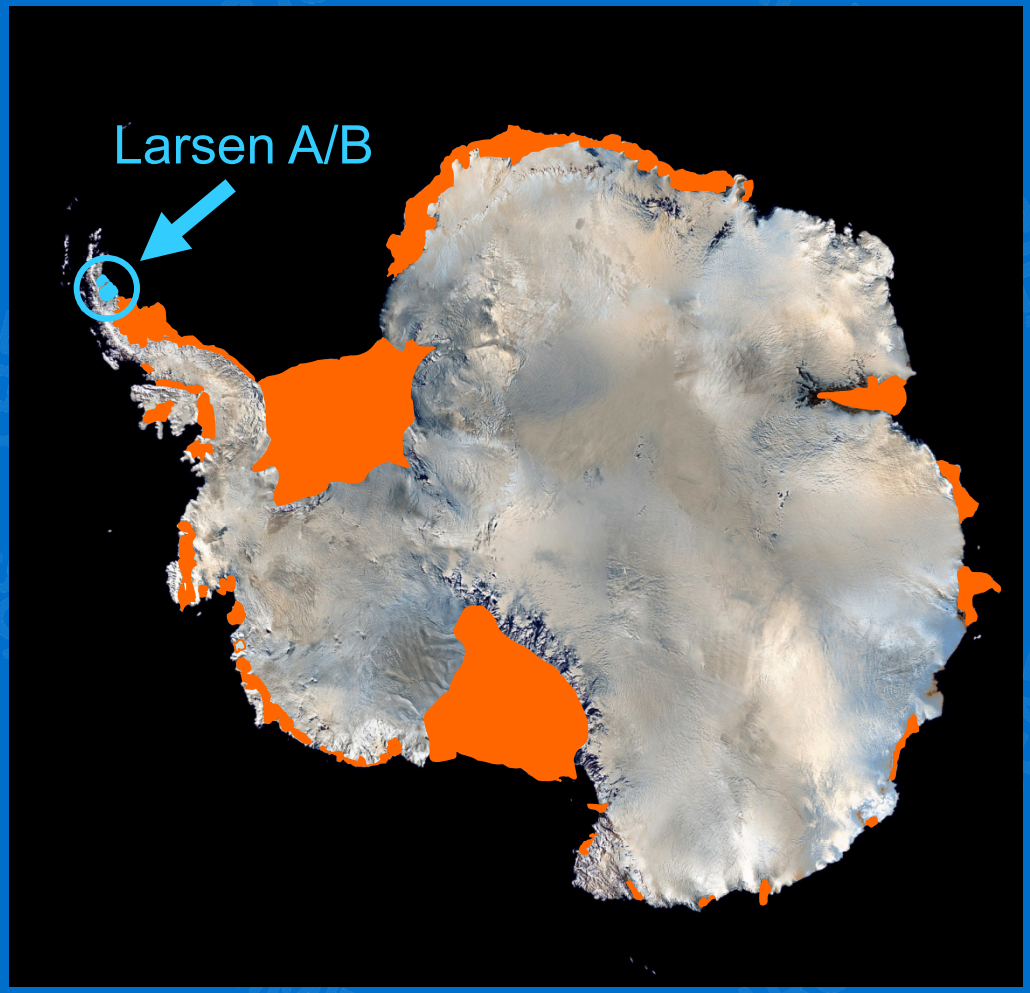


The Antarctic Ice Shelf



Changed after H. Grobe, AWI, Wikipedia

Antarctic Ice Shelf



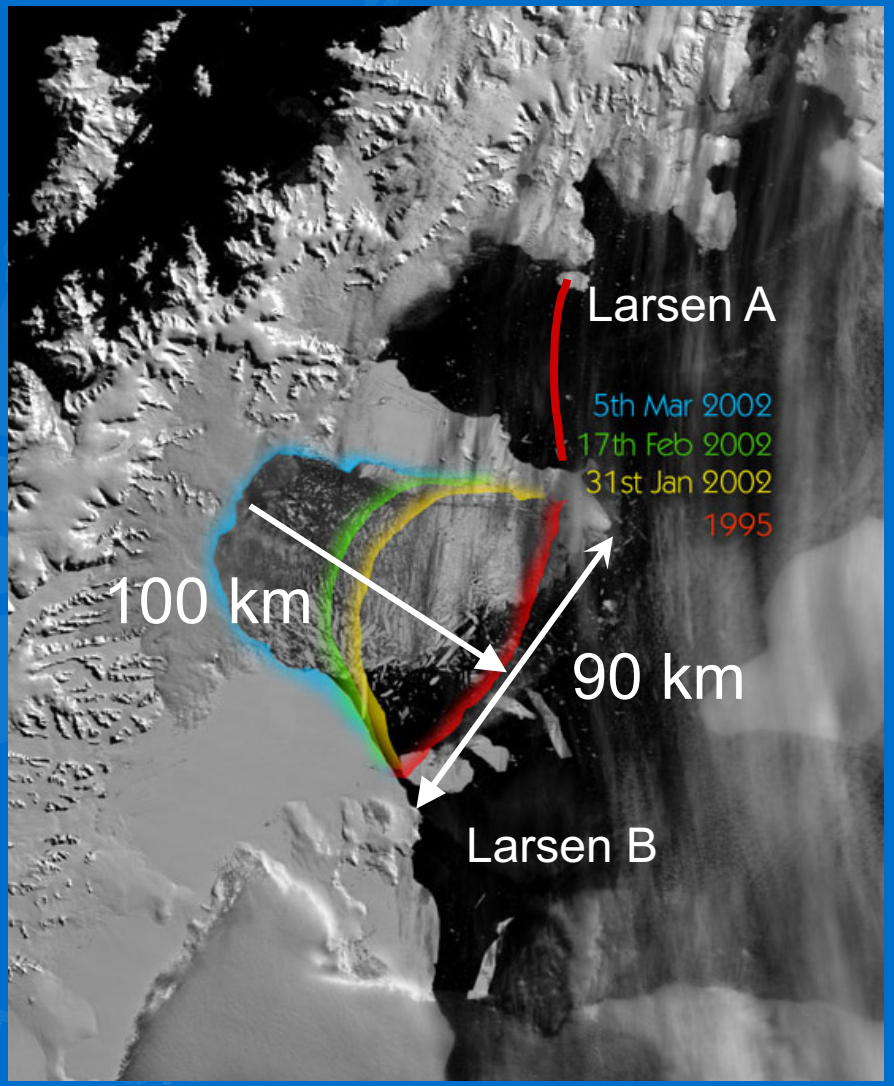
Extend: France + Spain + Germany
covering 1/3 of the Antarctic shallow waters

The former Larsen A/B – Ice Shelf

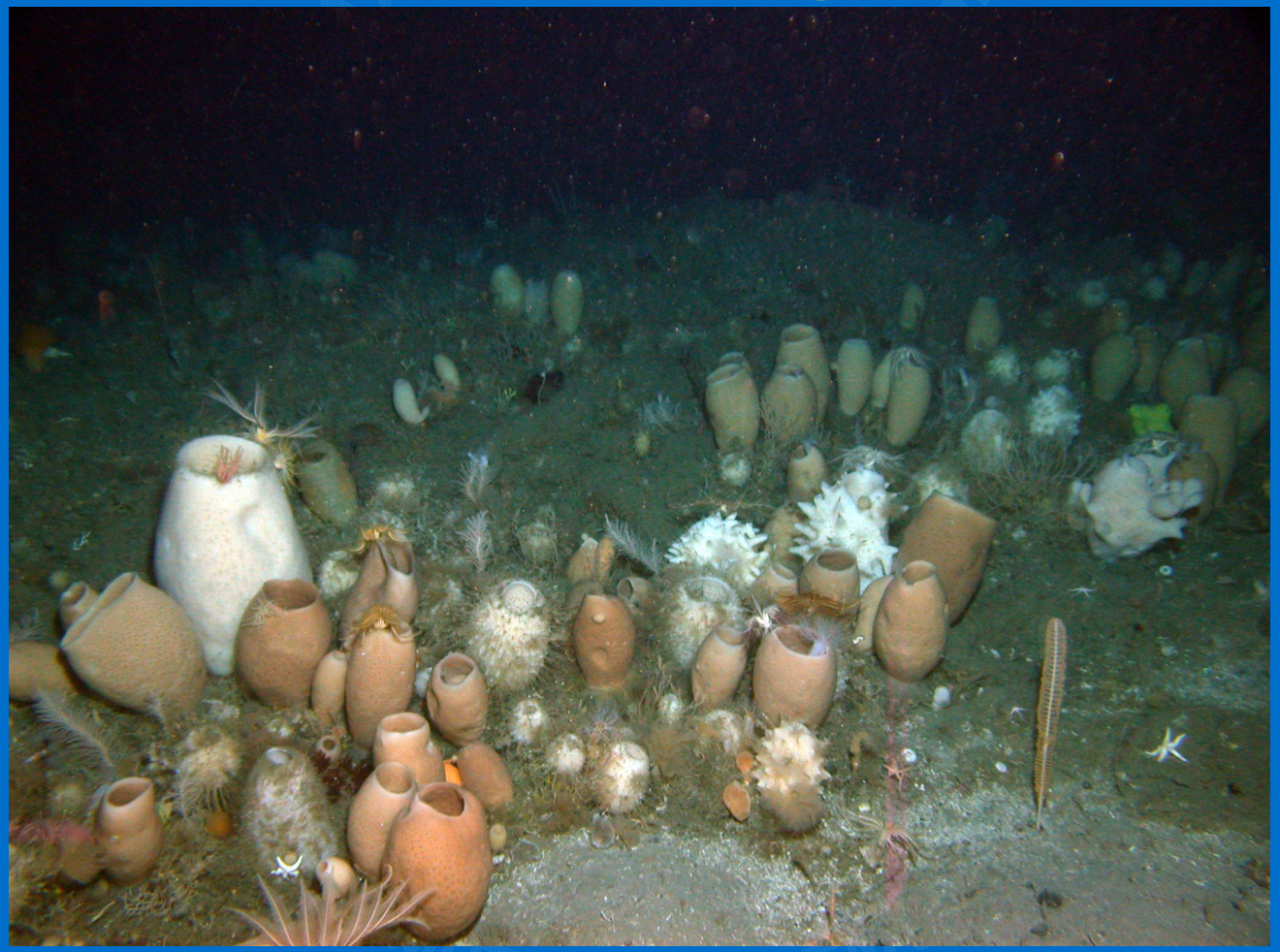
Break up:

18 x Berlin

„only“ 1% of
the Antarctic Ice Shelf



Life at the sea bottom:
In less than 200 m depth

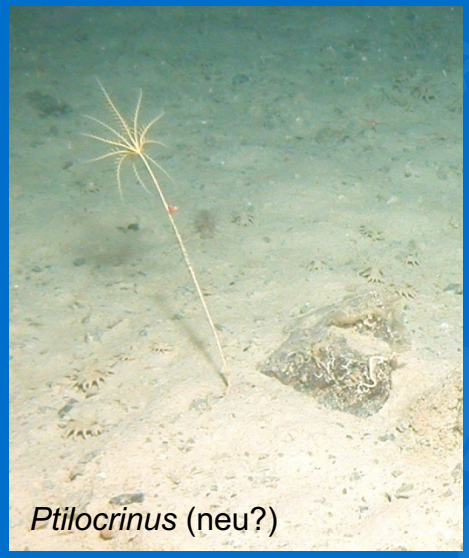


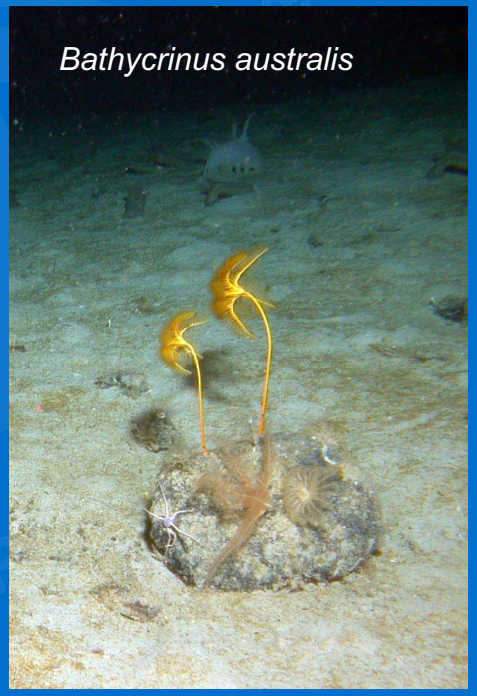
Credit: J. Gutt, AWI

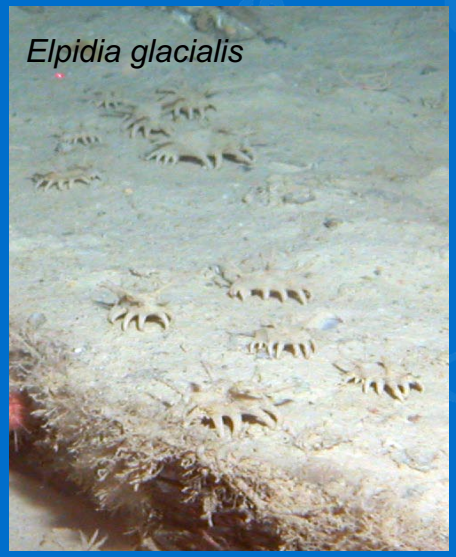
Life at the sea bottom:
In less than 200 m depth

Movie credit: J. Gutt, AWI

Larsen A/B: beyond 200m depth





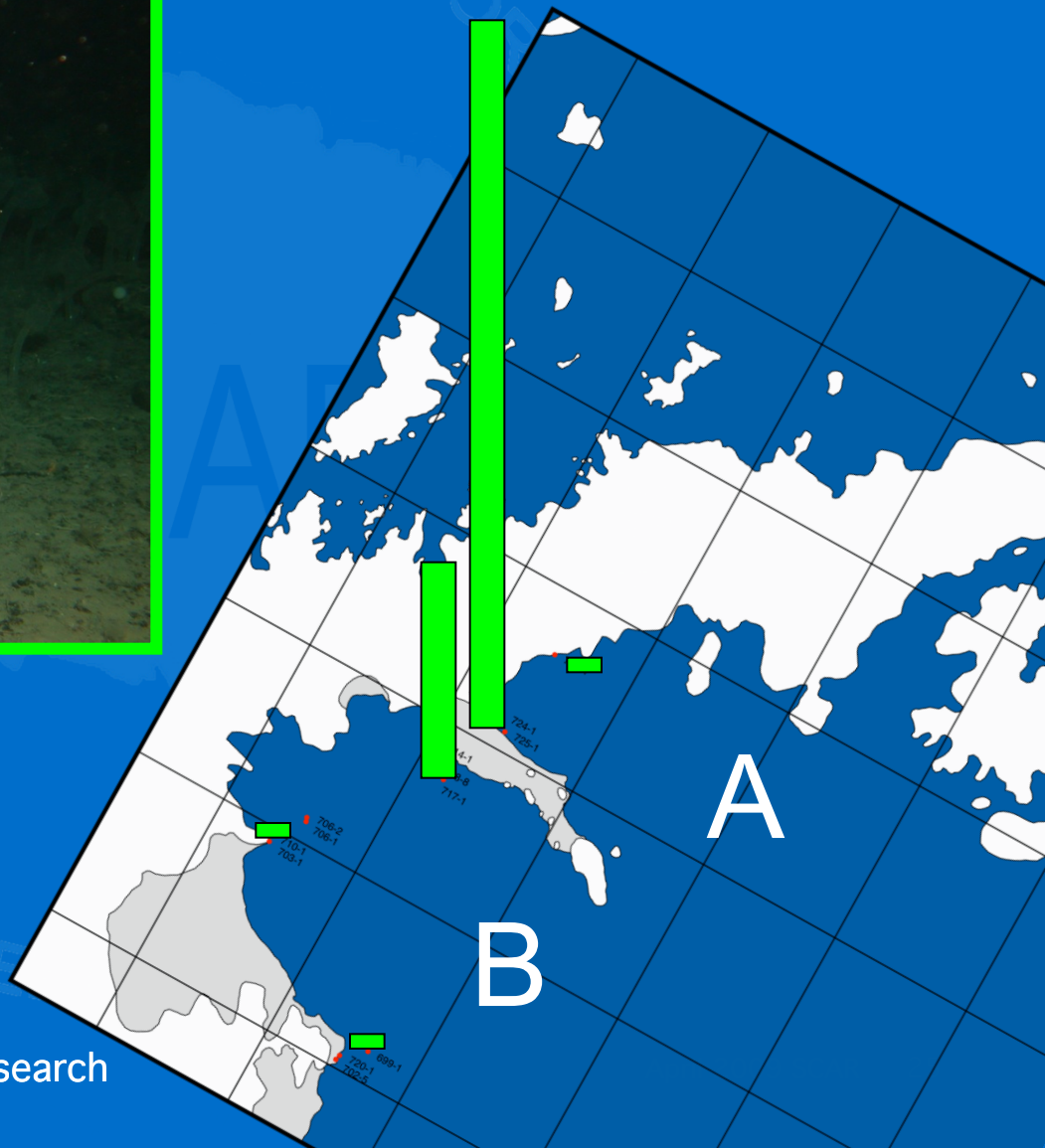


Credit: J. Gutt, AWI

Changing biodiversity on the sea bottom

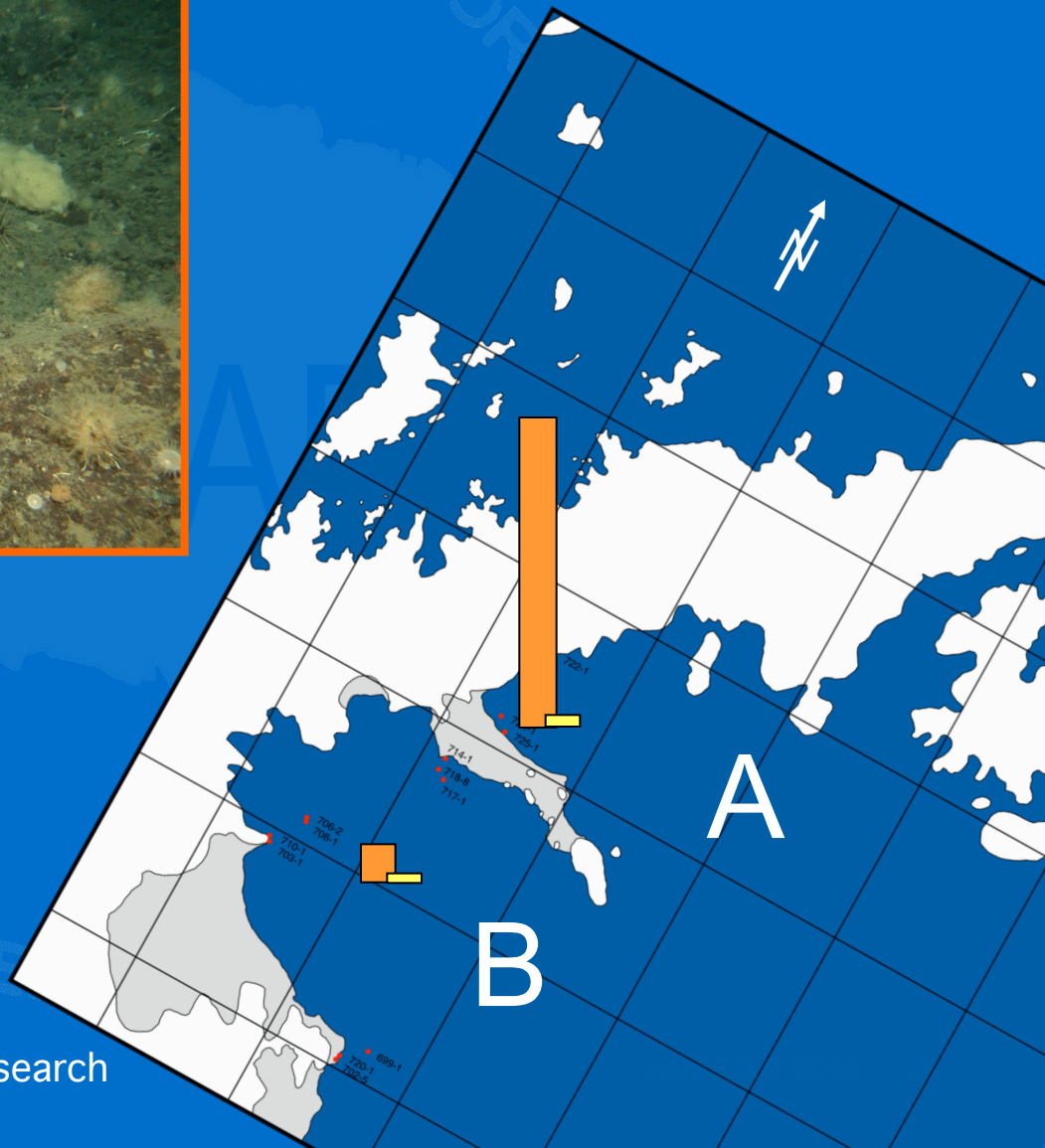
Molgula pedunculata (Acidian: 8 #/ m^2)

Credit: J. Gutt, AWI



Scientific Committee on Antarctic Research

Changing biodiversity on the sea bottom



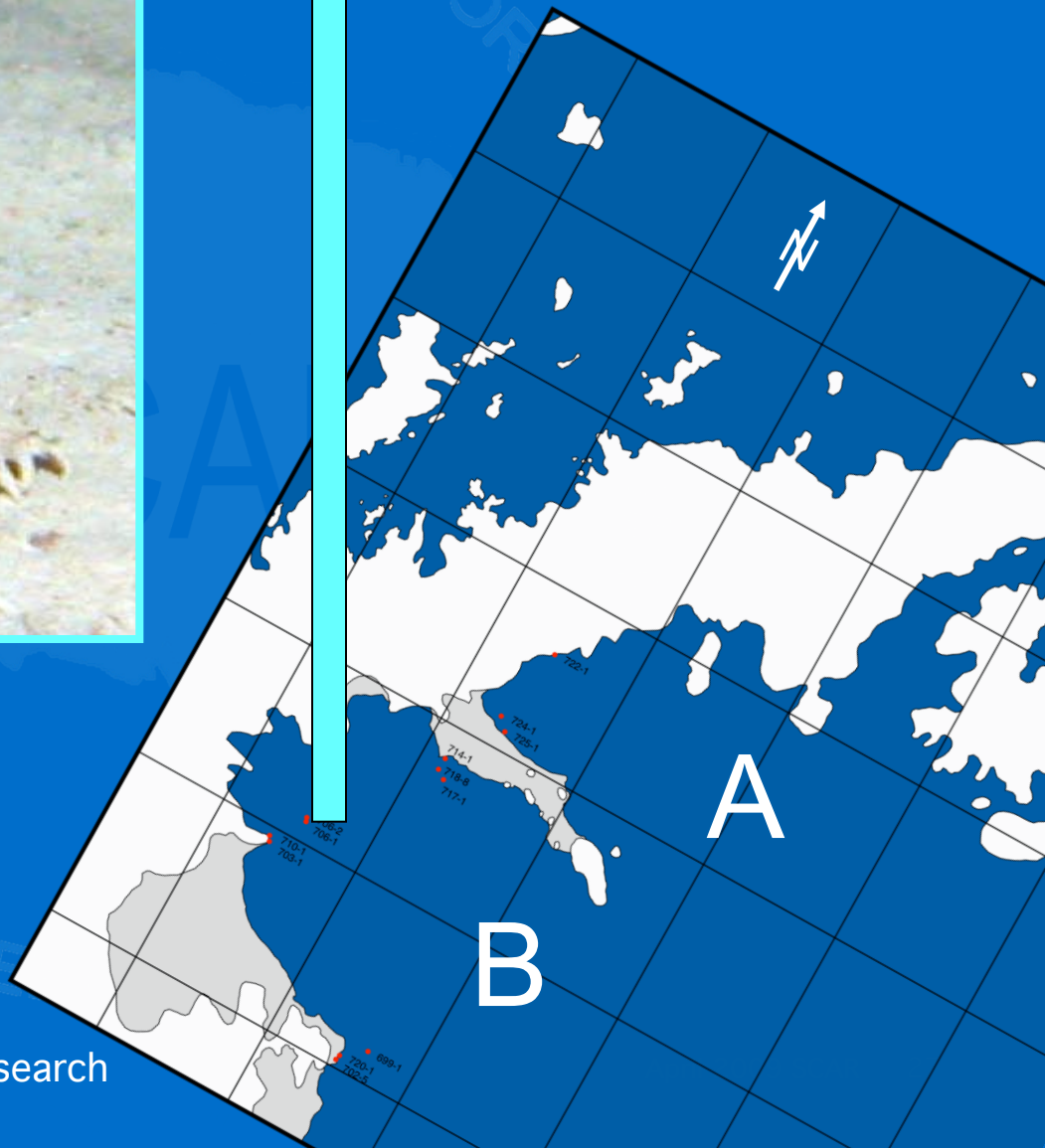
Scientific Committee on Antarctic Research

Changing biodiversity on the sea bottom

Elpidia glacialis (Sea urchin):

2005: 1 # / 5 m^2
2007: 13 # / m^2

Credit: J. Gutt, AWI



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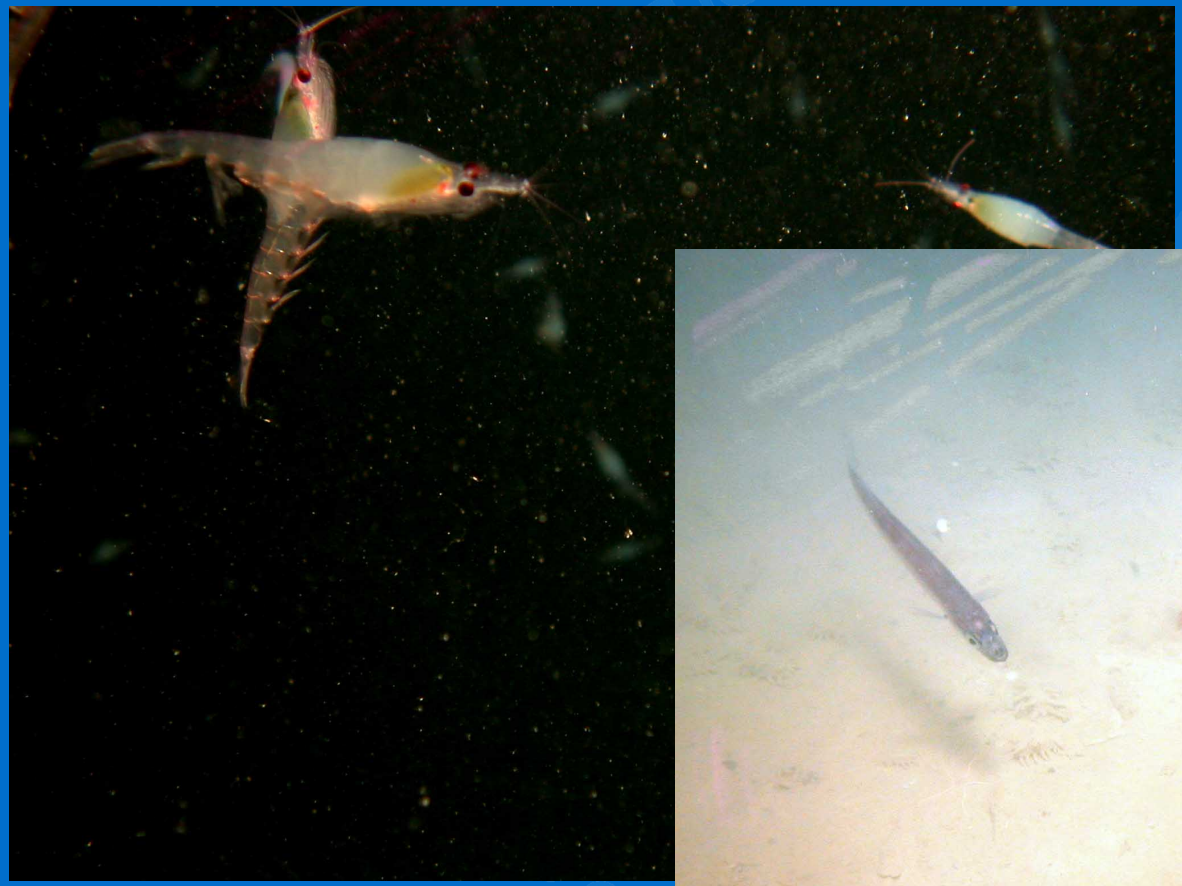
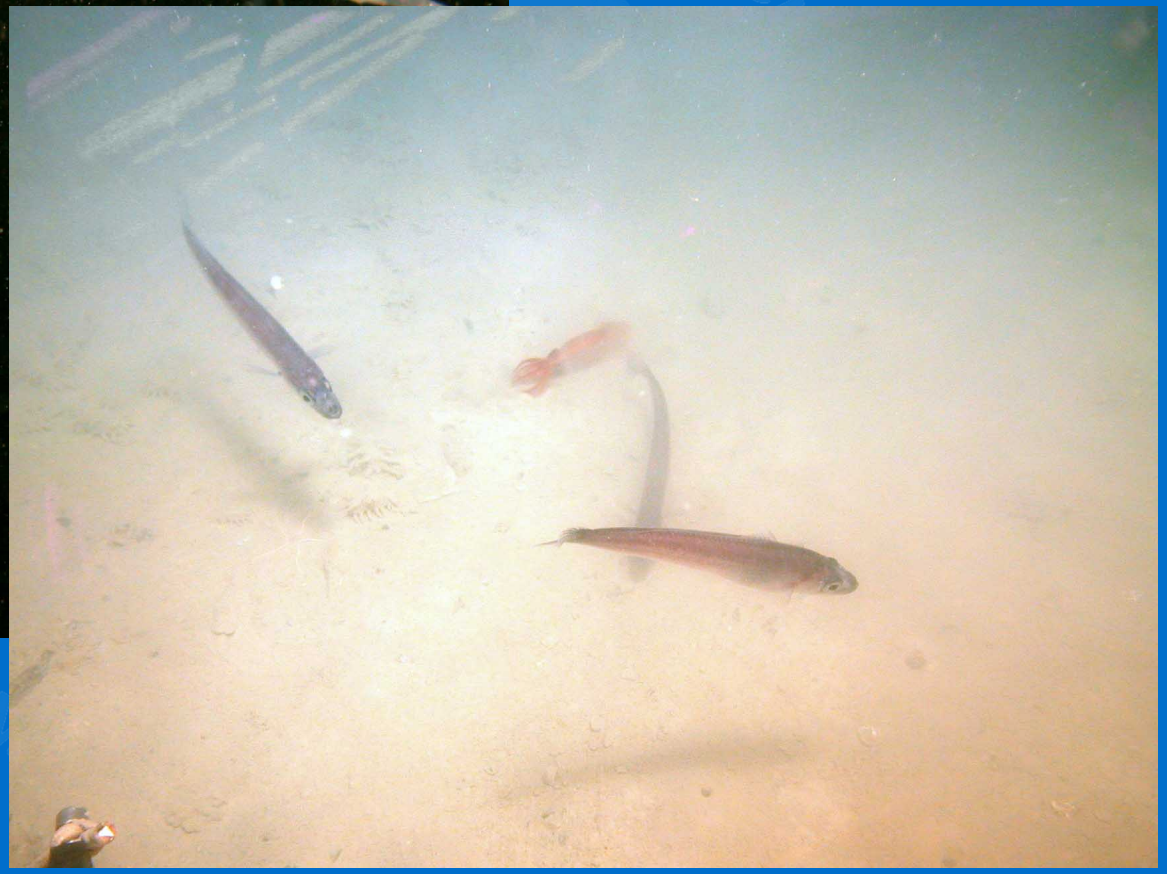
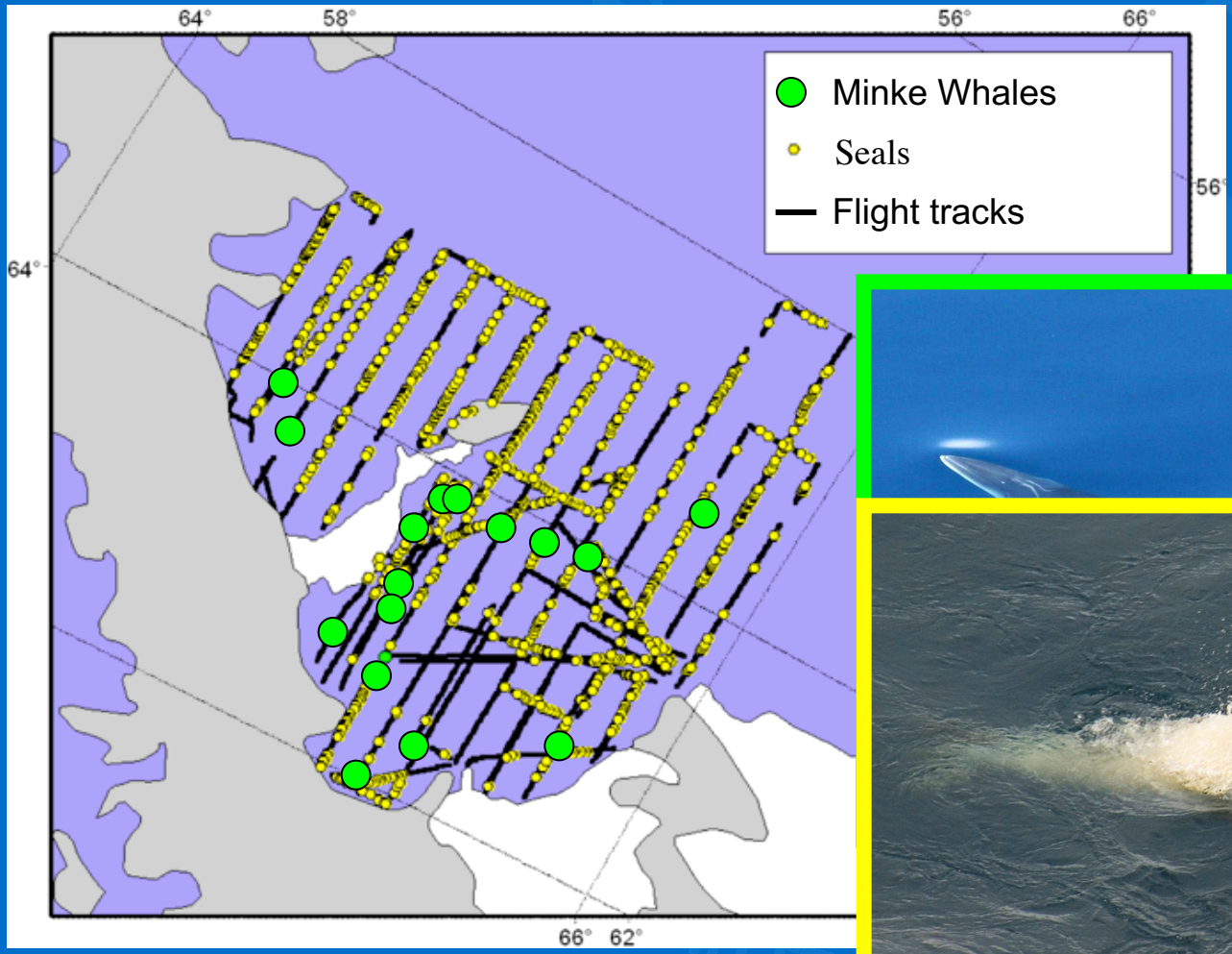
Krill & fish are immigrating…





Credit: J. Gutt, AWI

…likewise Minke whales and seals



M. Scheidat, L. Lehnert

The Future Development

Credit: J. Gutt, AWI

Conclusion

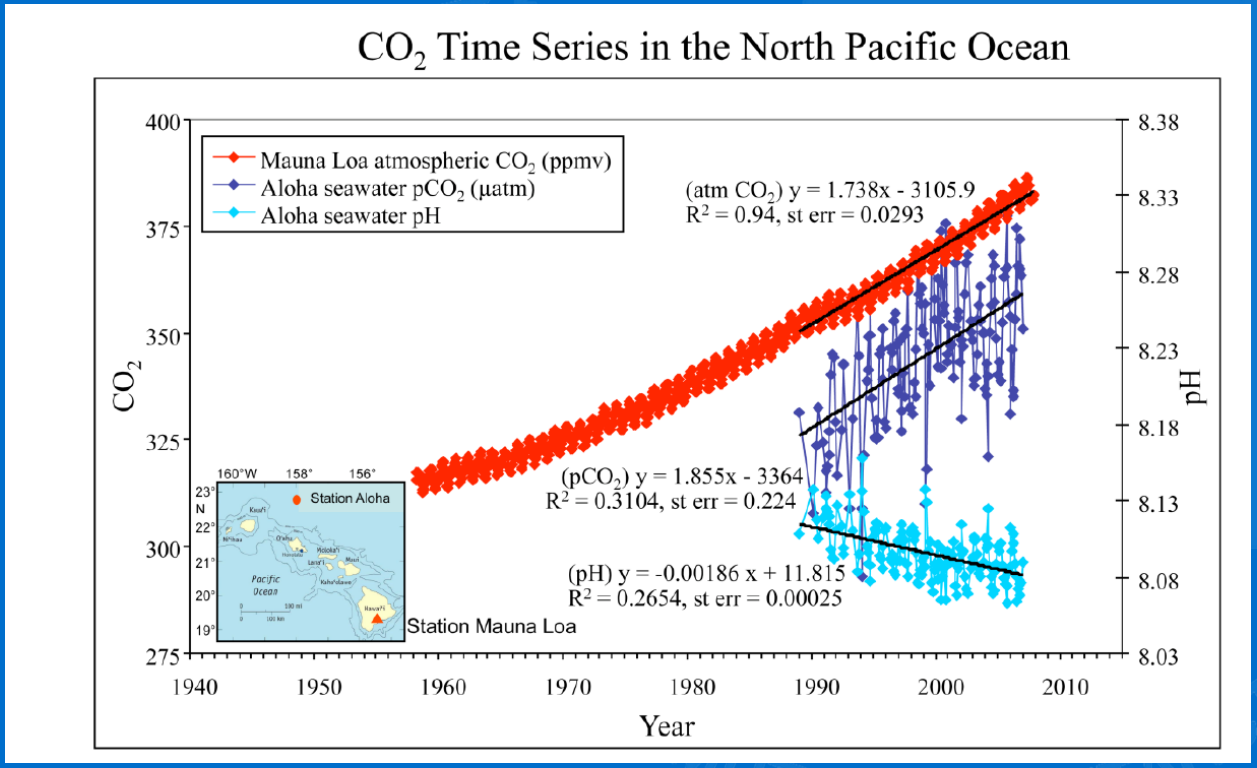
Reactions on the climatic ice shelf collapse:

- on the sea bottom: a few fast pioneers otherwise slow

- In the open ocean: much faster and more comprehensive.

Acidification of the Southern Ocean

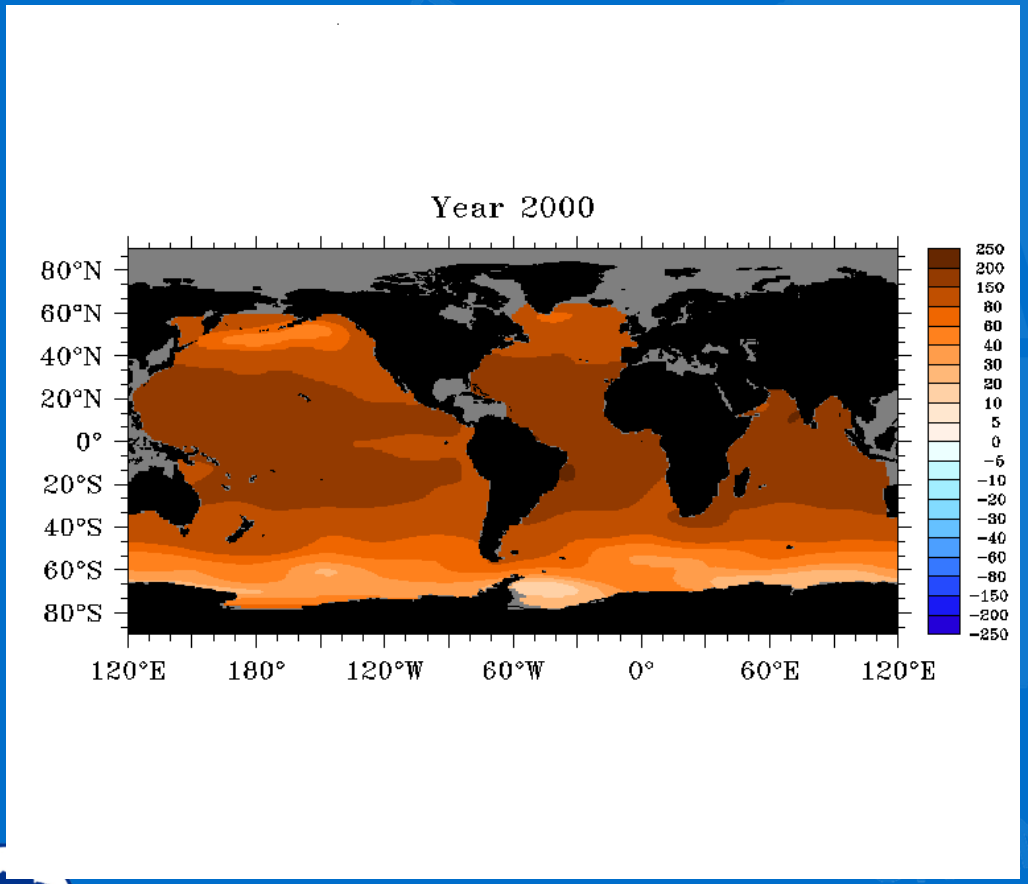
- CO_2 increased 280 to 380 ppm in 200+ years, pH decreased by 0.1
- By 2100, pH projected to decrease 0.5, possibly 0.77 eventually



Time series of atmospheric CO_2 at Mauna Loa (ppmv) and surface ocean pH and pCO_2 (µatm) at Ocean Station Aloha in the subtropical North Pacific Ocean. (Fabry 2008).

Acidification of the Southern Ocean

Animation of the saturation state of surface water with respect to aragonite.



The magenta line, which first becomes visible in 2025 (in the Weddell Sea), separates saturated waters (orange colors) from undersaturated waters (blue colors).

Undersaturated seawater is corrosive to $CaCO_3$ and, in the absence of protective mechanisms dissolution of aragonite will begin.

[Movie credit: James Orr, LSCE/CEA-CNRS France]

Acidification of the Southern Ocean

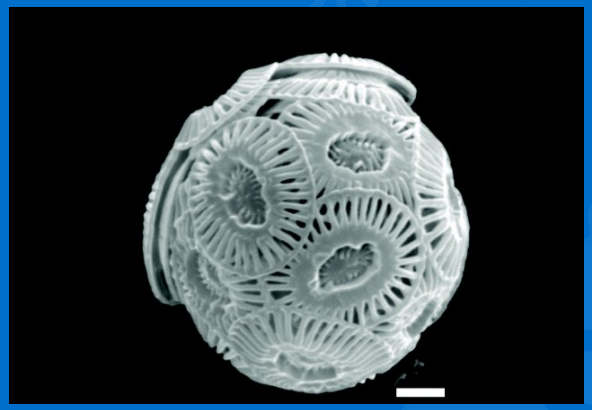
Pteropods need aragonite for their shells. They may become extinct in Antarctic waters due to ocean acidification 2050 to 2100.

Ecological profile of Pteropods:

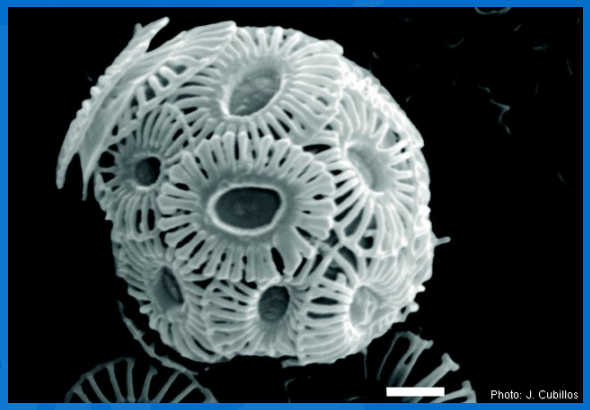
- Occur in upper 300 m
- Can be more abundant than krill
- Density $10^5 m^{-3}$ in Ross Sea
- Can account for large amount of the annual export flux of CO_3^{2-} and organic C
- South of the Polar Front can dominate the export flux of $CaCO_3$
- Food of carnivorous zooplankton, fish (myctophids & nototheniids)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

Acidification of the Southern Ocean

Coccolithophorids need calcite for their shells.



Shell plate development of the coccolithophorid, *Emiliania huxleyi*, under current atmospheric carbon dioxide levels. Photo: J. Cubillos



Incomplete shell plate growth under higher carbon dioxide concentrations.
Photo: J. Cubillos

Ecological profile of Coccolithophorids:

- Occur in upper 300 m
- Form immense blooms
- Can account for large amount of the annual export flux of CO_3^{-2} and organic C

Acidification of the Southern Ocean

There are more effects on the marine ecosystem

- Physiological, oxygen metabolism of animals – fish and squid … krill?
- Change in availability and chemical form of nutrients

Acidification of the Southern Ocean

Recommendation:

The Royal Society 2005, Ocean acidification due to increasing atmospheric carbon dioxide, Policy document 12/05

Research into the impacts of high concentrations of CO_2 in the oceans is in its infancy and needs to be developed rapidly. A major, internationally coordinated effort be launched to include global monitoring, experimental, mesocosm and field studies. Models that include the effects of pH at the scale of the organism and the ecosystem are also necessary.

For this reason, the necessary funding should be additional and must not be diverted from research into climate change.

Invasive species

The threat of the introduction of non-native species into the Antarctic has received a high priority in the ATS.

Occurrence of introduced species

- Approaching 200 known alien plants and animals established,
- most in terrestrial sub-Antarctic
- Some drastic impacts on native species and ecosystems
- Most invertebrate groups and locations poorly surveyed
- Microbial data (?)
- Many more species arrive and/or exist synanthropically
- One evidence of marine introductions to date
- Anthropogenic frequency far outweighs natural dispersal events

Jon Davies/JNCC (published on the MarLIN Web site)

First marine invasive species

Male and female North Atlantic spider crabs (*Hyas araneus*) have been found in waters off the Antarctic Peninsula.

Concerns:

• marine traffic (science & tourism), introducing alien species via fouled vessels and ballast water

Reactions:

• SCAR and COMNAP are working pro-actively, developing guidelines for shipping and land based expeditions

Jon Davies/JNCC (published on the MarLIN Web site)

SCAR
Marine Research Pogramme

Evolution and Biodiversity in the Antarctic - The Response of Life to Change (EBA):

- Understand the evolution and diversity of life in the Antarctic;
- Determine how these have influenced the properties and dynamics of present Antarctic ecosystems and the Southern Ocean system;
- Make predictions on how organisms and communities are responding and will respond to current and future environmental change; and
- Identify EBA science outcomes that are relevant to conservation policy and communicate this science via the SCAR Antarctic Treaty System Committee.

SCAR Action Groups

- Census of Antarctic Marine Life (CAML)
- SCAR-MarBIN - the Antarctic Marine Biodiversity Information Network

Antarctica in Changing World

Credit: NASA Earth Observatory