Projected temperature-mediated range shifts in the distribution of Arctic and boreal benthic fauna

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Photo: E. Svensen

Akvaplan niva

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SINTEF

Research Network ARCTOS

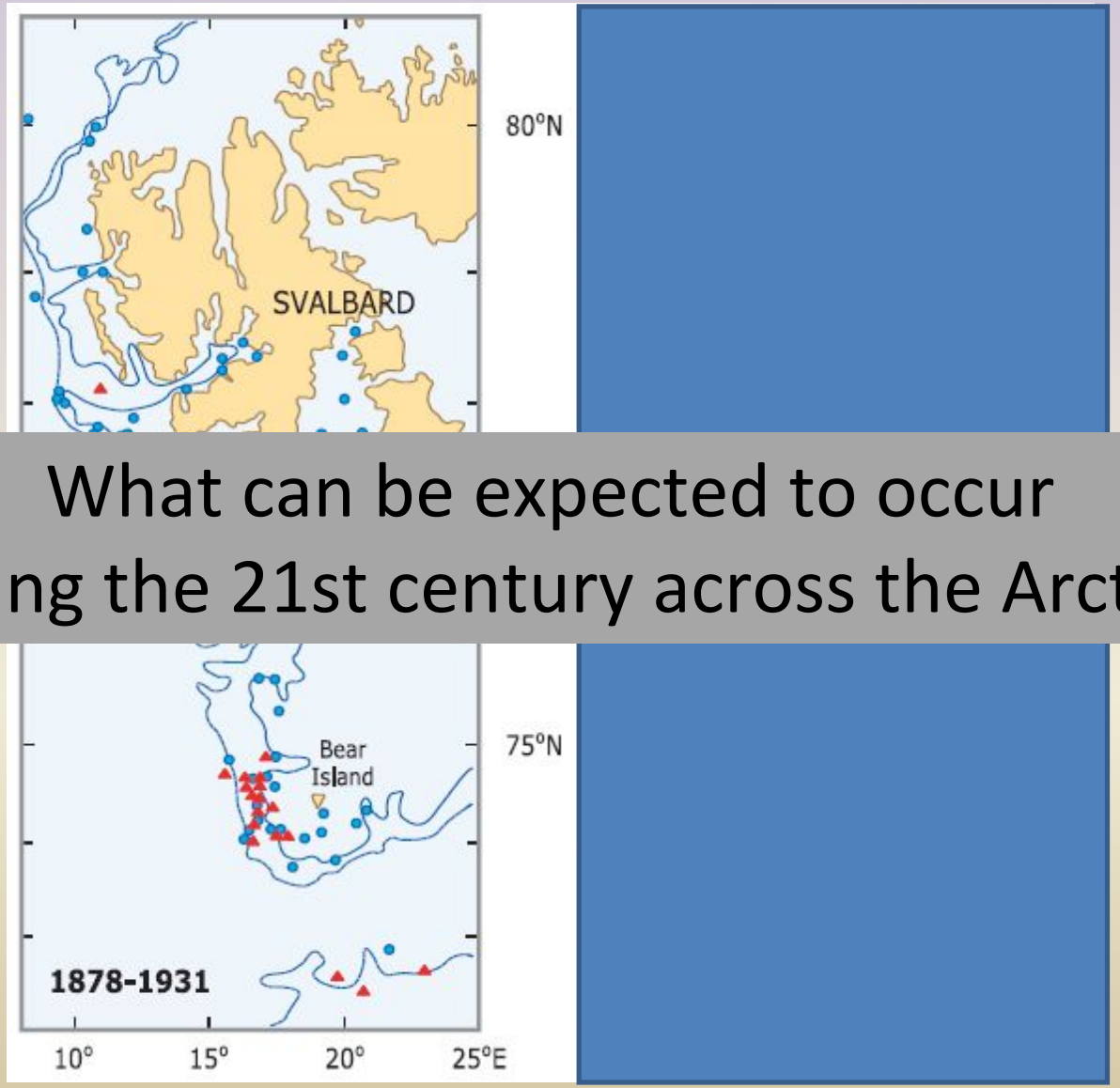
Climatic change and species distributions

Predictions

- Temperate/boreal species establish in Arctic (e.g. ACIA 2005, Parmesan 2006, Doney et al. 2012)…and retraction of Arctic species
- Arctic waters likely to experience high invasion intensity (Cheung et al. 2009; Ware et al. 2014)

➢But few studies provide evidence suggesting which taxa will expand/ contract, and where this will happen

Empirical evidence of distributional shifts



What can be expected to occur
during the 21st century across the Arctic?

Blacker 1965

Study questions

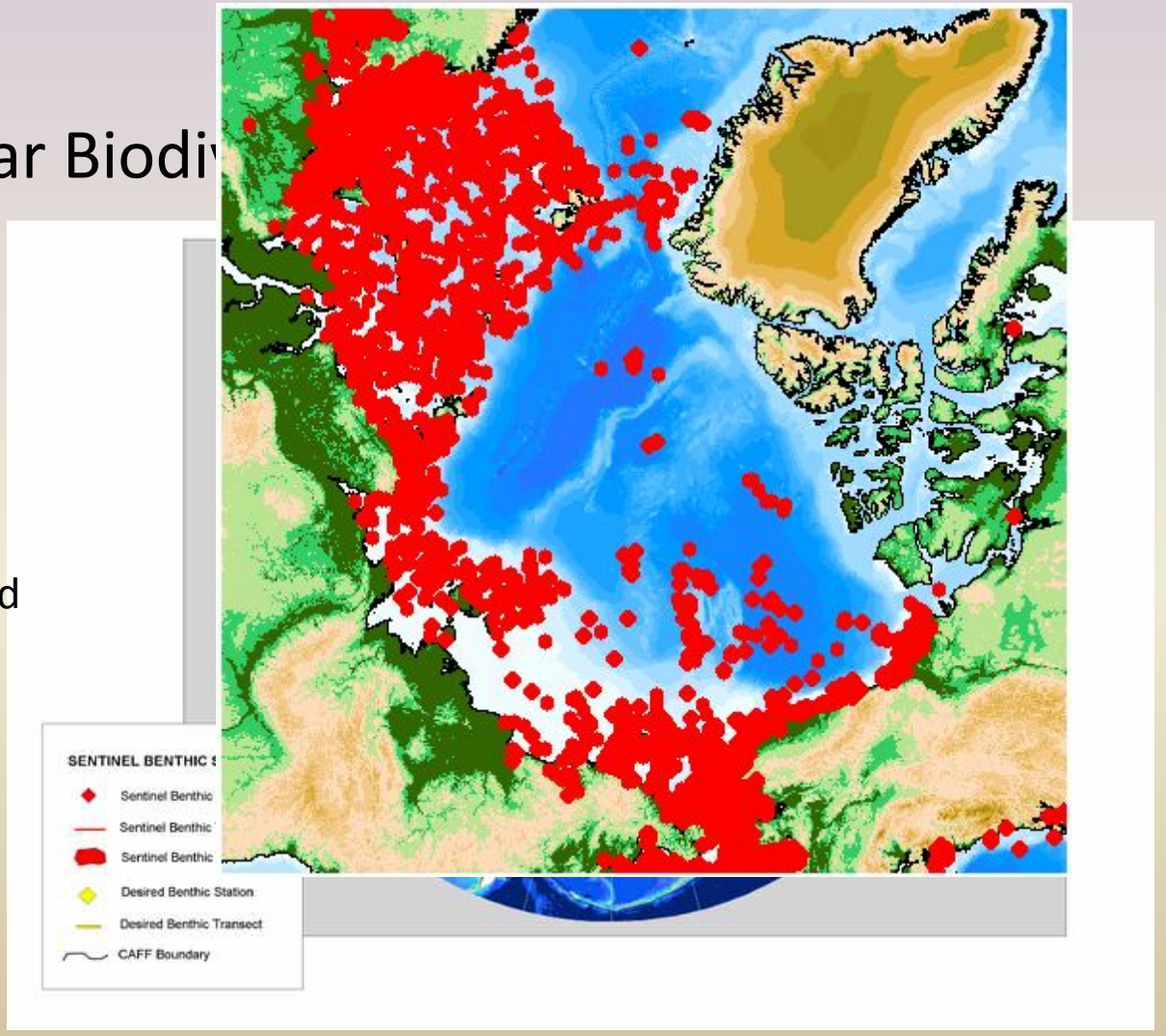
1. What is the biodiversity status of the Arctic today?
2. What biological and physical factors are most important for determining biogeographical boundaries?
3. What changes in these drivers are expected?
4. Which habitats/regions/taxa are most likely to exhibit biodiversity change in the coming decades?

The baseline problem

- How do we detect new arrivals/expansion?
- What is current biodiversity status of the Arctic?
- What are current species ranges near the boreal-Arctic border?

Recent efforts to set the baseline

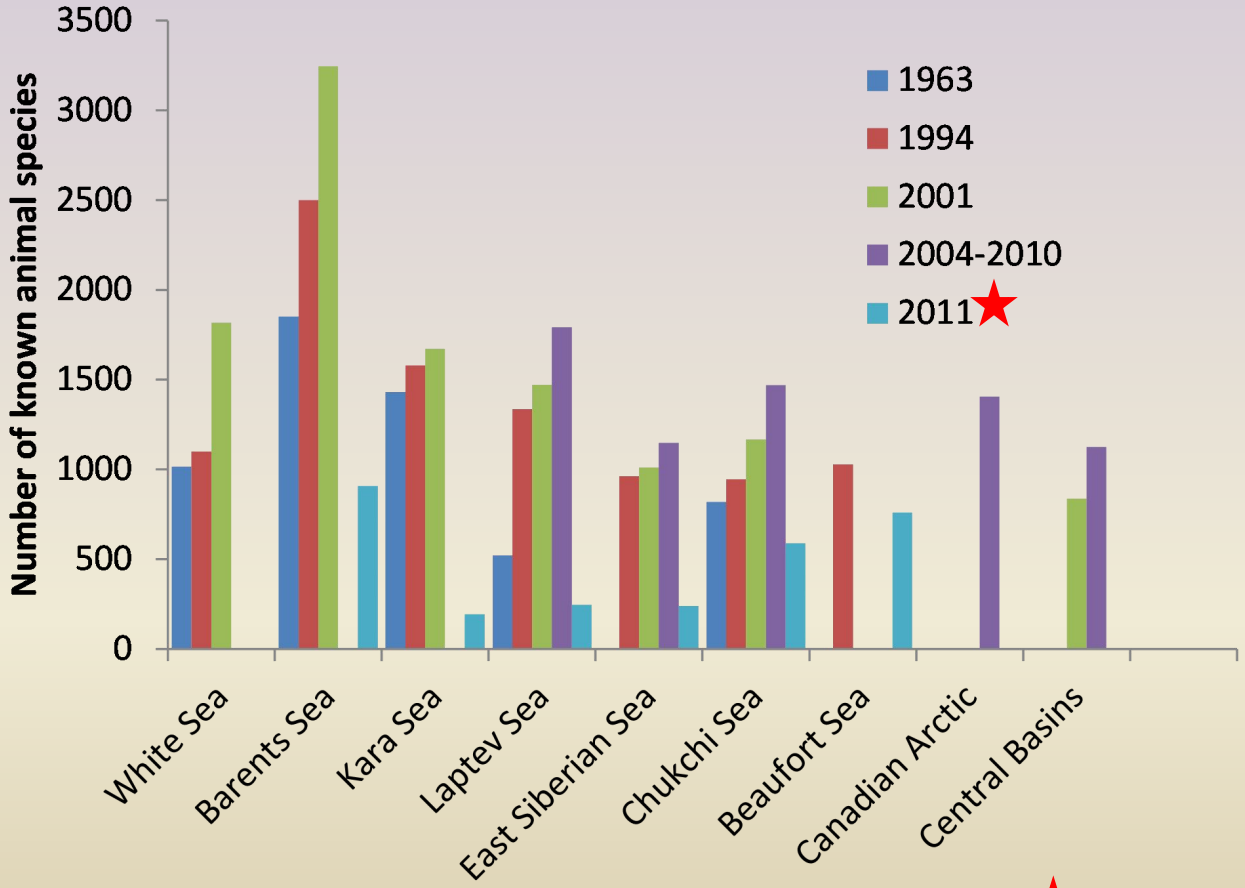
- ArcOD/ CoML
- CAFF Circumpolar Biodi



- Current and desired sites
- 200,000 records
- Most from
- Mostly from shelf areas
- Deposited in OBIS and GBIF

- Common methods described
- Most from phase

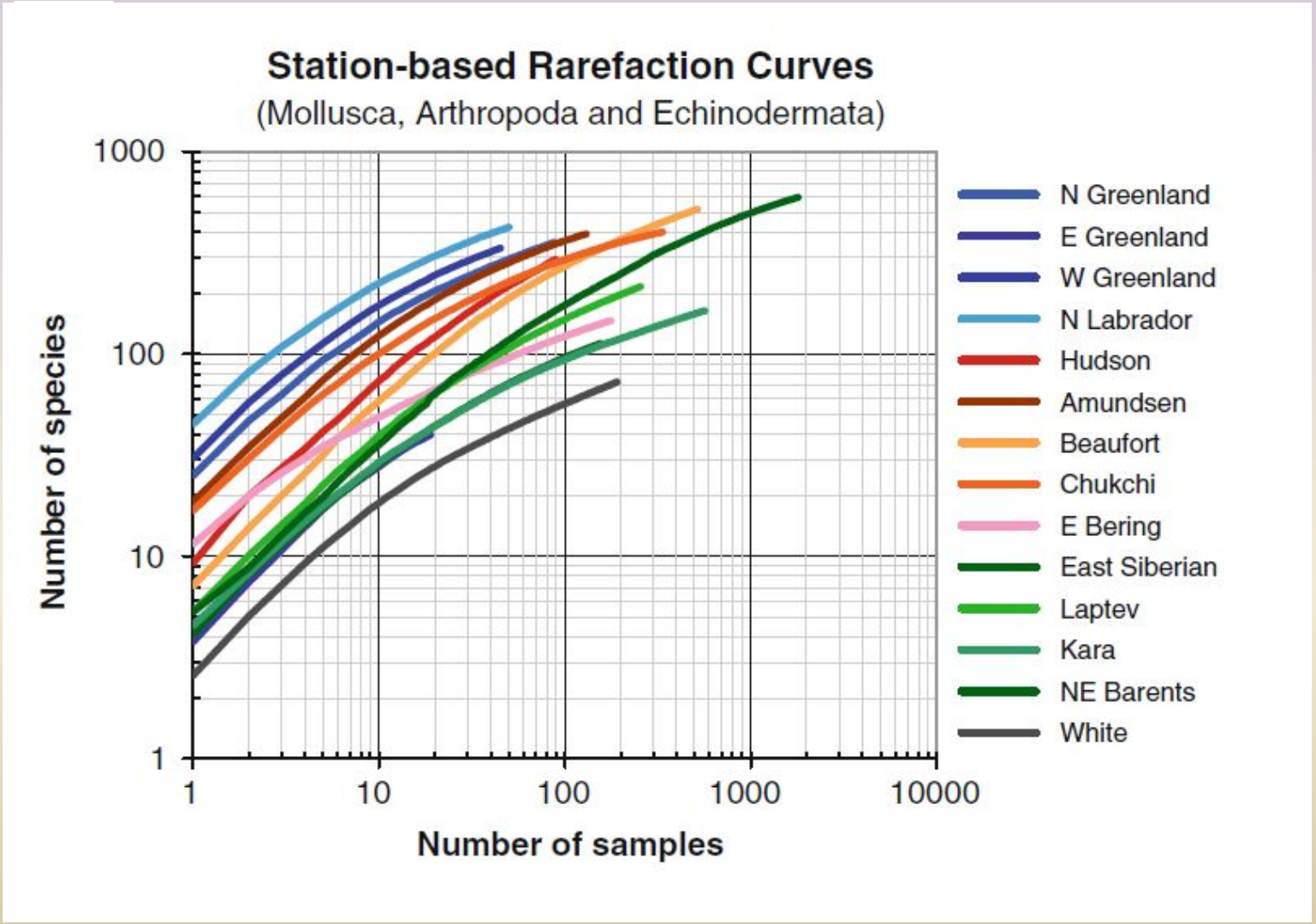
Biodiversity: Arctic inventory



★ Arthropoda, Echinodermata, Polychaeta from 68,000 georeferenced records (Piepenburg et al. 2011)

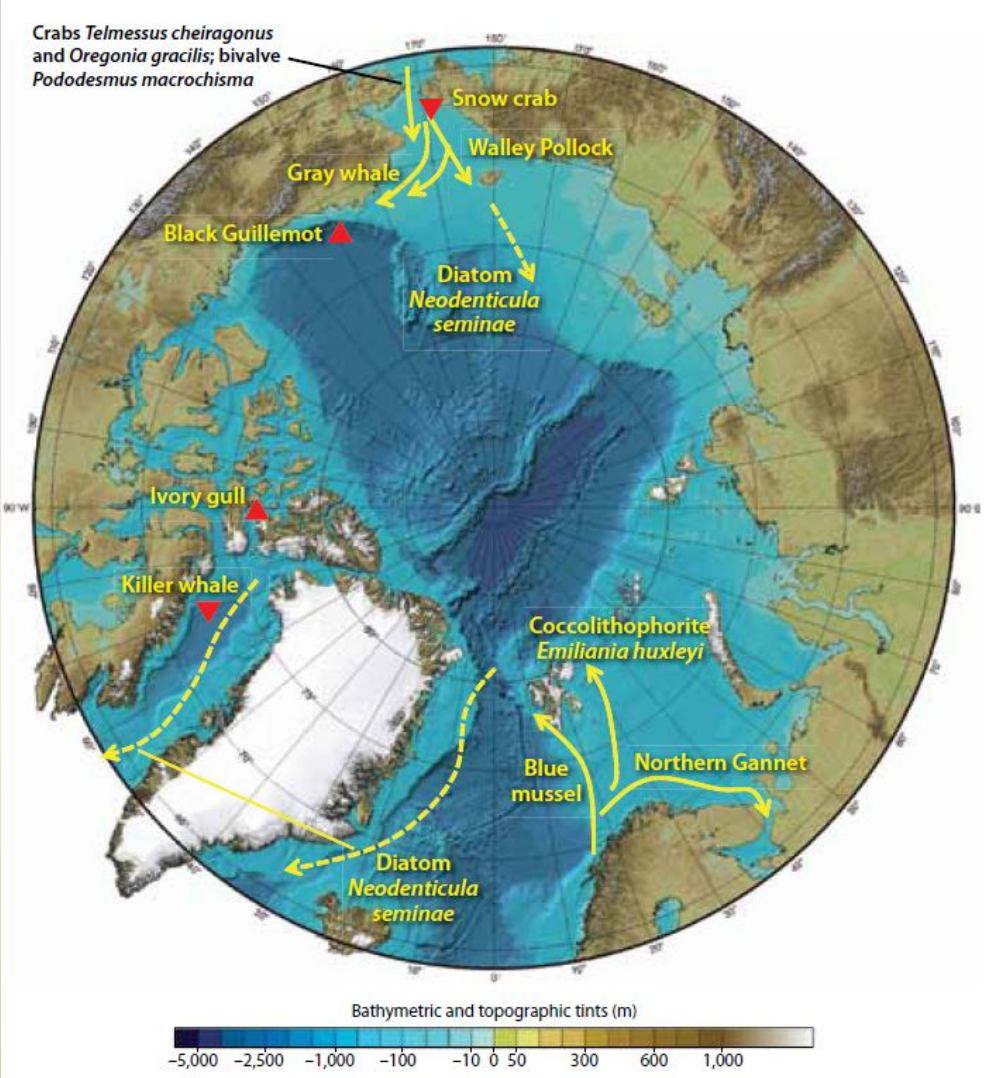
Renaud et al., in press; Progr Oceanogr

Species richness still incomplete



Piepenburg et al. 2011

Some of the evidence thus far

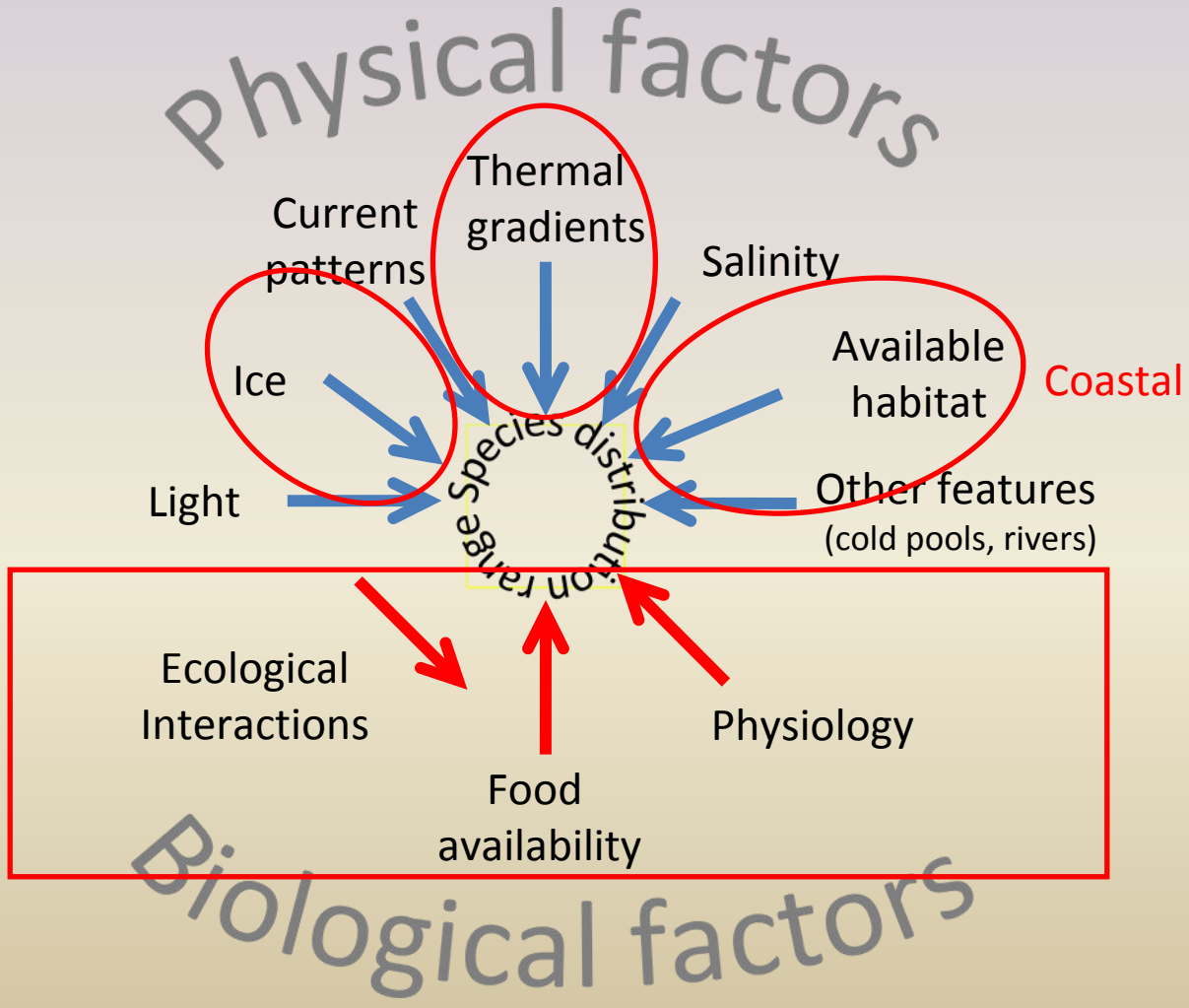


- ✓ Mostly on the shelves
- ✓ Follow prevailing current direction
- ➢ But what is the mechanism for expansion?

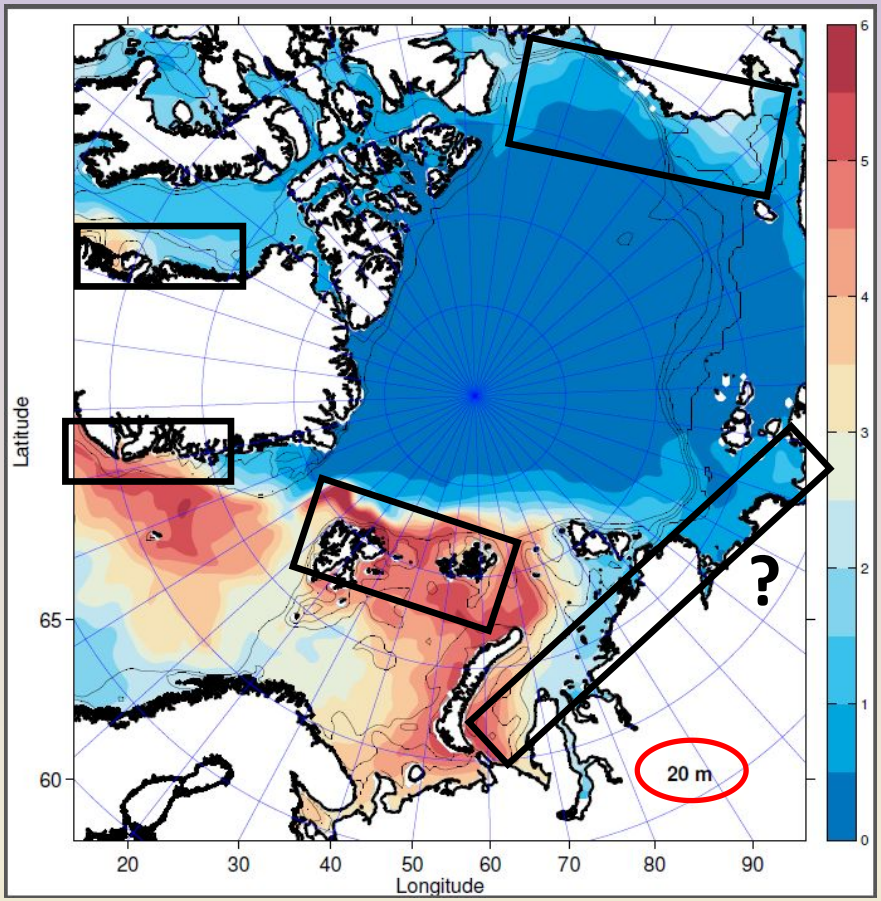
Bluhm et al. 2011

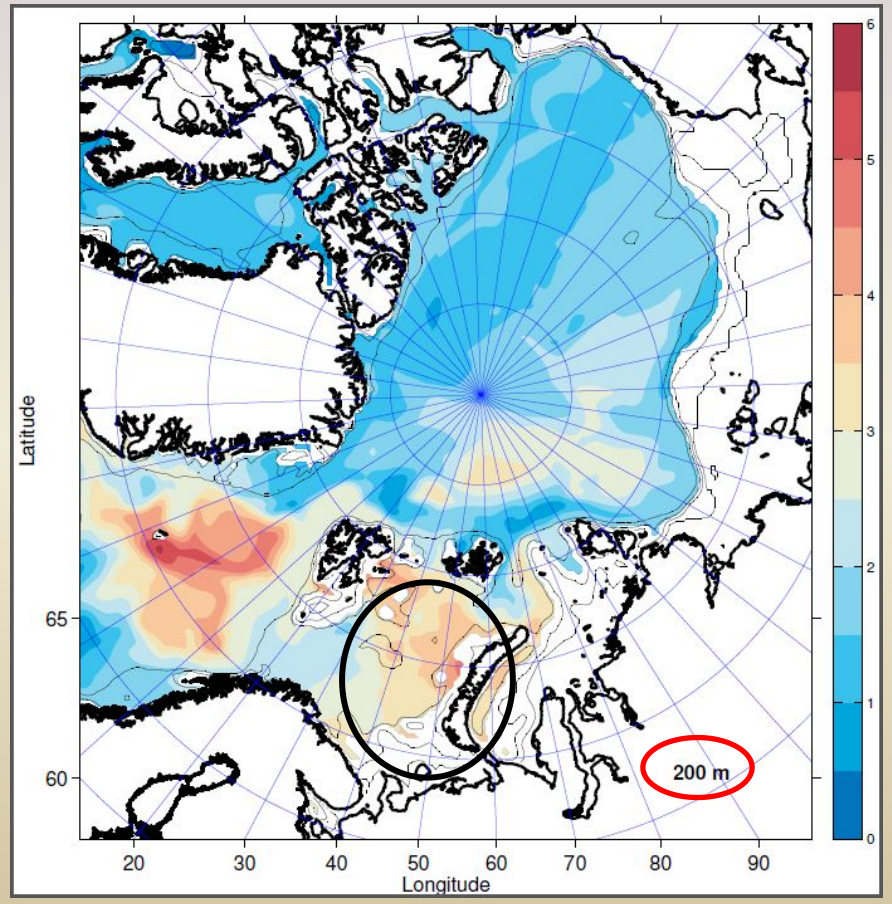
What defines species boundaries?

What factors will experience greatest change?



Future warming





Temperature change:

(2090:2099) - (2001:2010)

SINMOD simulation IPCC A1B

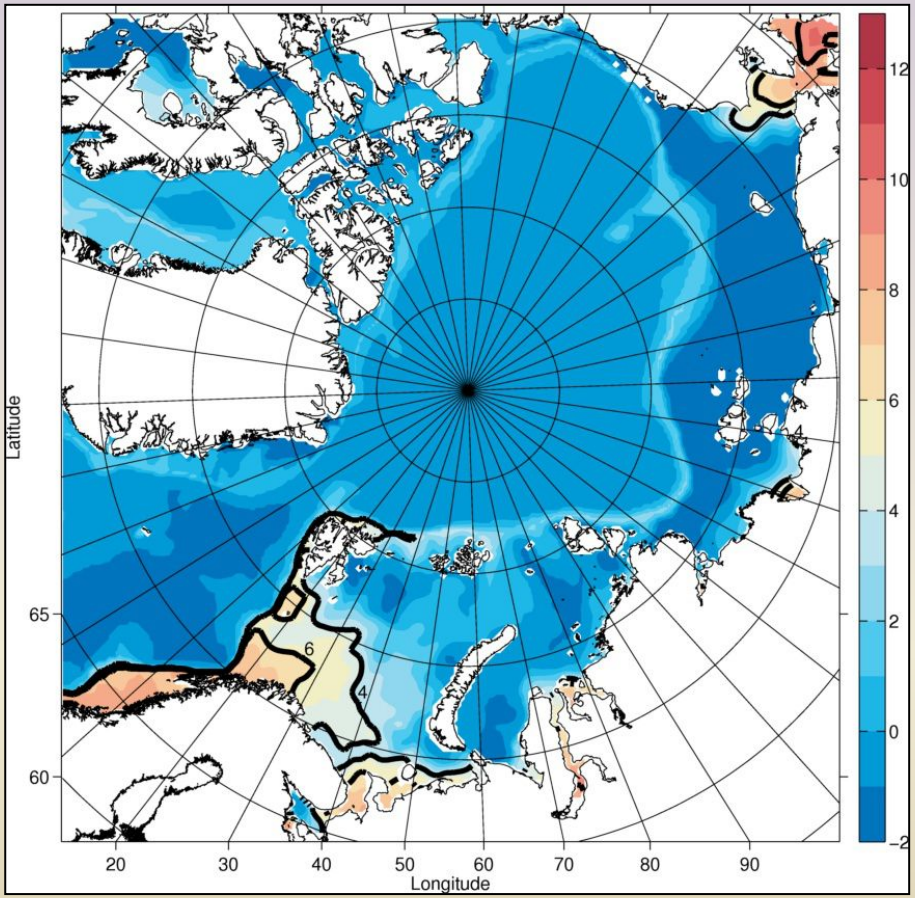
Renaud et al., in press; Progr Oceanogr

Which taxa?

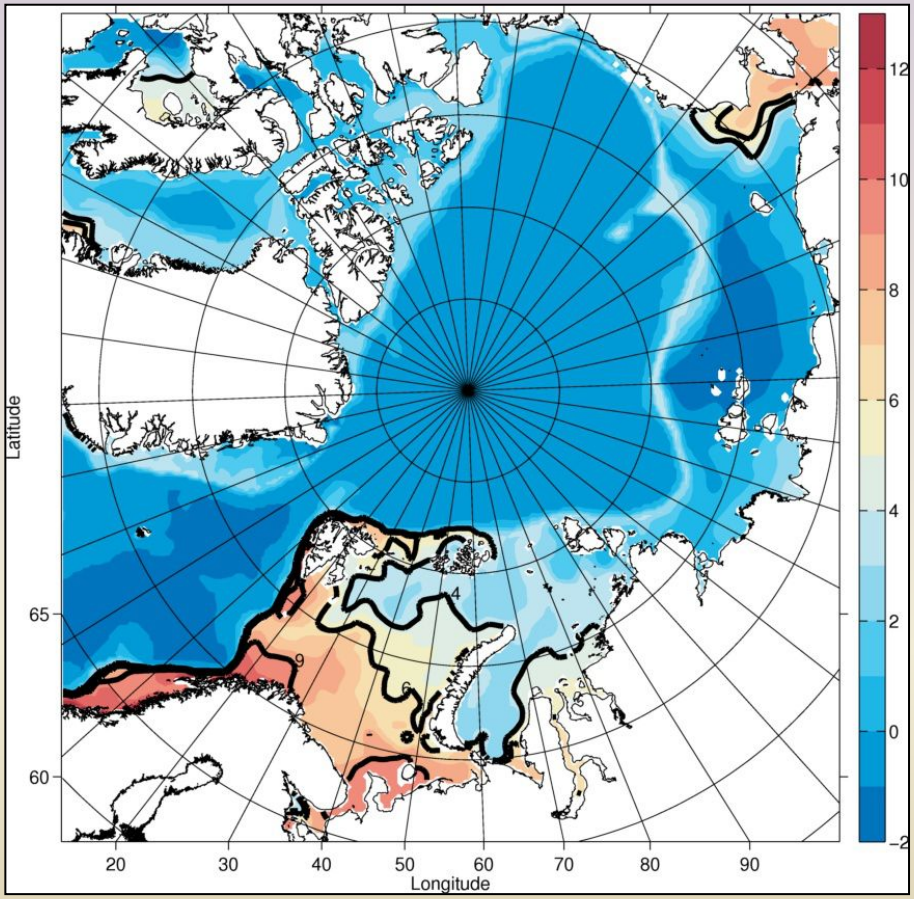
- Pelagic dispersal stages
  - But historically may not have been so important
  - Dependent on current patterns
- Cold tolerance (small changes may have large effects)
- Habitat-limited taxa?
- Flexible life-histories?

- ➢ All records for 65 benthic taxa from OBIS (boreal and Arctic)
- ➢ Determine bottom temperature (model)
- ➢ Plot thermal tolerances for 44 species

Modelled bottom-water temperatures



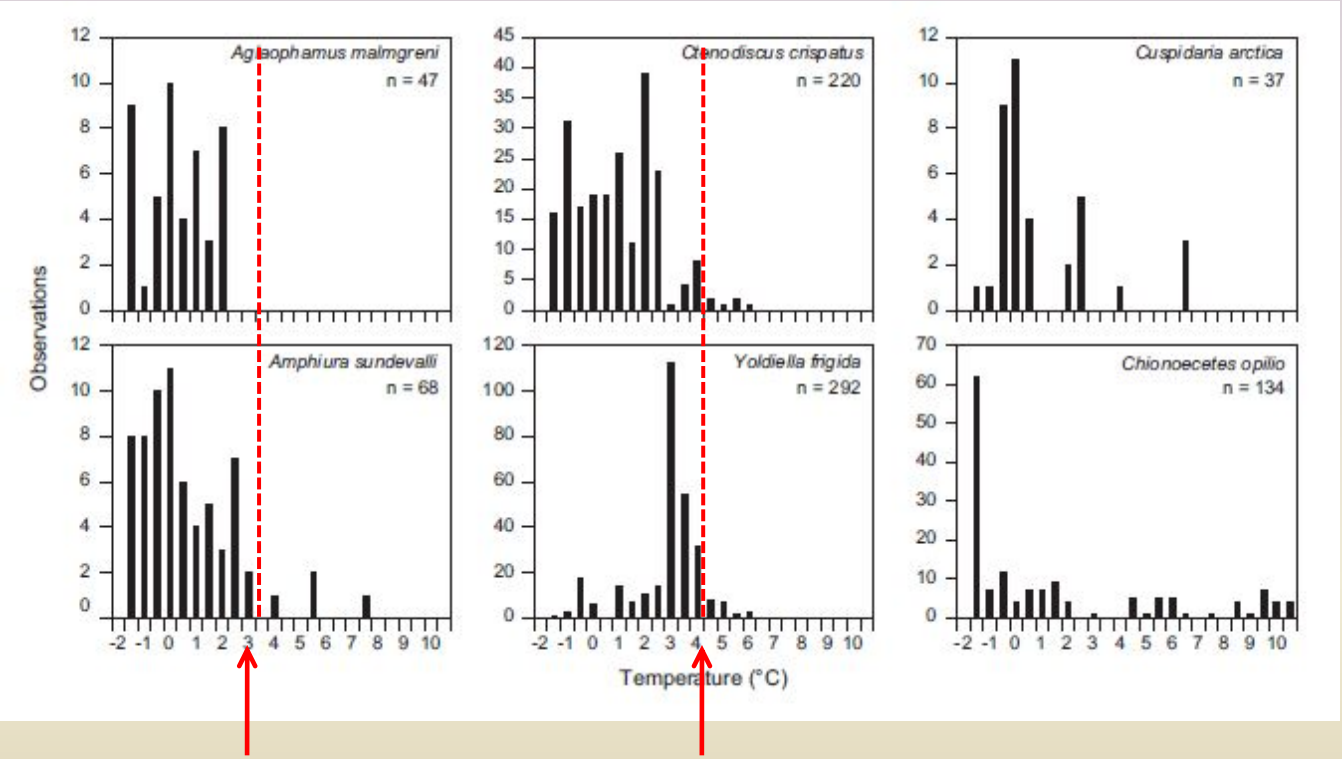
Mean 2001-2010



Mean 2090-2099

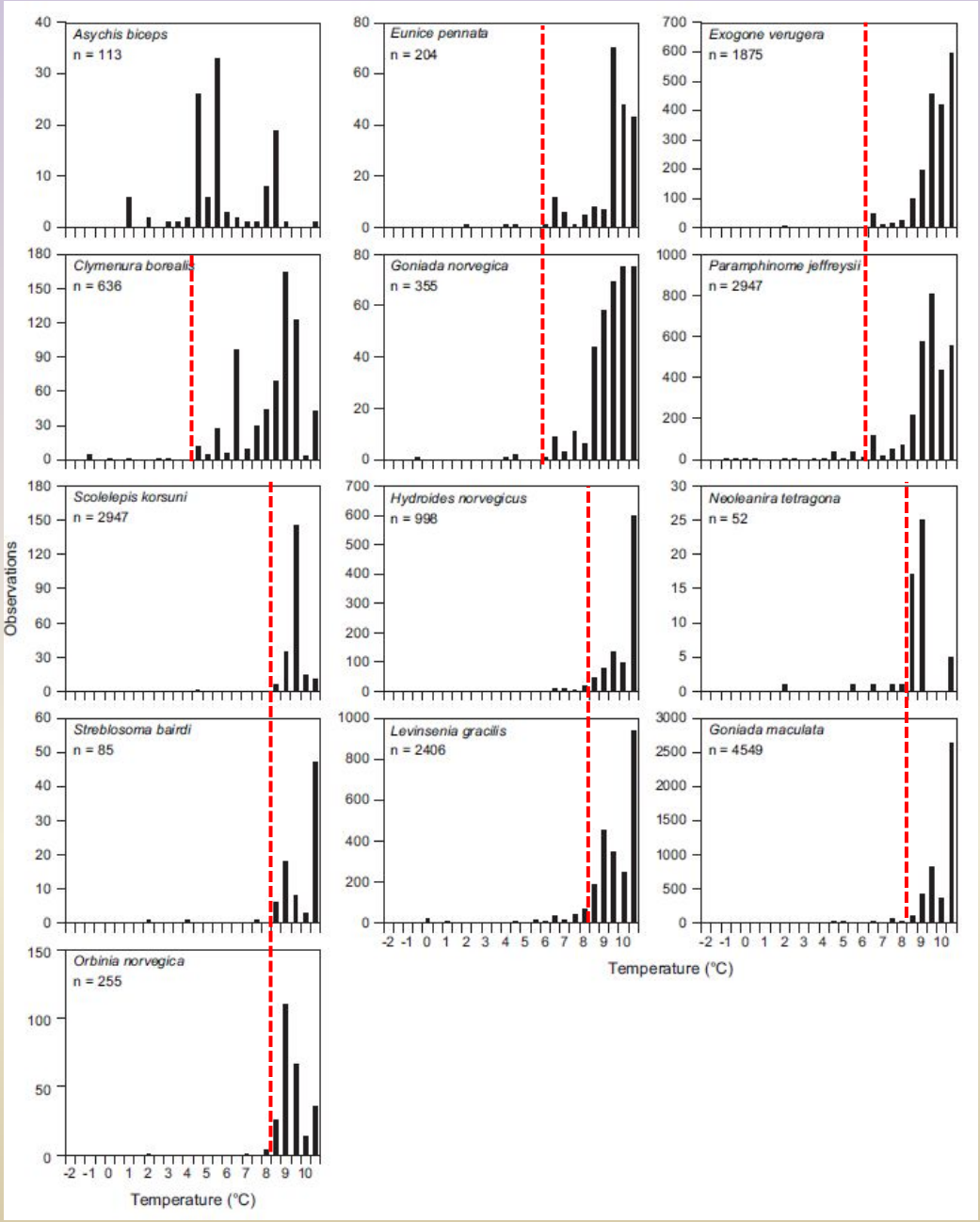
Renaud et al., in press; Progr Oceanogr

Thermal ranges for selected ‘Arctic’ species



Renaud et al., in press; Progr Oceanogr

Ranges for selected ‘boreal’ species



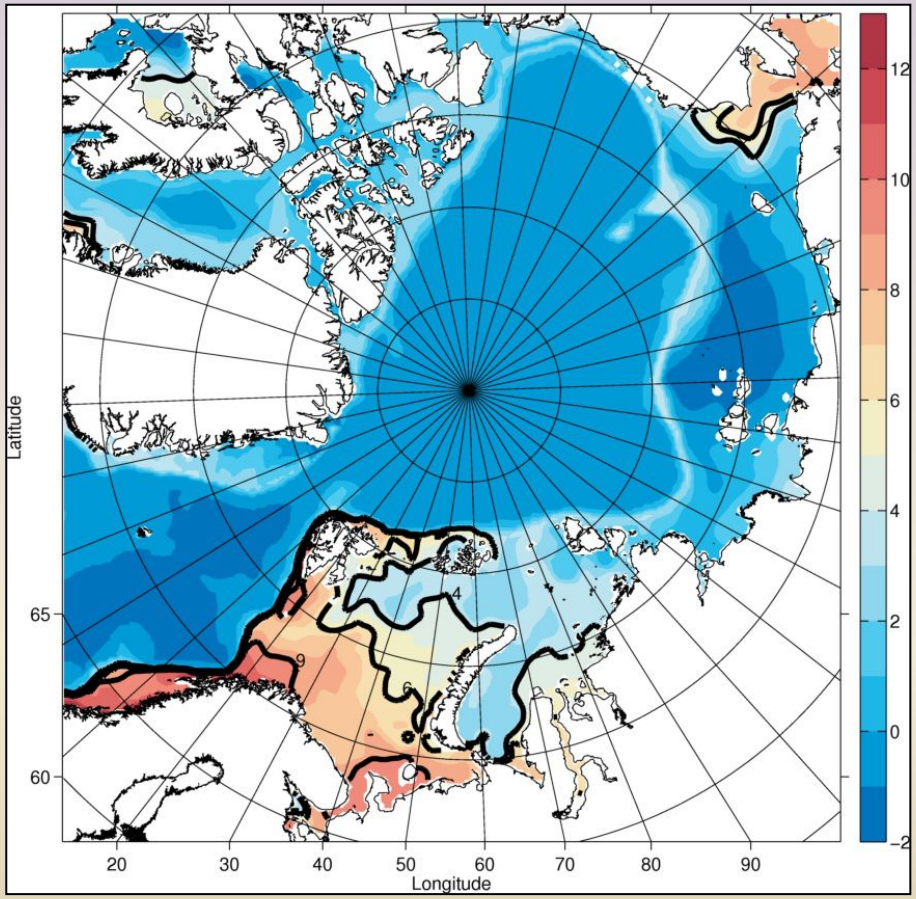
4 °C

6 °C

9 °C

Renaud et al., in press; Progr Oceanogr

Which taxa respond?



- Arctic and boreal
- 4 main infaunal phyla
- Most data for polychaetes
- Analyses limited by data archive

Renaud et al., in press; Progr Oceanogr

Conclusions

1. Biodiversity monitoring must be improved (focus area)
2. Improved autecological knowledge of residents and potential invaders is vital
3. Ecological interactions among Arctic taxa poorly known and such knowledge is important for predictions
4. Time-series, public databases, and improved distributional models are critical tools
5. Ecosystem consequences of biodiversity change unstudied

Thanks…

- Paul Wassmann
- H. Andrade, S. Aniceto
- PINRO, Danish Meteorological Survey
- Akvaplan-niva
- University of Alaska-Fairbanks
- Danish Environmental Protection Agency

Renaud PE, Sejr MK, Bluhm BA, Sirenko B, Ellingsen IH. The future of Arctic benthos: Expansion, invasion, and biodiversity. Progress in Oceanography, in press

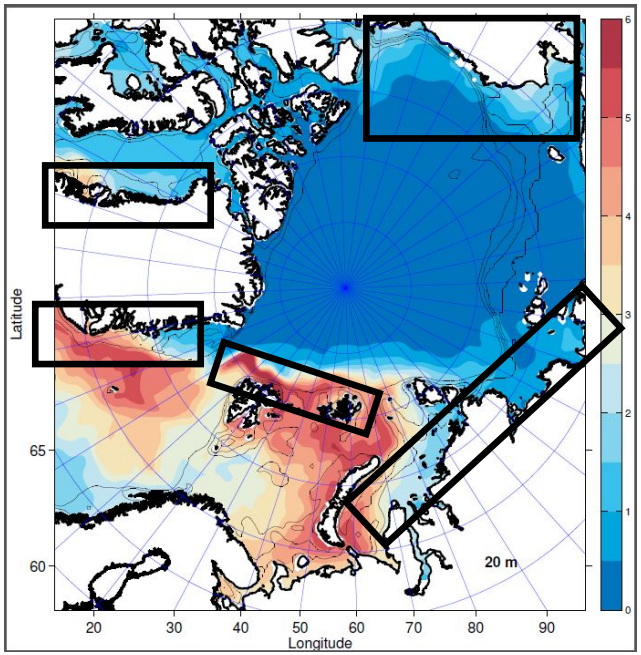
Photo: E. Svensen

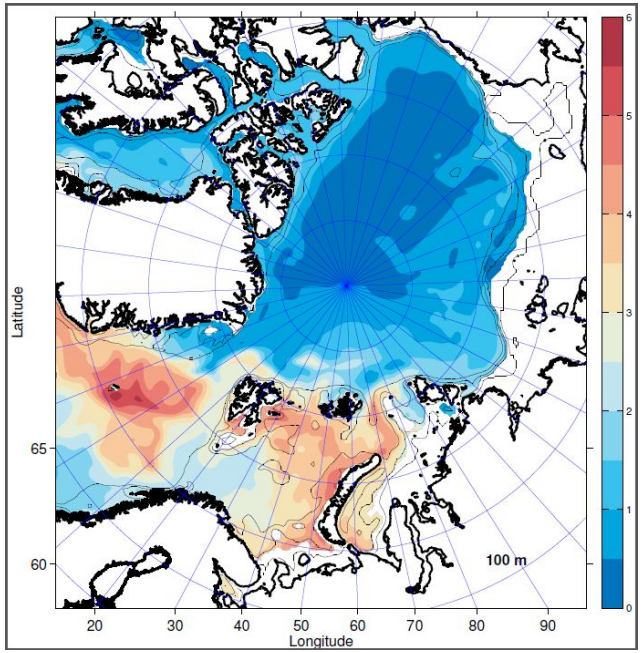
Existing Arctic benthic time series

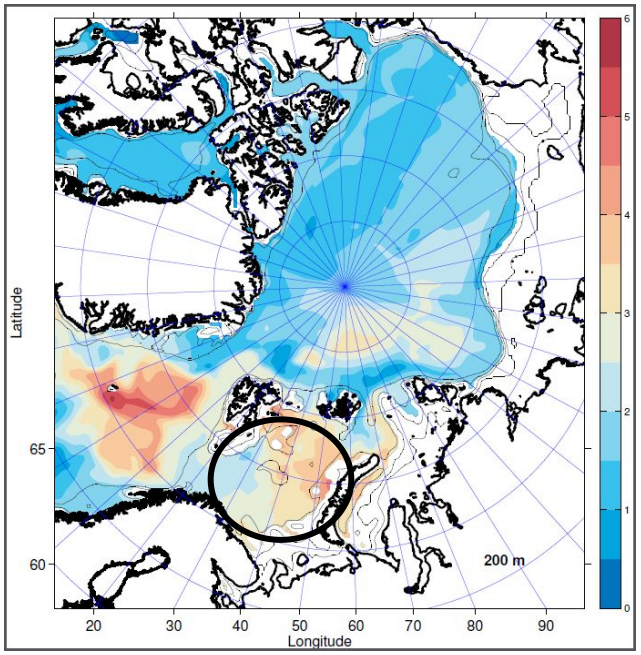
Source	taxa	time span	Response	Area
Berge et al. 2009	Decapods	1908-2007	change in species composition	Isfjorden, Svalbard
Solyanko et al. 2011	All	1920-2004	no major changes observed	Gorlo Strait, White Sea
Renaud et al. 2007	All	1980-2001	no major changes observed	van Mijenfjord, Svalbard
Kortsch et al. 2012	All	1980-2010	increase in macroalgae	Svalbard fjords
Grebmeier et al. 2006	All	1988-2003	decrease in biomass and benthic respiration	Northern Bering Sea
Blacker 1965	All	1878-1959	northward expansion of boreal species	Barents Sea
Beuchel et al. 2006, Beuchel and Gulliksen 2008	all	1980-2003	change in species composition and diversity	Kongsfjorden, Svalbard
Kozlovskiy et al. 2011	All	1927-2007	no major changes observed	SW Kara Sea
Kedra et al 2010	all	1997-2006	homogenisation of outer and middle fjord communities	Kongsfjorden, Svalbard
Weslawski et al 2010	macroalgae	1988-2008	increase in biomass and vertical distribution	southern Spitzbergen
Grebmeier 2012	bivalves	1987-2008	decrease of *Nuculana radiata*	St. Lawrence Island
Bergman et al. 2011	all megafauna	2002-2007	decrease in standing stock, relative composition of feeding guilds	Fram Strait
Coyle et al. 2007	ampeliscid amphipods	1986-2003	decrease in biomass, particularly of larger size clases	Chirikov Basin
Krause-Jensen et al. 2012	macroalgae	1999-1011	effect of ice cover on macroagal growth	Young Sound NE Greenland
Sirenko et al. 2009	all	1939-2006	Increase in biomass	Chukchi Sea
Sirenko and Koltun 1992	bivalves	1933-1988	Change in dominant species	St. Lawrence Island
Time series proxies				
Ambrose et al. 2006, Carroll et al. 2011	bivalve growth series	1974-2009	growth corresponded positively with phase shifts in climatic indices	Svalbard and vicinity
Sejr et al 2009	bivalve growth series	1979-2003	growth related to open water period	W Greenland

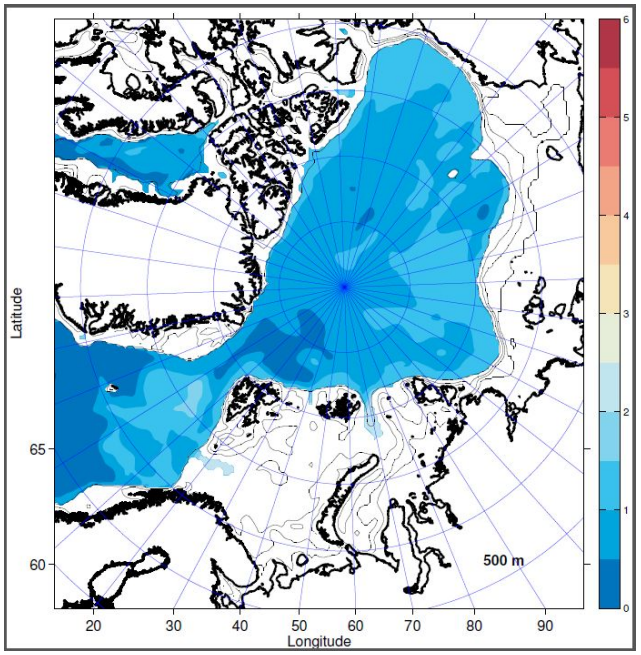
Arctic time series

- Not very common, but maybe more than we think!
- Extremely valuable
  - Detecting change
  - Identifying invasions/range extensions
  - Linking change with process/mechanism
  - Developing testable hypotheses
- ‘Regionality’ limits pan-Arctic relevance









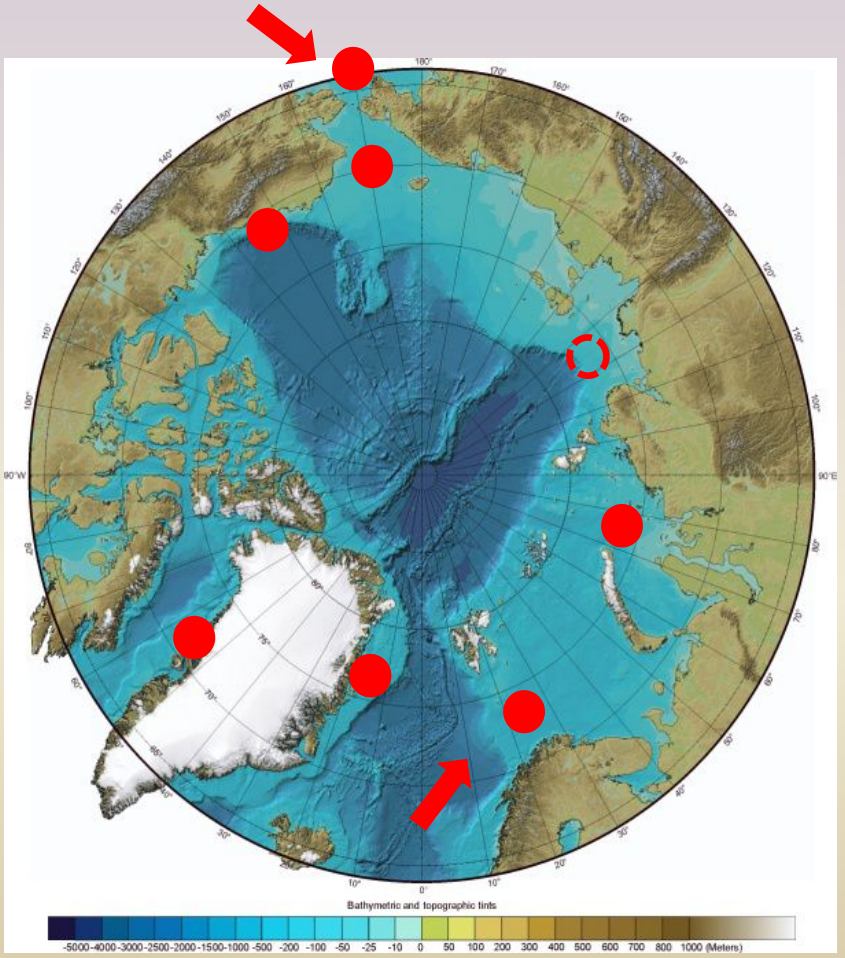
Temperature change:
2090-2099 vs.
2001-2010

SINMOD simulation
IPCC A1B

Where?

- Bering-Chukchi-Beaufort
- Barents-Kara(-Laptev?)
- East/West Greenland

- Shelf habitats
- Soft sediments (easier dispersal)
- New hard substrate



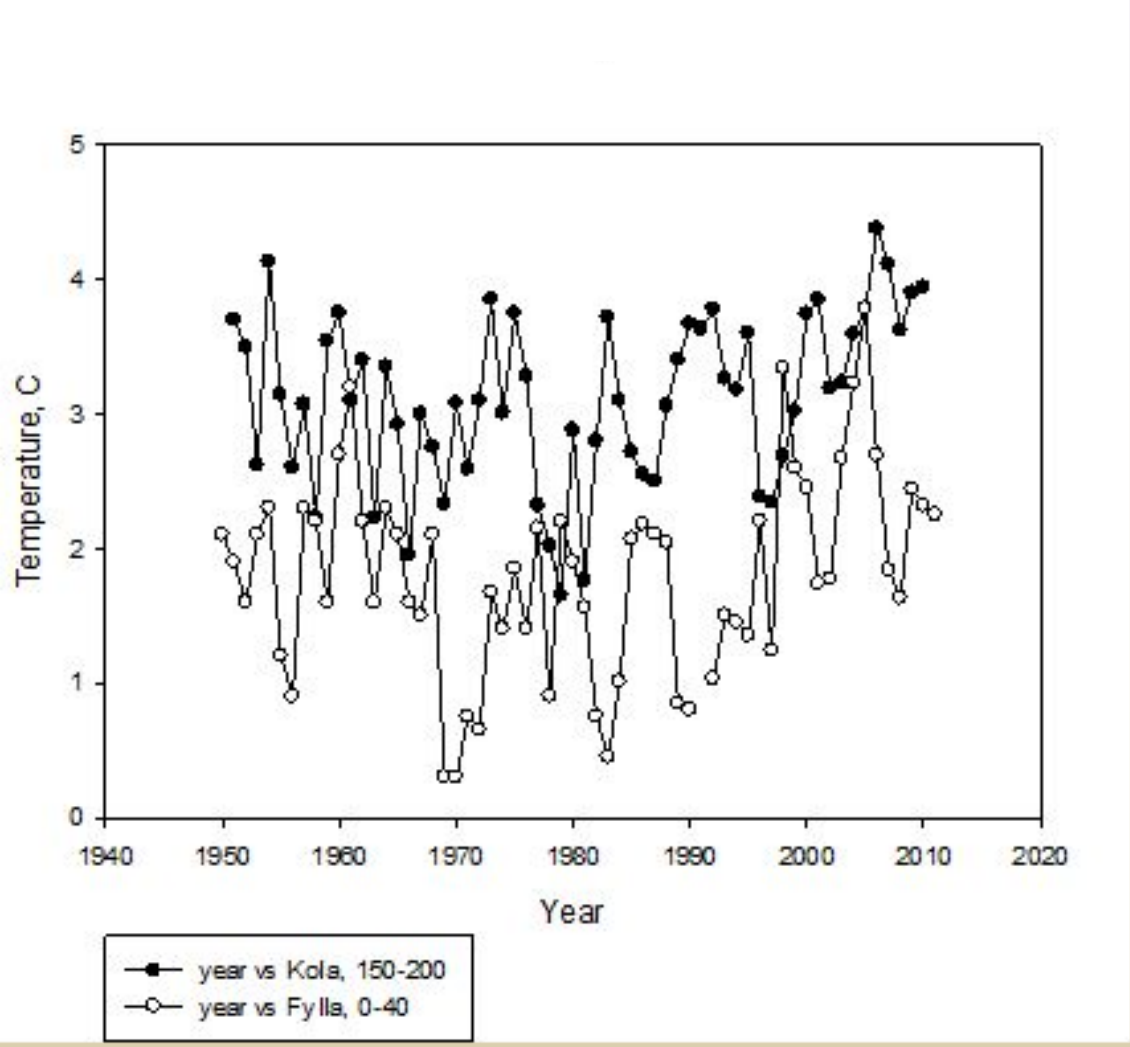
What defines species boundaries?

- Physical factors
  - Thermal gradients
  - Available habitat
  - Current patterns
  - Ice/light
  - Other features (rivers, cold pools, etc.)
- Biological factors
  - Physiology
  - Food availability (primary production, flux to benthos)
  - Ecological interactions

Where will we see the greatest change in these factors?

- Climate change directly affects :
  - Temperature and ice
  - Available benthic habitat (esp. coastal habitat)
- Climate change indirectly affects :
  - Primary production, by altered nutrient supply and changes in light field (due to ice, rivers, erosion)
  - Competitive ability, mediated by changes in physiological responses (e.g. to temperature, pH, etc.)
  - Predation pressure, due to earlier invasions by boreal predators

Warming on local and regional scales



Empirical evidence (2)

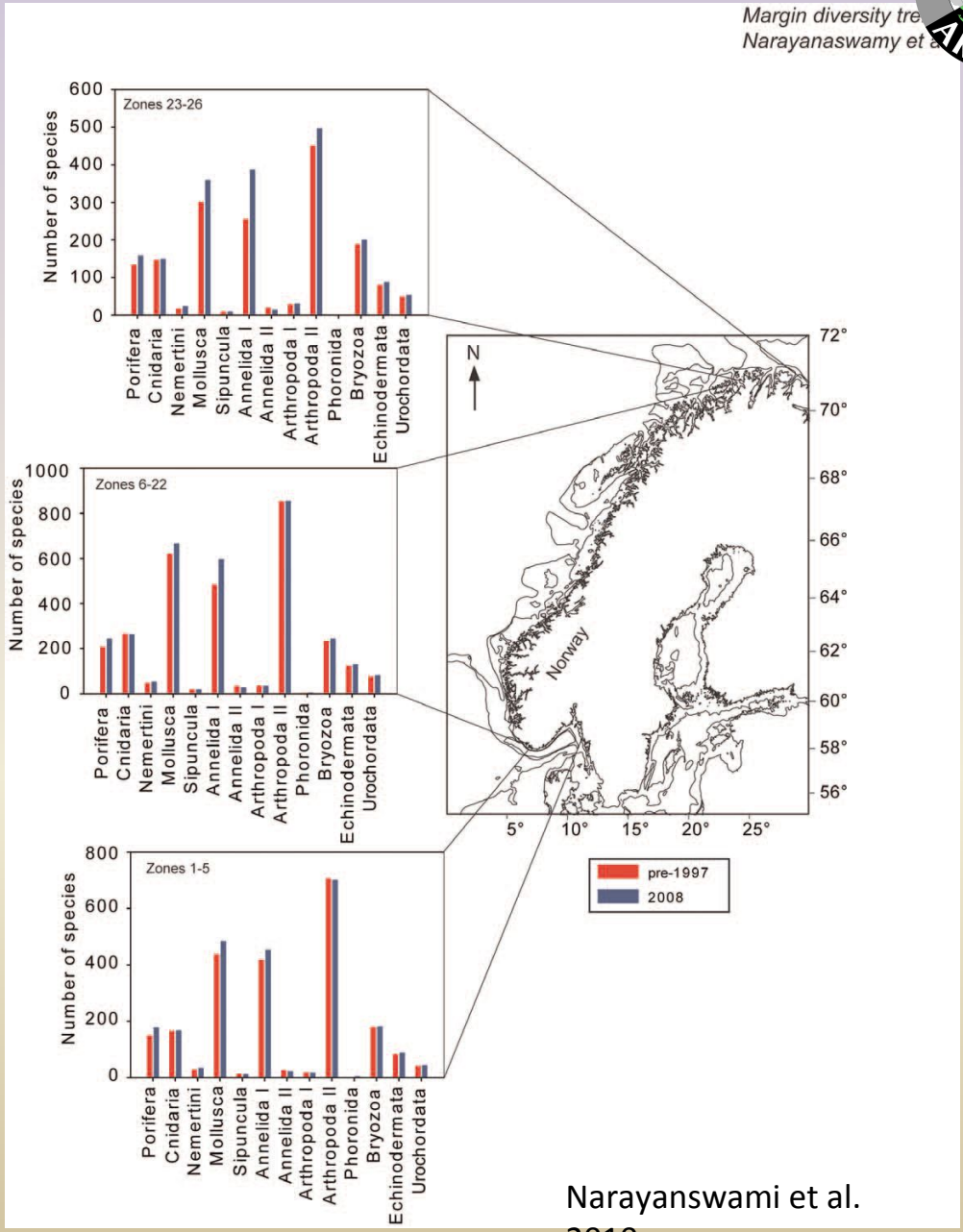
Since late 1990s:

- +17% in Finnmark
- +7% W Norway
- +5% Skagerrak

- +9% Svalbard

- Expanded northern limits

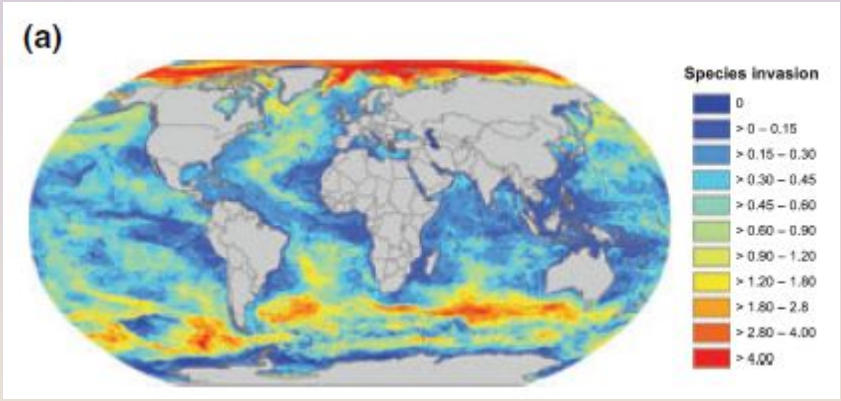
- Sampling effort?
- Real change?

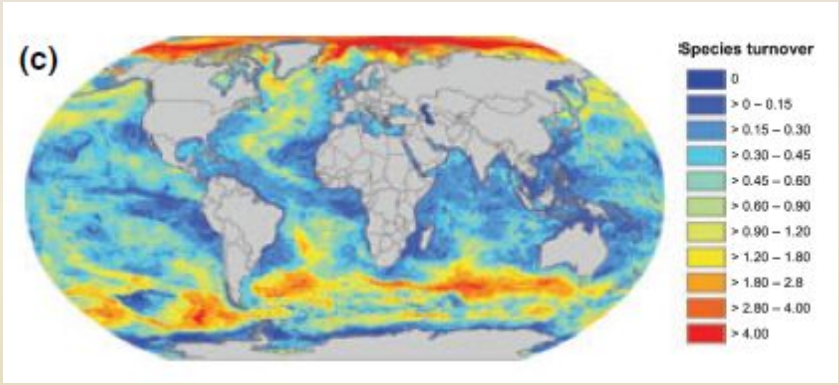


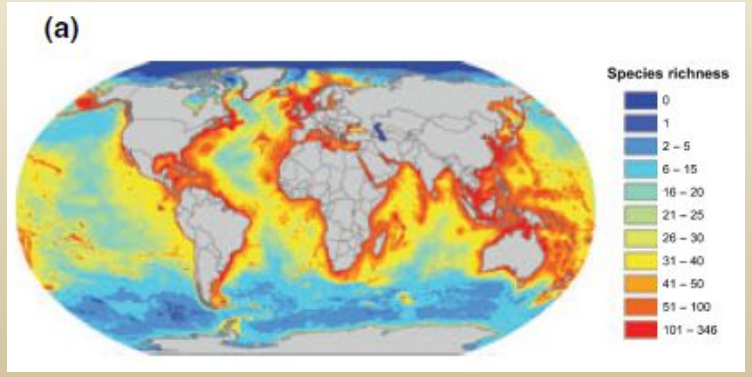
Narayanswami et al. 2010

Predicted changes in biodiversity by 2050

- Species invasions most intense in Arctic and Southern Ocean
- Invasion main contributor to species turnover (extinction)
- …strong bias by taxa chosen







Cheung et al. 2009

Which factors will experience the greatest change?