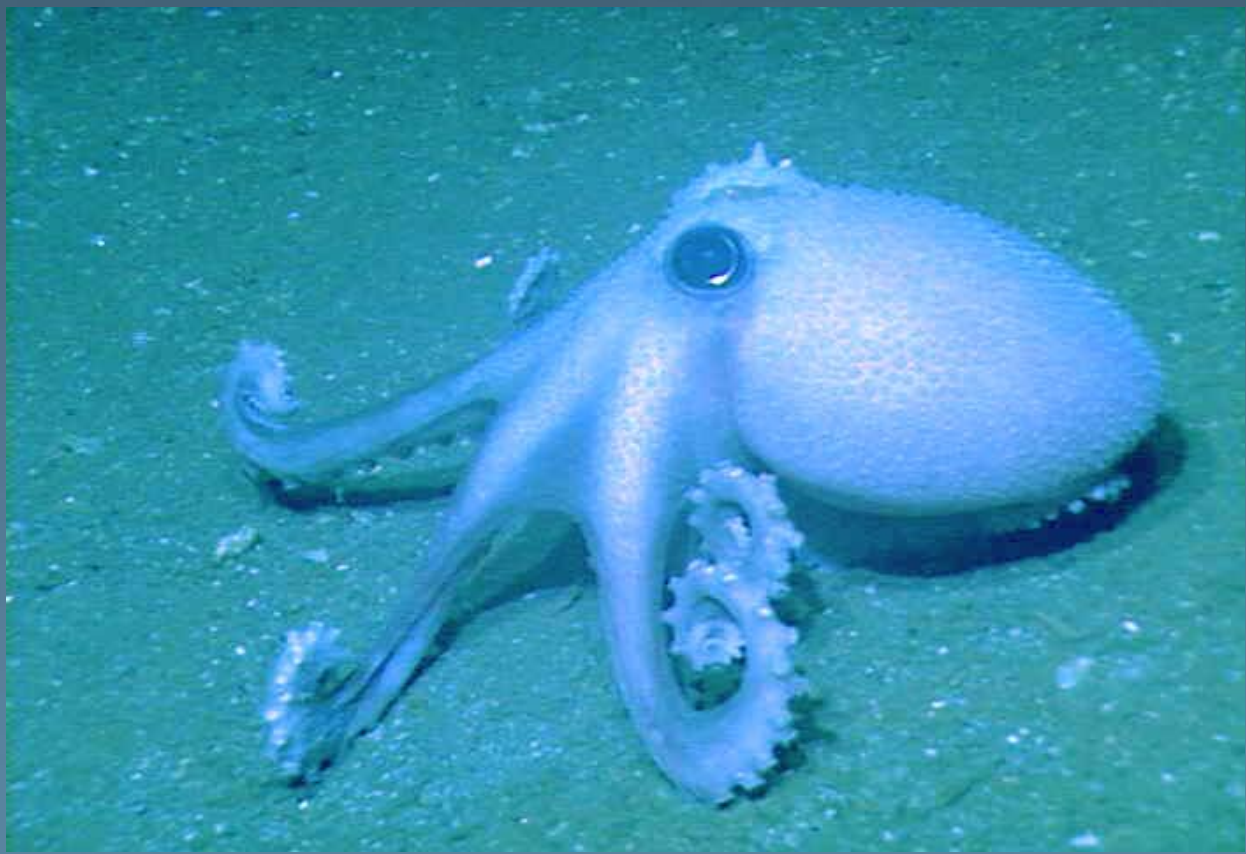
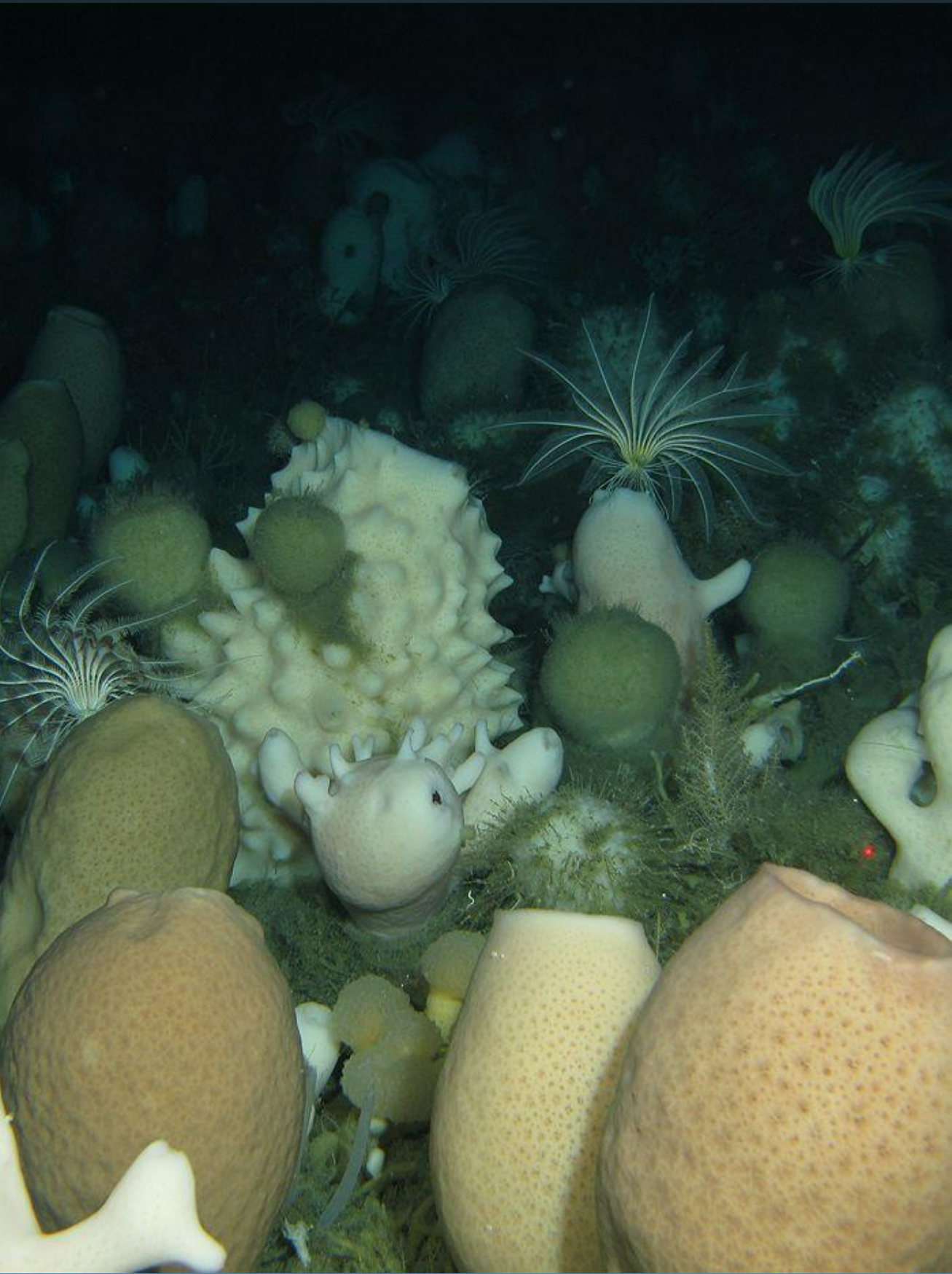
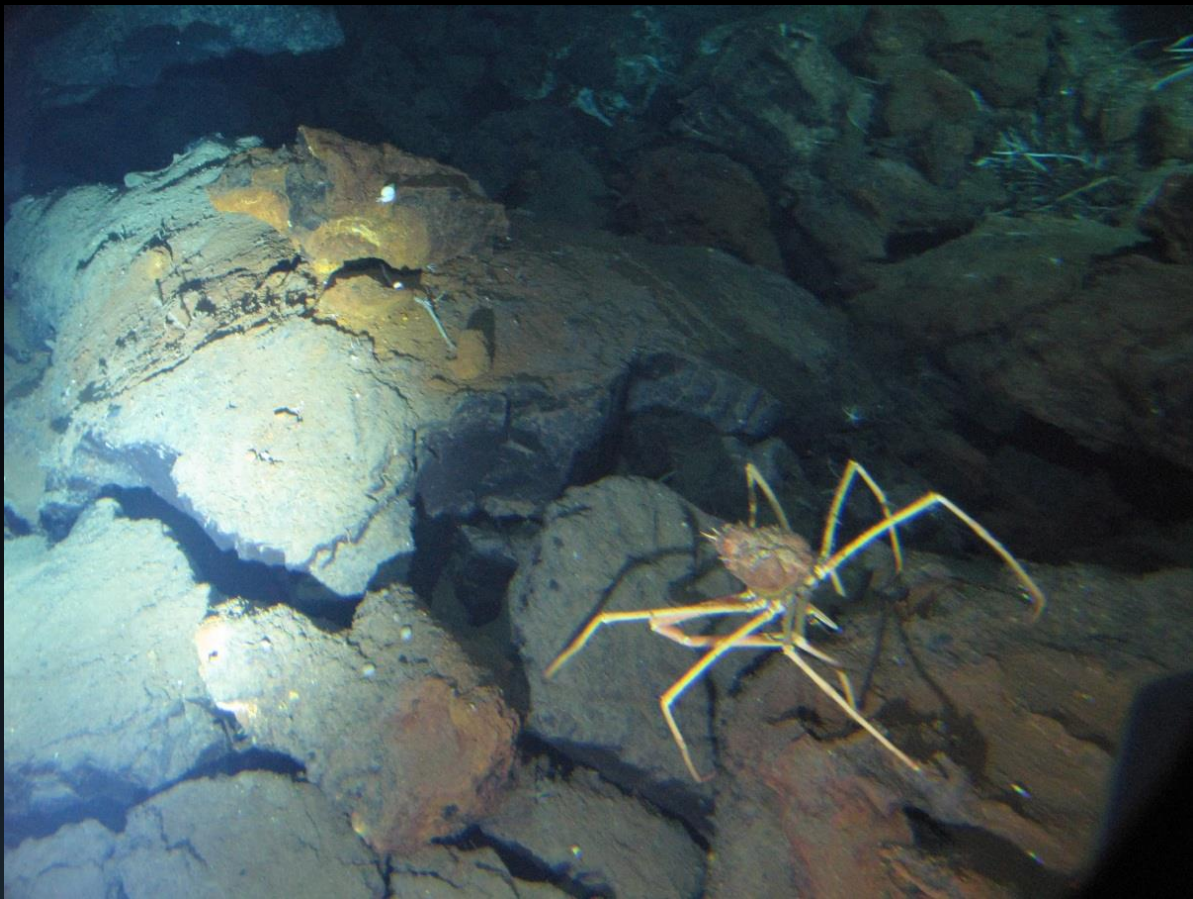


What lies beneath? Melting sea ice and conservation of Arctic benthic habitats

Peter T. Harris
GRID-Arendal
NORWAY



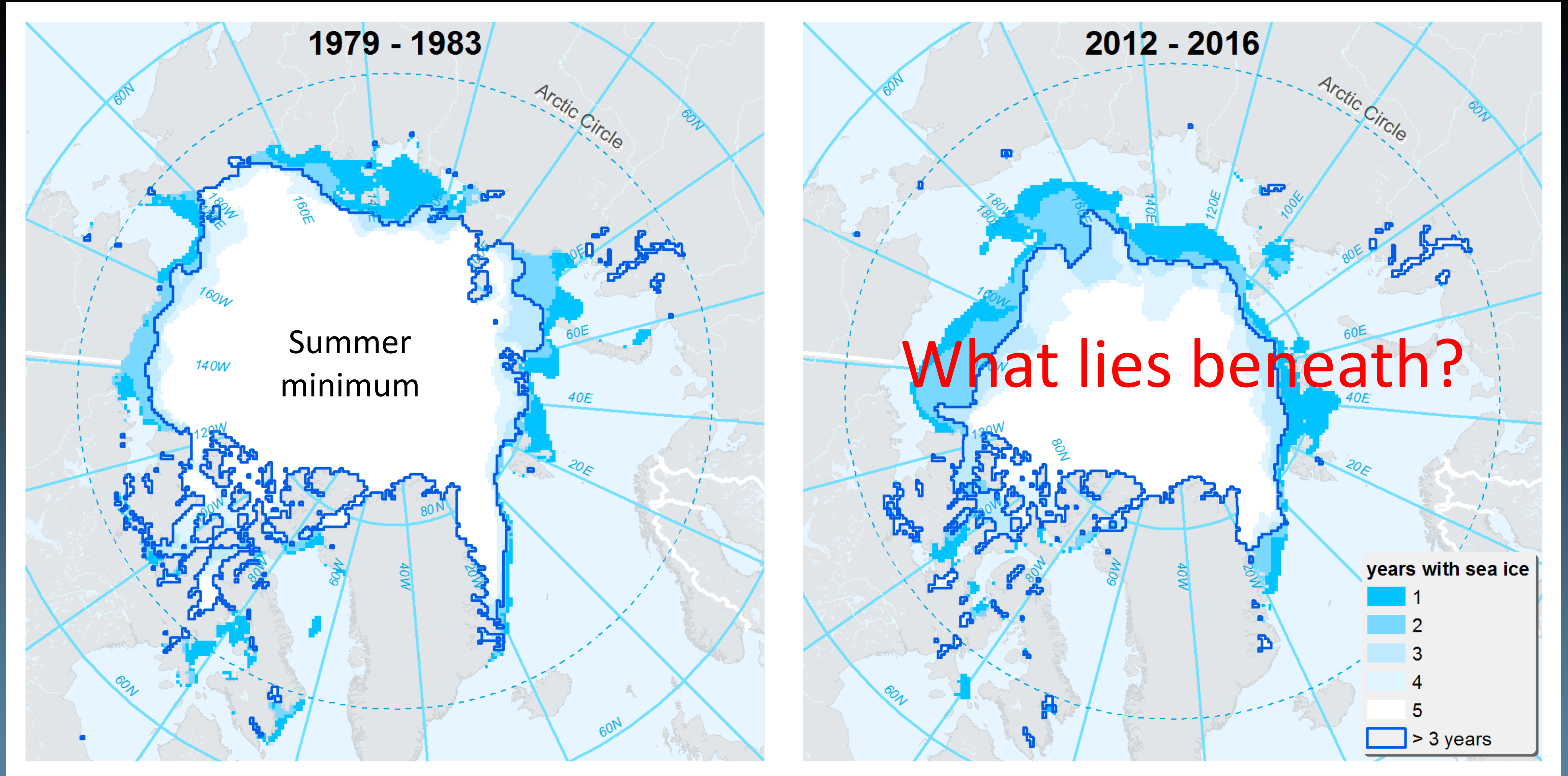




Profound changes in Arctic ecosystems due to climate change

1. In a seasonally ice-free Arctic, more open-water conditions may result in a three-fold increase in primary productivity.
2. Absence of sea ice allows ocean-atmosphere coupling >>> currents, waves (coastal impacts), more surface mixing >>> regime shift.
3. Warmer ocean conditions have already caused changes to the ranges and ecology of Arctic fish, benthos, birds and mammals.

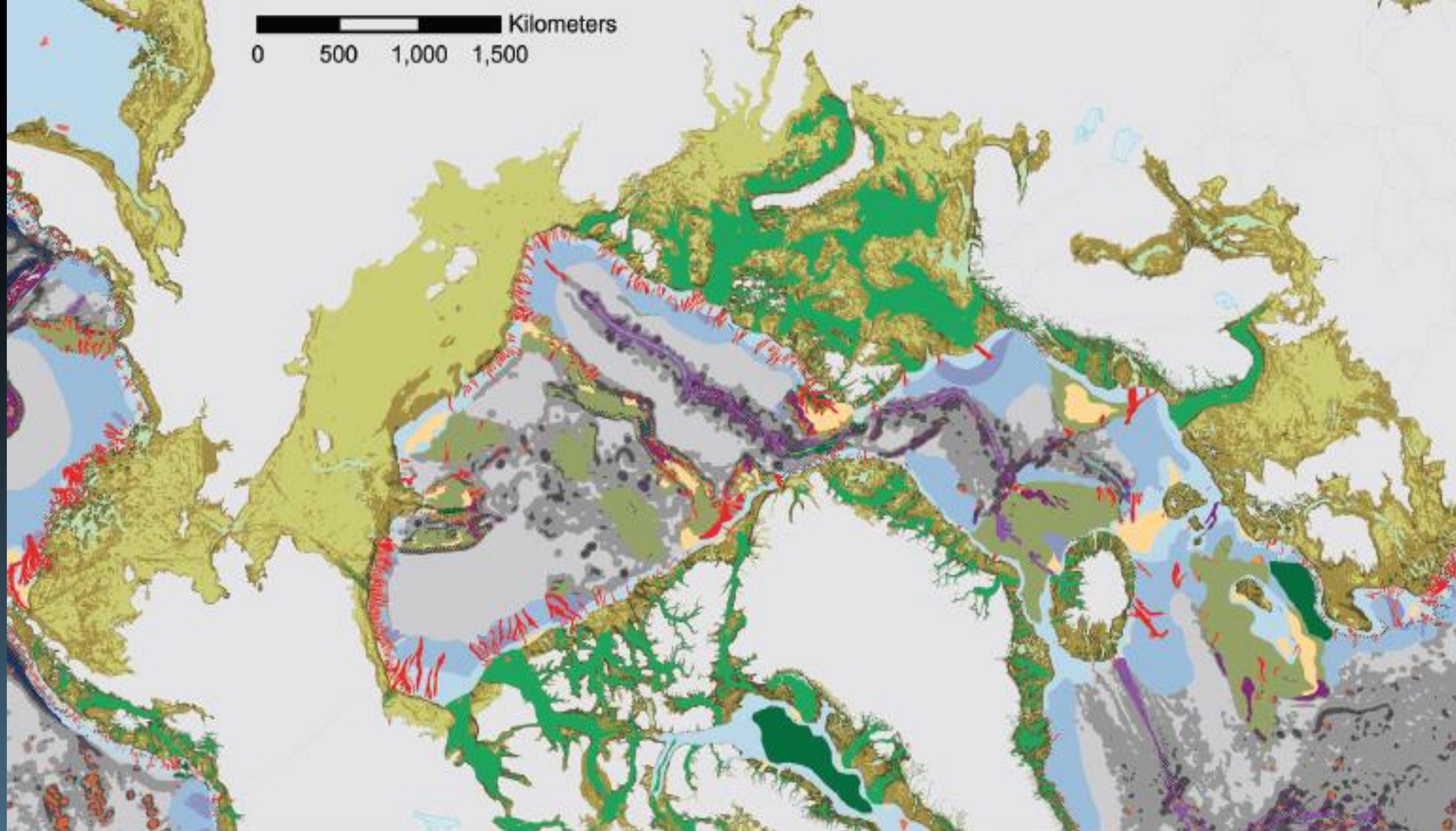
Shrinking sea ice from 7.5 million km² in 1979 to around 4 million km² in 2016



Source: National Snow and Ice Data Center, Sea Ice Index, Version 2 (Fetterer et al 2016) spatial resolution (pixel size) of 25 x 25 km.

Seafloor geomorphic features

are also benthic
habitats - seamounts,
canyons, ridges and
plateaus each support
unique (endemic)
benthic communities.



Shelf - high profile	Hadal	shelf valley	rise
Shelf - medium profile	canyon	rift valley	terrace
Shelf - low profile	guyot	glacial trough	trench
Slope	seamount	trough	plateau
Abyss - mountains	bridge	ridge	
Abyss - hills	sill	spreading ridge	
Abyss - plains	escarpment	fan/apron	

Harris, P.T., MacMillan-Lawler, M., Rupp, J., Baker, E.K., 2014. Geomorphology of the oceans. *Marine Geology* 352, 4-24.

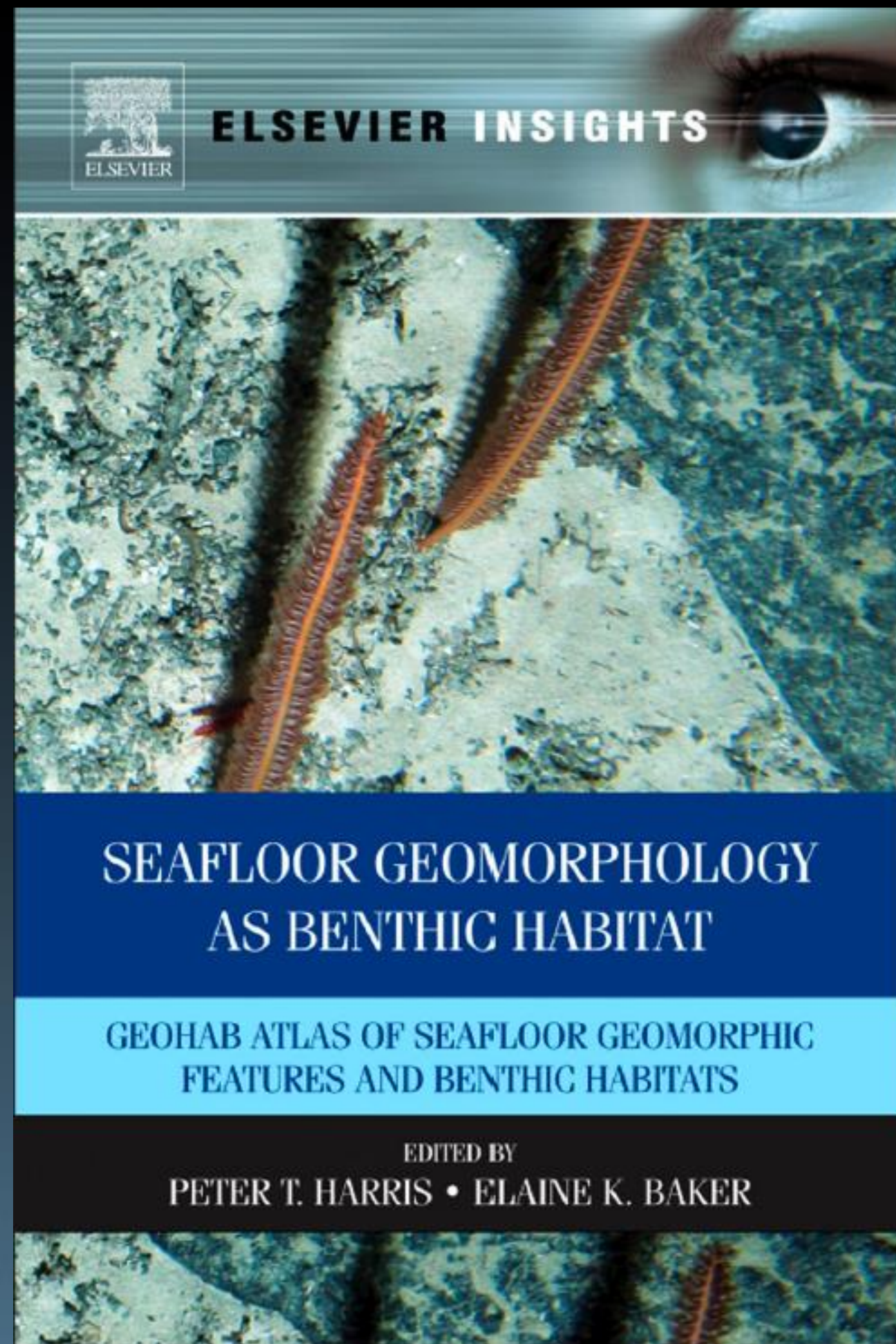
Canada

Greenland

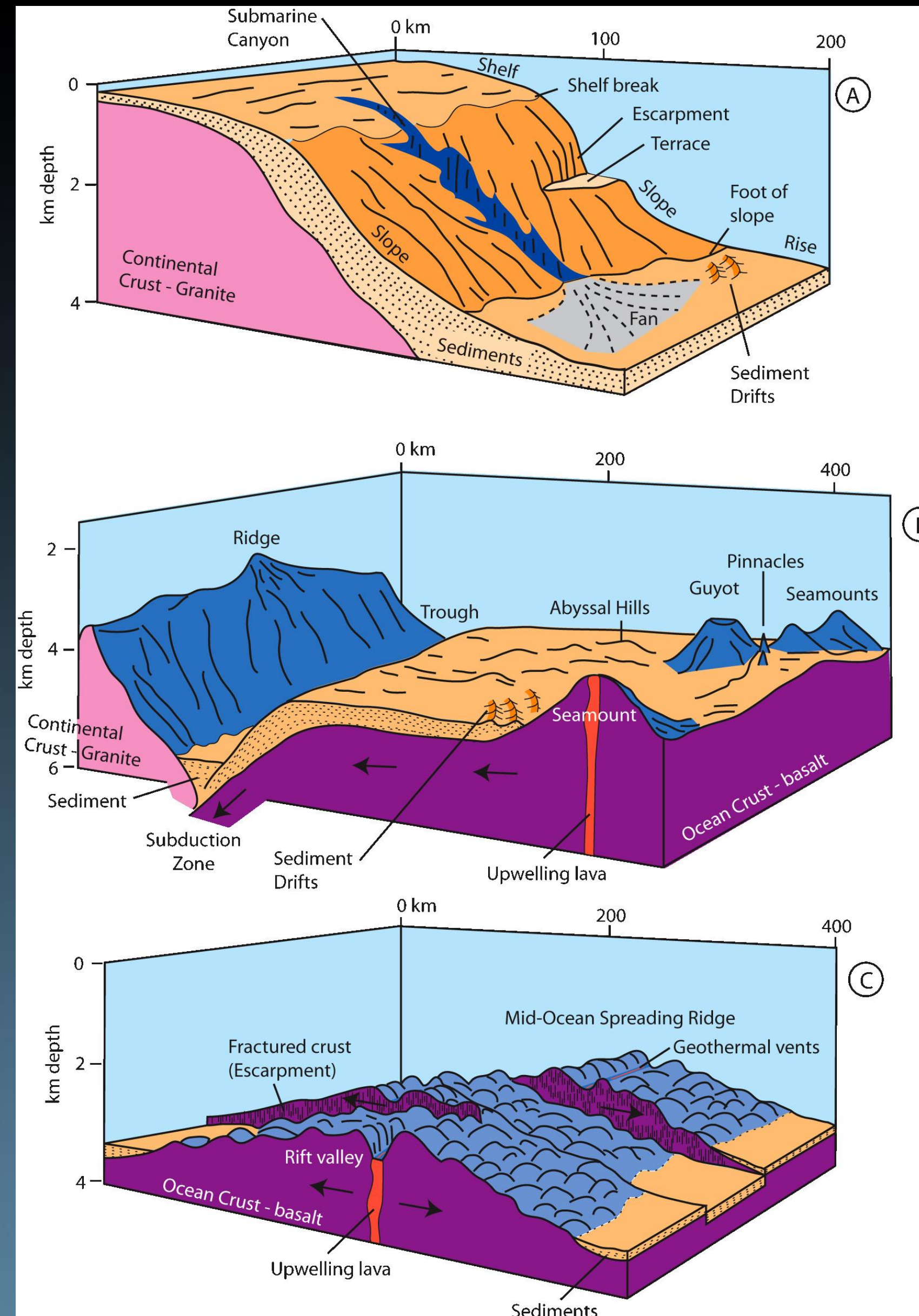
Norway

Russia





Harris and Baker, Eds. (2012). *Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of seafloor geomorphic features and benthic habitats*. Amsterdam, Elsevier.



Fernandez-Arcaya et al (2017). "Ecological Role of Submarine Canyons and Need for Canyon Conservation: A Review." *Frontiers in Marine Science* 4(5).

Clark et al (2010). "The Ecology of Seamounts: Structure, Function, and Human Impacts." *Annual Review of Marine Science* 2(1): 253-278.

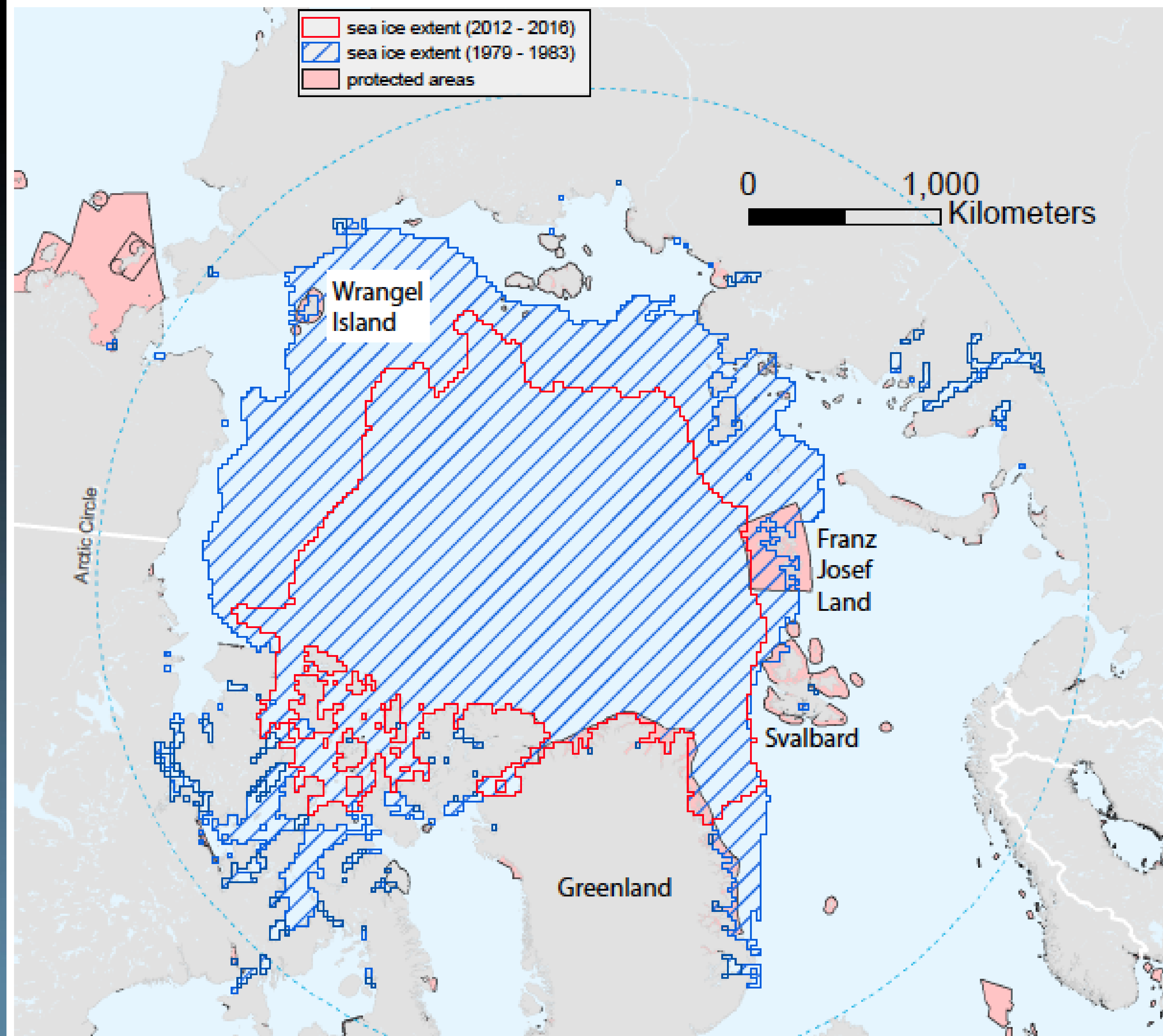
Jamieson et al (2010). "Hadal trenches: the ecology of the deepest places on Earth." *Trends in Ecology & Evolution* 25(3): 190-197.

Van Dover, C. (2000). *The ecology of deep-sea hydrothermal vents*. Princeton University Press.

Marine protected area boundaries

IUCN and UNEP-WCMC database.

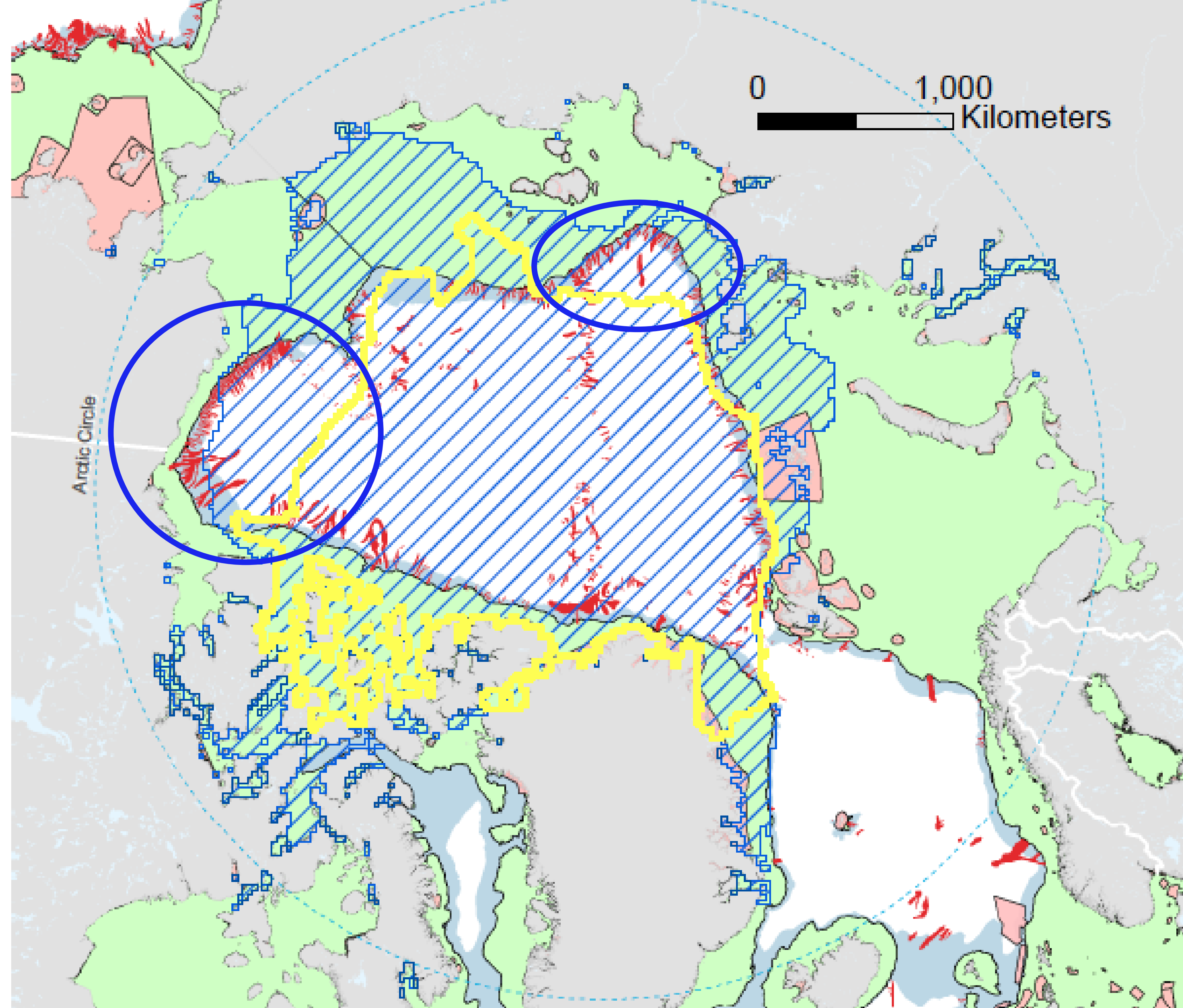
MPAs cover 173,000 km² or 2.3% wrt (1979) permanent sea ice zone



37% of canyons now in open water

Submarine canyons contain potential fishing grounds, biodiversity hotspots, cold-water coral communities and cetacean feeding grounds. Shelf-incising canyons are associated with oceanographic upwelling zones and enhanced productivity.

>400 Arctic canyons
295,000 km²
0.08% within MPAs

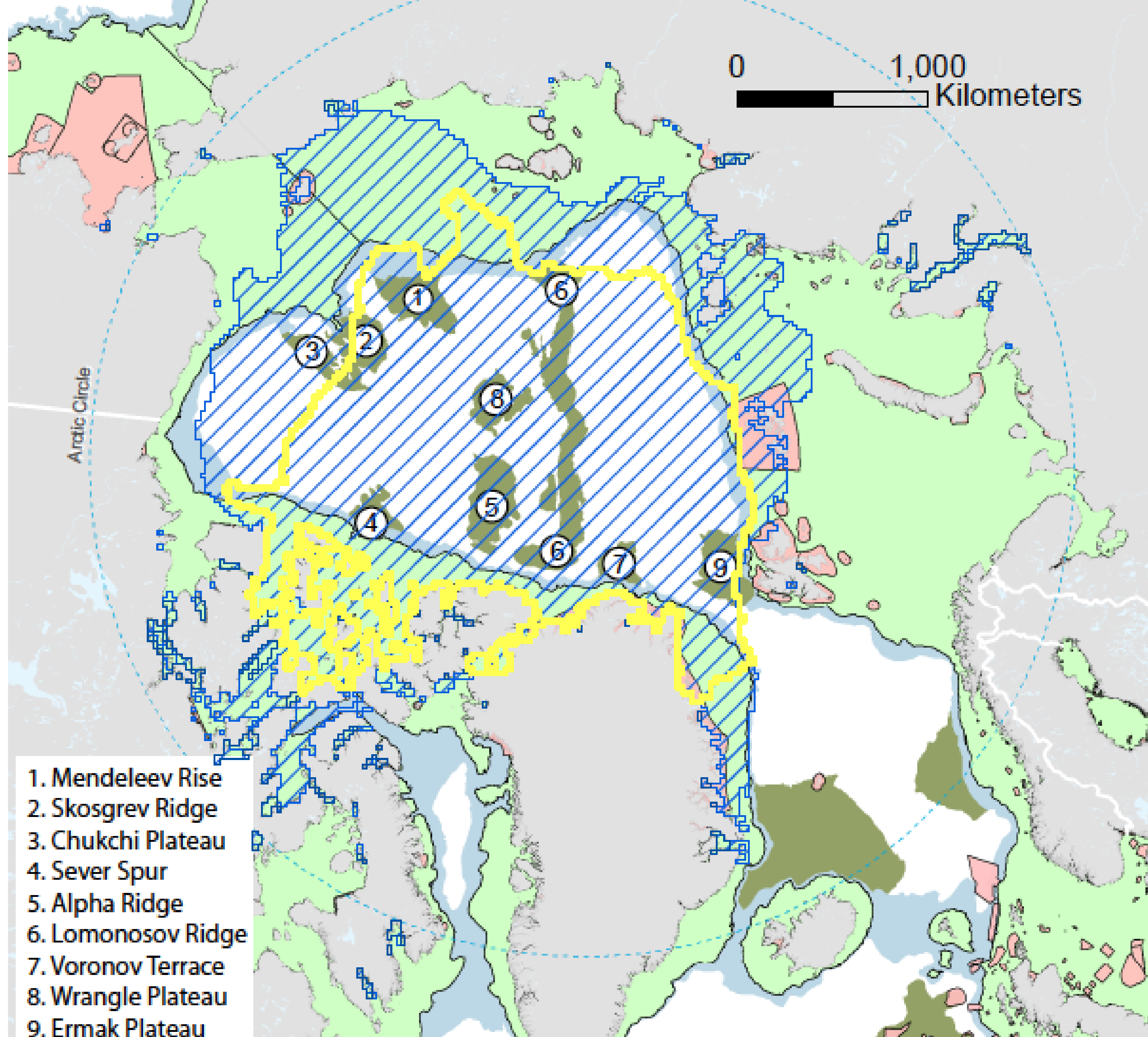


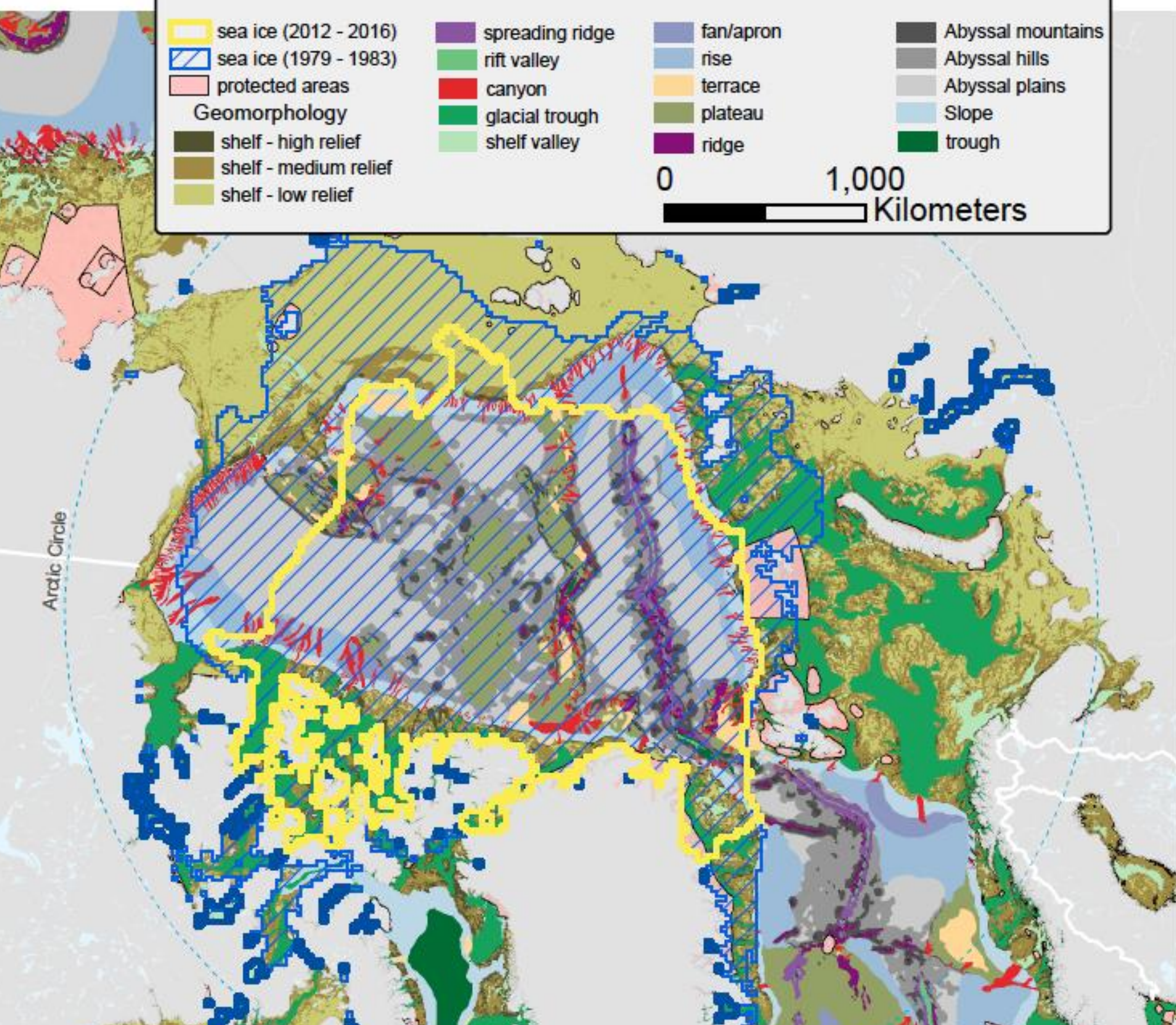
8.3% of plateaus now in open water

- Benthic ecology of submarine plateaus is poorly studied.
- Biodiversity is thought to be increased in association with rocky habitats (eg. along plateau margins).
- Bottom trawl fisheries impact plateaus in other areas.

773,000 km²

0% within MPAs





Geomorphology of the Arctic Ocean

Change in sea ice cover:

Shelf	65%
Glacial troughs	50%
Slope	48%
Submarine canyons	37%
Plateaus	8%
Abyssal plains	19%
TOTAL	38%

Conserved in MPAs:

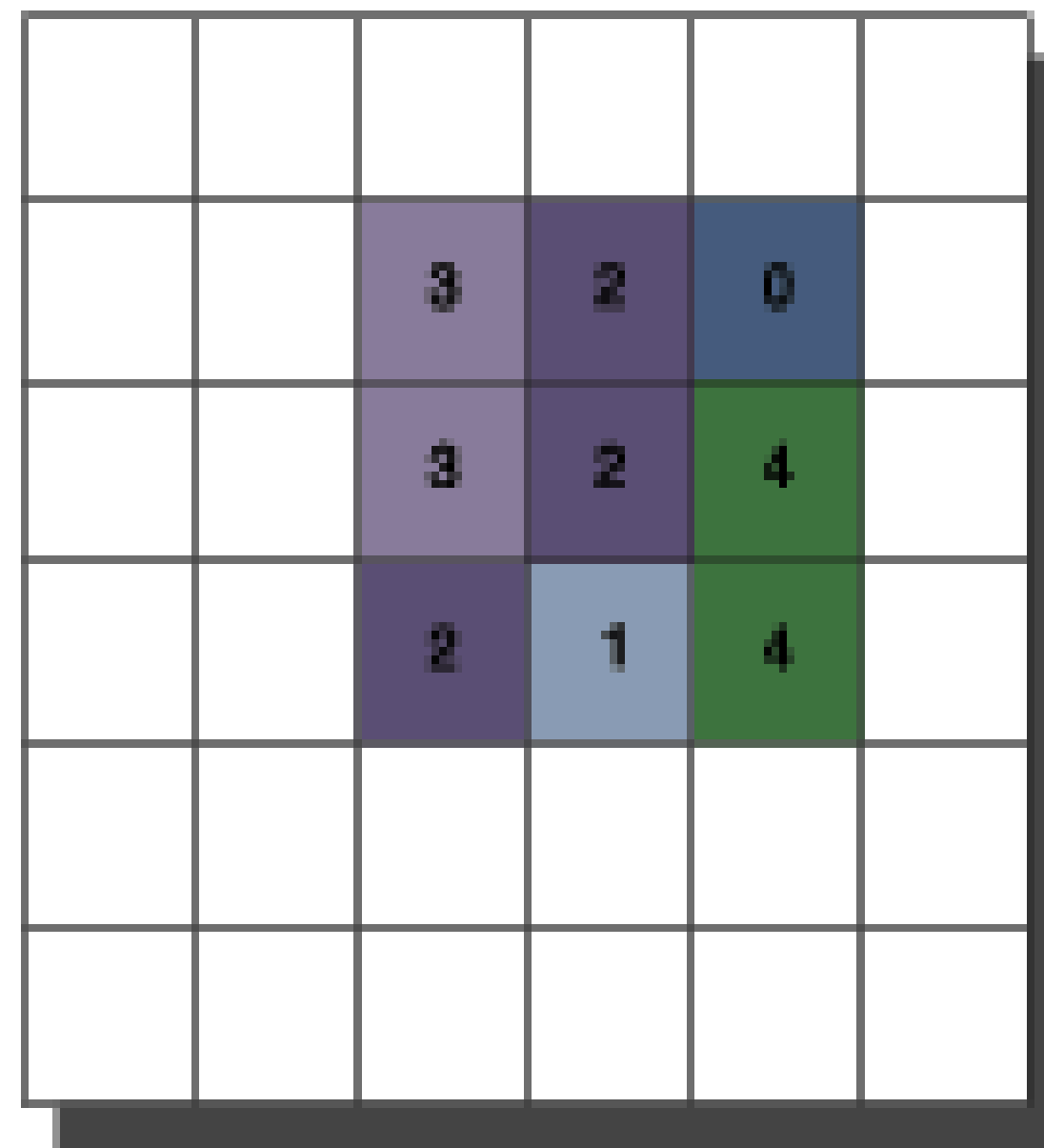
Shelf	4%
Glacial troughs	5.7%
Slope	0.3%
Submarine canyons	0.08%
Plateaus	0%
Abyssal plains	0%
TOTAL	2.3%

Where to place MPAs to protect biodiversity?

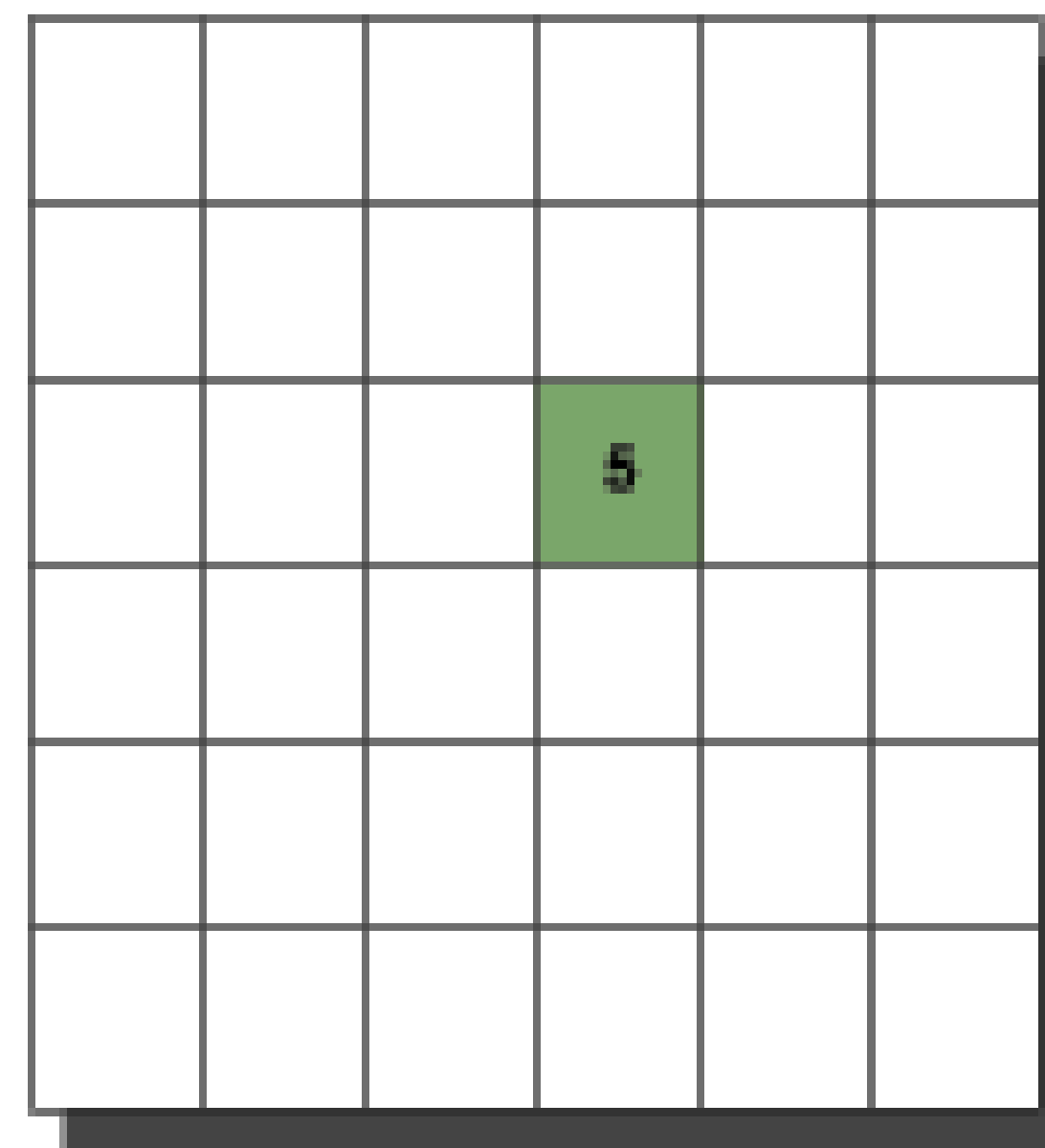
Geomorphic features = habitats

Therefore diversity of seafloor geomorphology = benthic biodiversity.

The Neighborhood Function on an Individual Neighborhood



=



INGRID1

OUTGRID

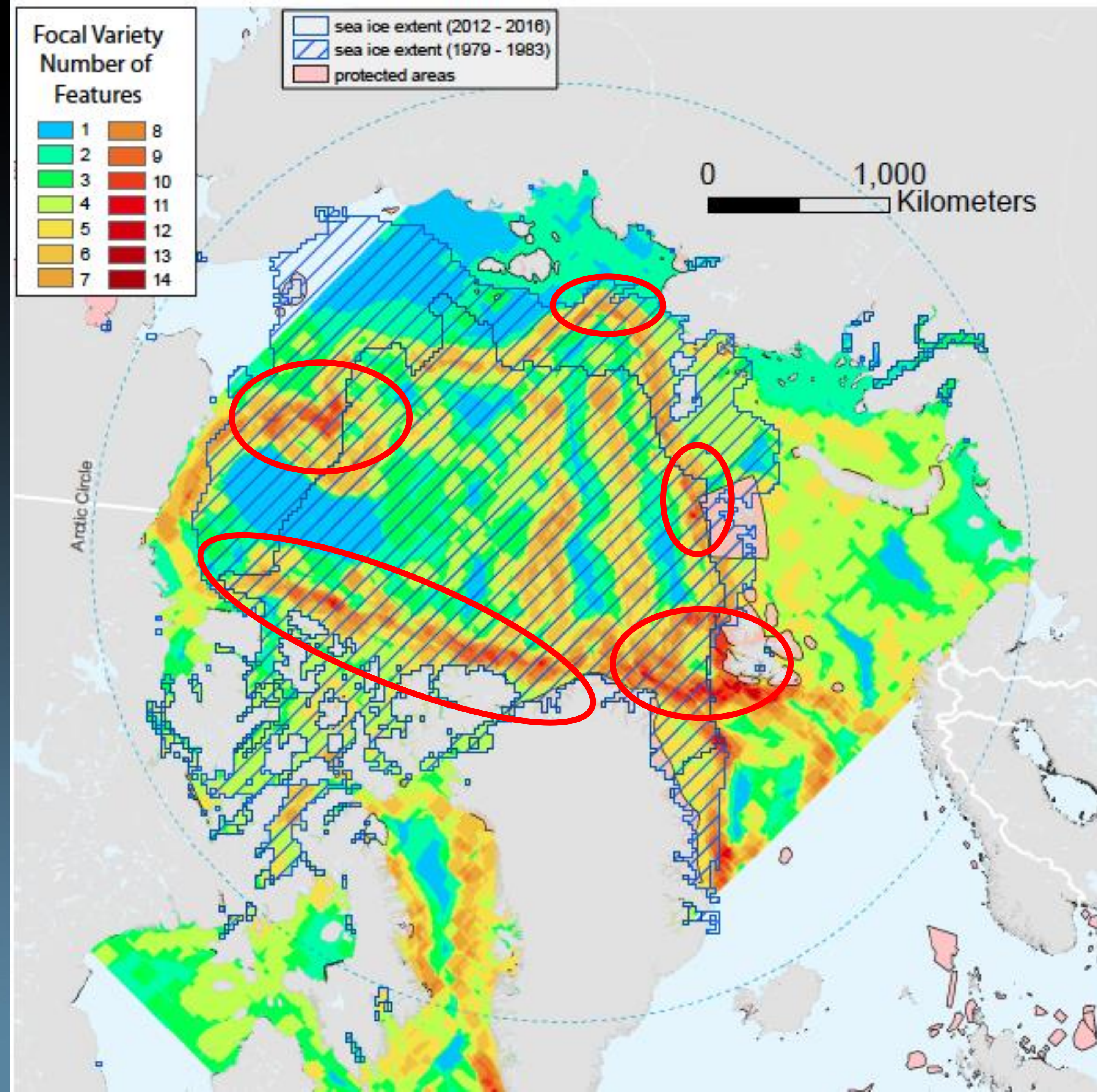
Convert map to raster file

Use focal variety
100 x 100 cell radius =
(100km x 100km)

heterogeneity is an
estimate of biodiversity.

Heterogeneity hot spots
suggest themselves as
possible MPAs

Harris, P. T., M. MacMillan-Lawler, L. Kullerud and J. Rice (2018). "Arctic marine conservation is not prepared for the coming melt." ICES J. Mar. Sci. **75**(1): 61-71.



Conclusions

1. Mapping seafloor geomorphic features provides a consistent, ecologically meaningful approach to regional-scale MSP
2. Existing MPAs cover only 2.3% of the area under year-round sea ice circa 1979-84, located mainly along coastlines
3. Abyssal habitats are not included in existing MPAs and negligible protection is provided to slope habitats
4. Many habitats in near-pristine condition, never previously exploited, value to science as benchmarks for future research.
5. Species and ecosystems adapting to the new, post-anthropogenic climate change environment is a further consideration to protect and conserve these habitats.