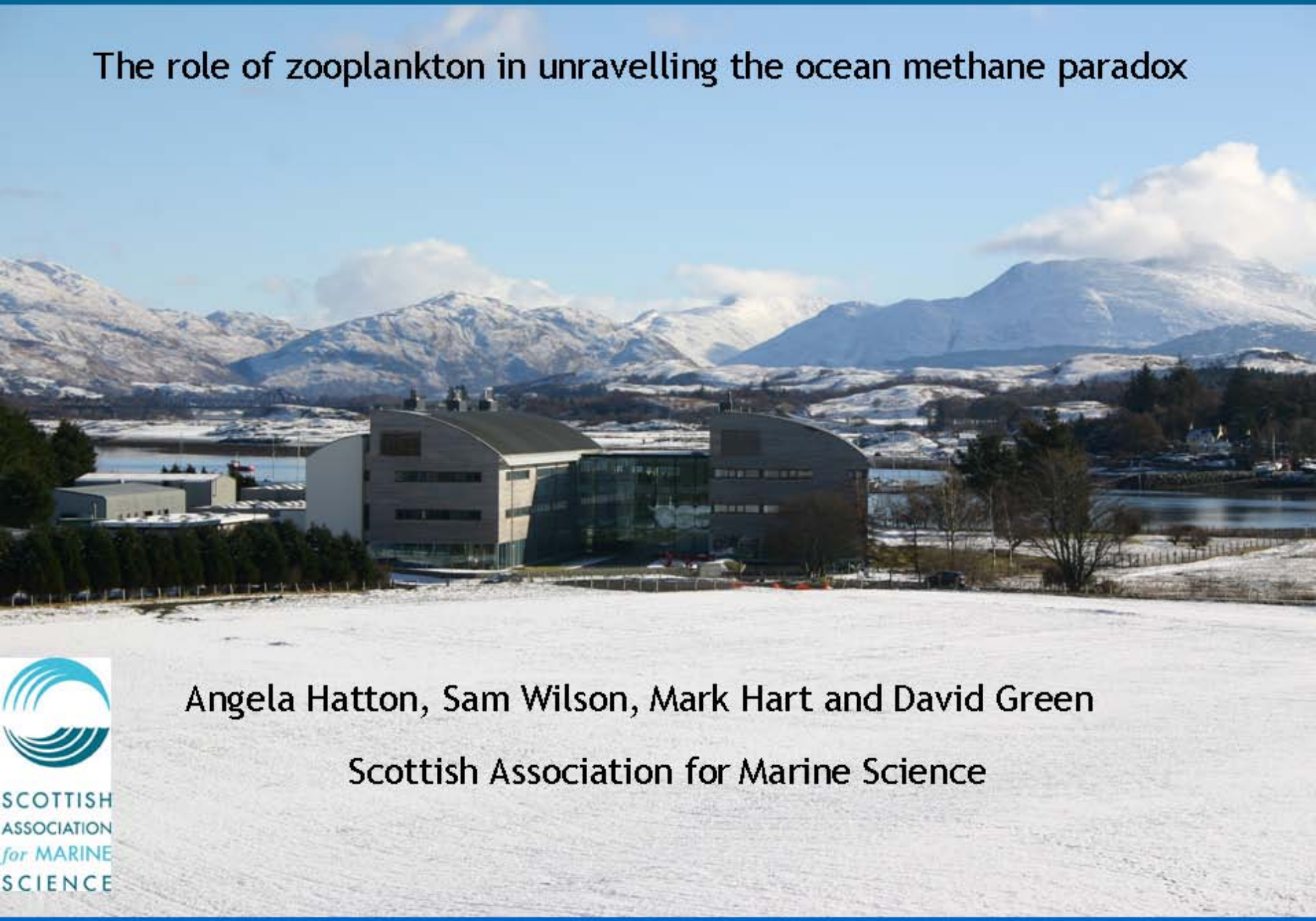
The role of zooplankton in unravelling the ocean methane paradox

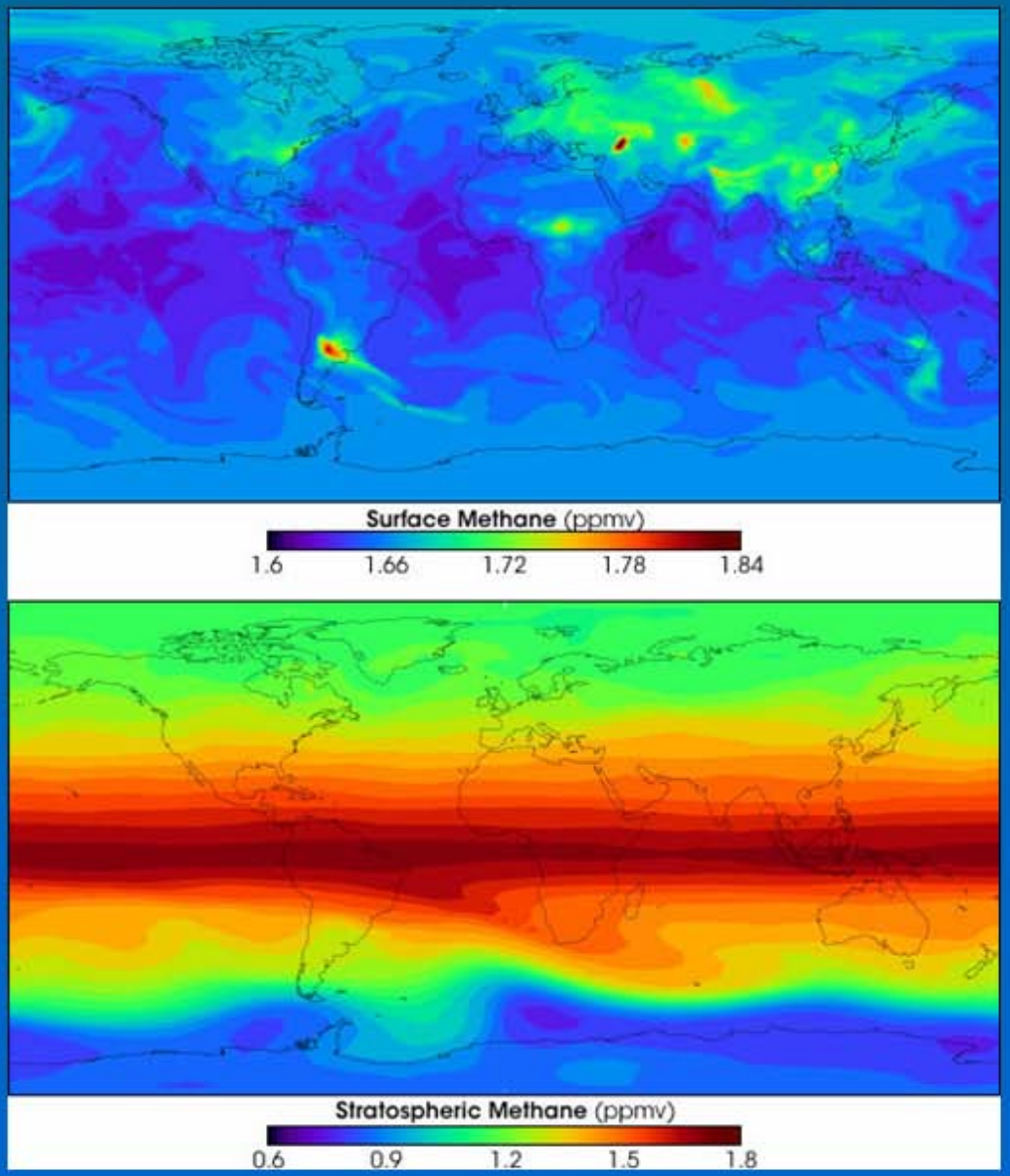


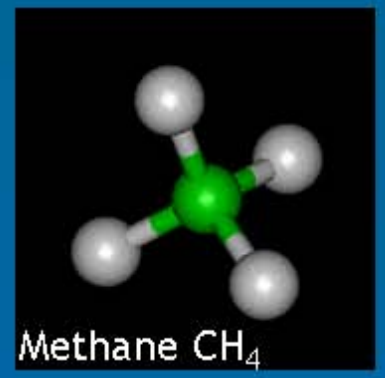
Angela Hatton, Sam Wilson, Mark Hart and David Green

Scottish Association for Marine Science

SCOTTISH ASSOCIATION *for* MARINE SCIENCE

Why is methane important?





Potent greenhouse gas (GWP = 21)

Responsible for 20% of greenhouse gas warming

Important role in atmospheric chemistry.

Estimated that the oceans produce between 5 & 50 Tg CH_4 per year (3%)

http://earthobservatory.nasa.gov/Newsroom/NewImages/images

Why is methane important?

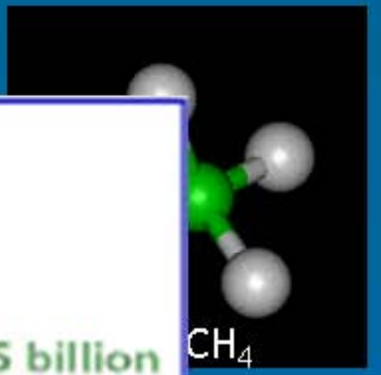
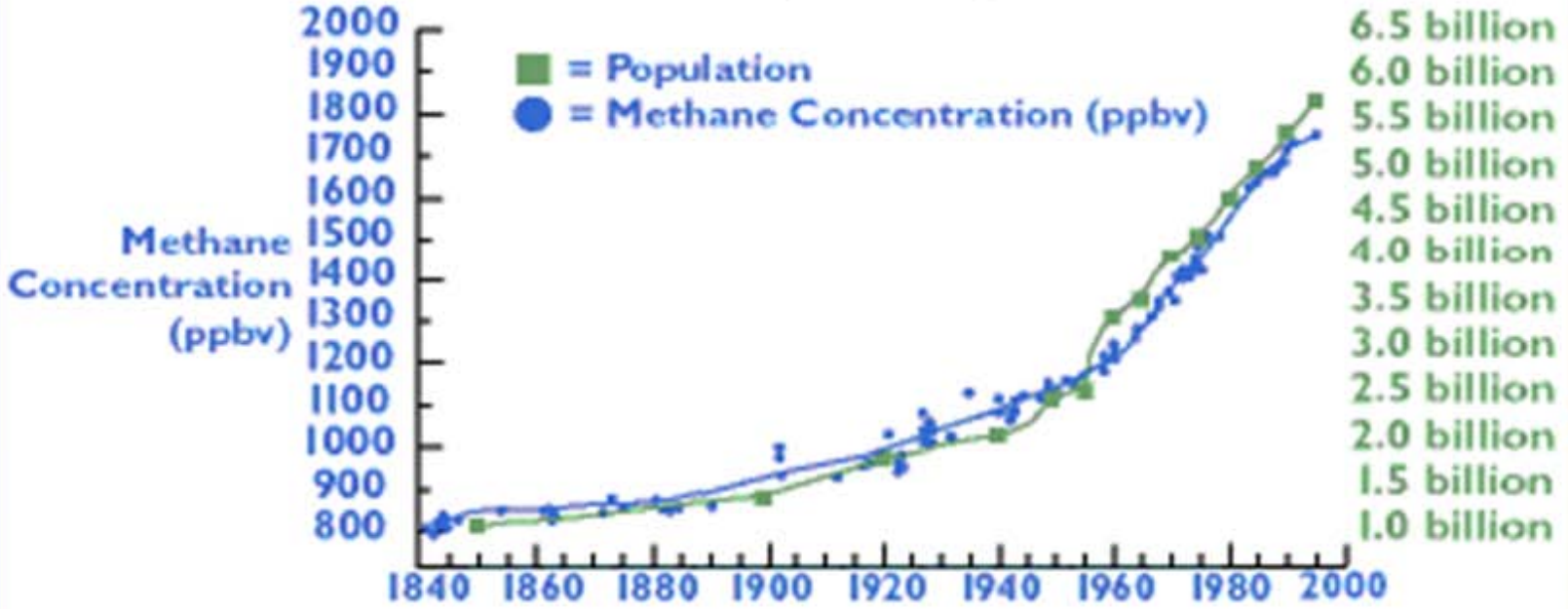
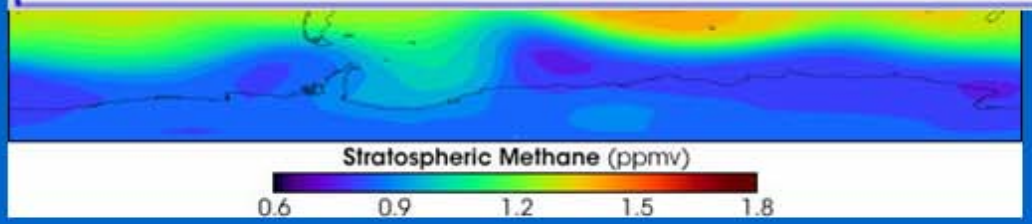


Figure 1-1
Increases in Methane Concentrations
Compared to World Population Growth
(1841-1996)



Source: Etheridge et al., 1994; CDIAC, 1993; IPCC, 1996; U.S. Bureau of the Census.



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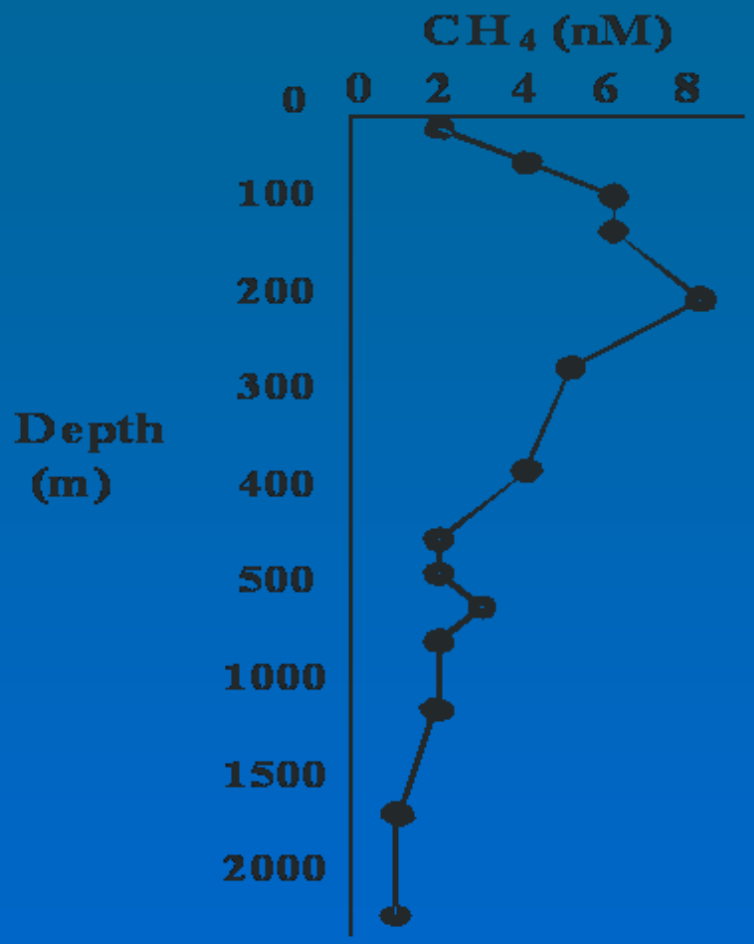
Why are we interested in methane in the Oceans?



Sediments and methane hydrates

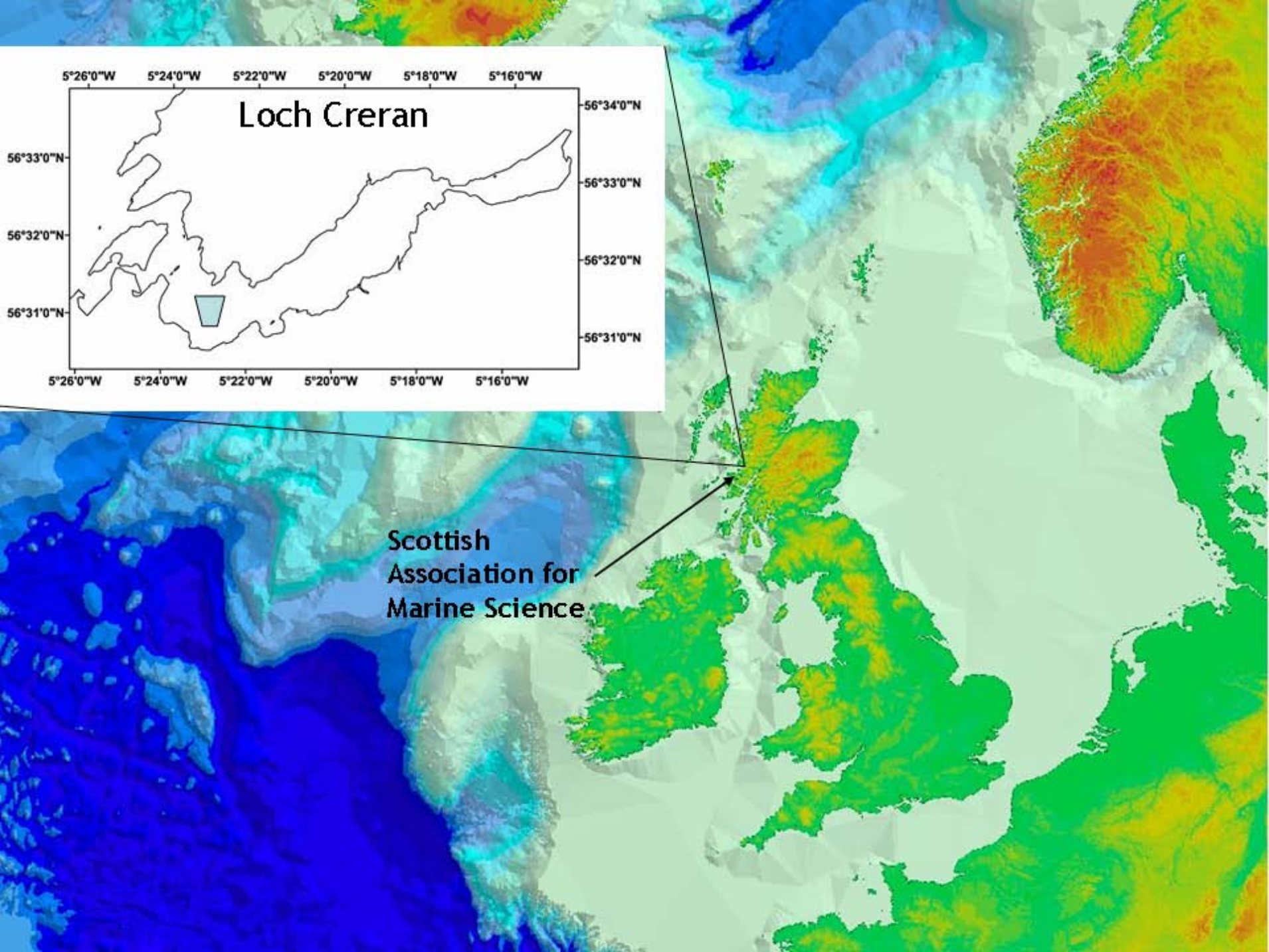
The worlds upper ocean is supersaturated with methane, but why?

This would mean that methane must come from *in situ* production in oxygenated waters

Ocean Methane Paradox

- Strict anaerobes
- Out competed in sulphate rich environments

Do zooplankton and their pellets represent microsites for anaerobic processes including methanogenesis?


Loch Creran
5°26'0"W
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5°18'0"W
5°16'0"W
56°34'0"N
56°33'0"N
56°32'0"N
56°31'0"N
Scottish
Association for
Marine Science

Zooplankton samples

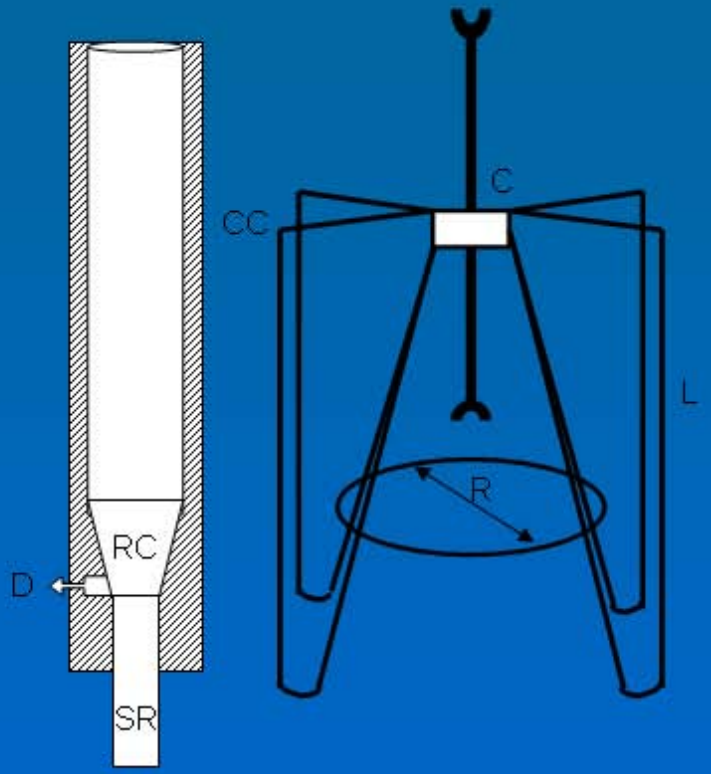
Acartia clausi

Temora longicornis

Mixed natural population

Particulate material - sediment traps

At 25 m in a 40 m water column



Used for both molecular studies and slurry experiments

Identification of methanogens from microsites

Collect Sample

↓

DNA extraction + cleaning

↓

PCR amplification

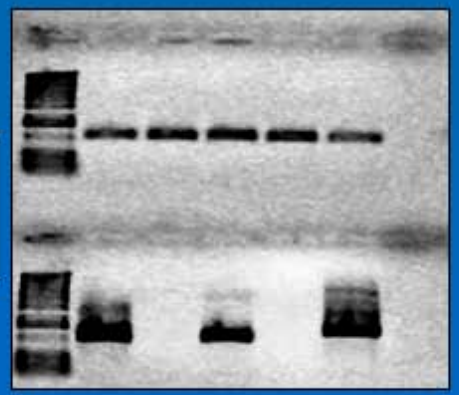
↓

Cloning

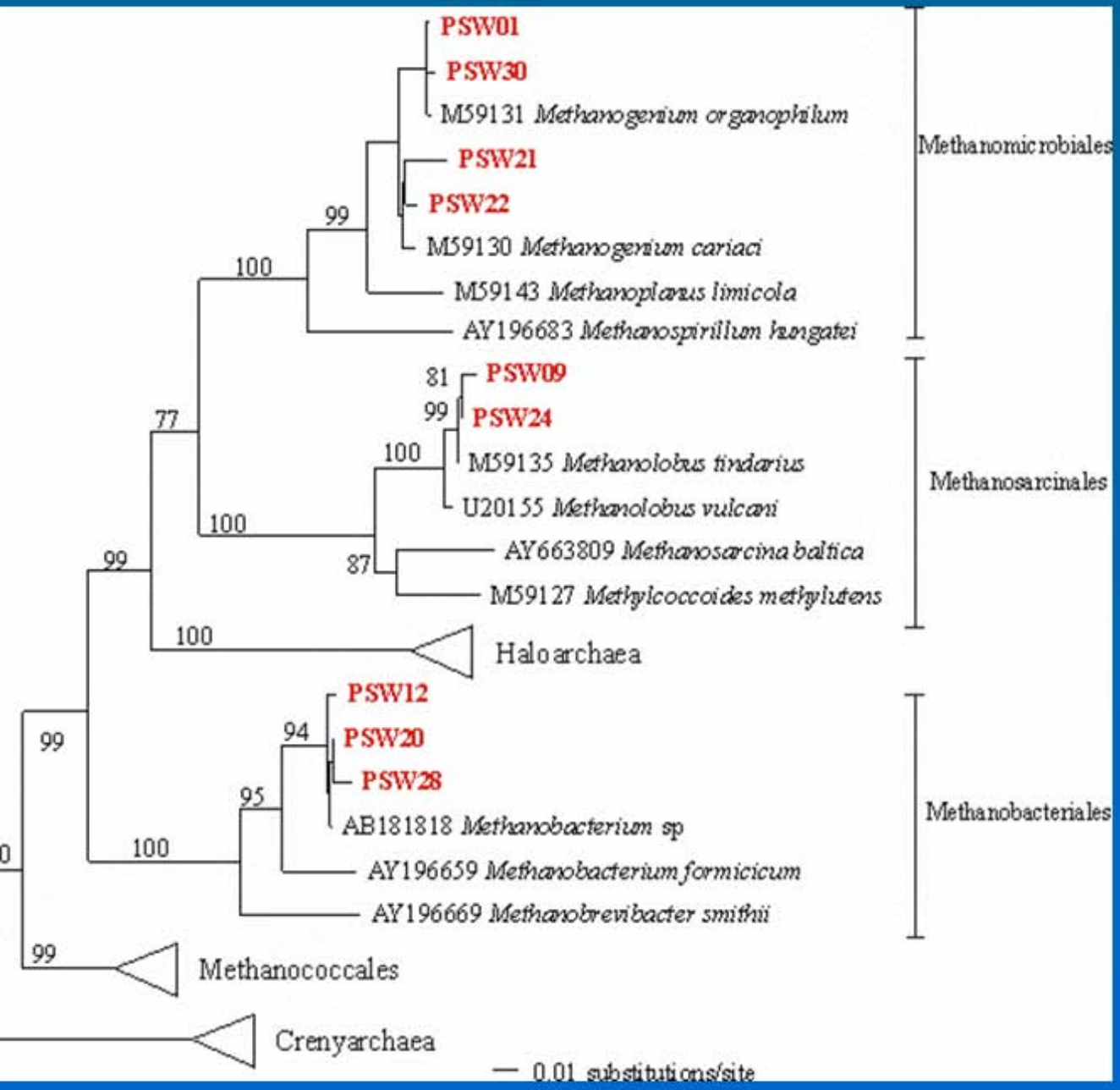
↓

Sequencing

Semi-nested universal 16S ribosomal archaeal primers



We identified methanogenic archaea in faecal pellets from cultured copepods, natural zooplankton assemblages and in sedimenting particulate material



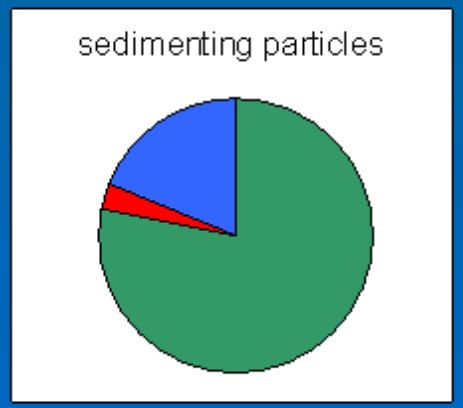
Phylogenetic analysis showed that all methanogens identified fell within three major phylogenetic families

Species related to

Methanogenium organophilum

Methanolobus vulcani

Methanobacterium bryantii



Methanogenium

Methanolobus

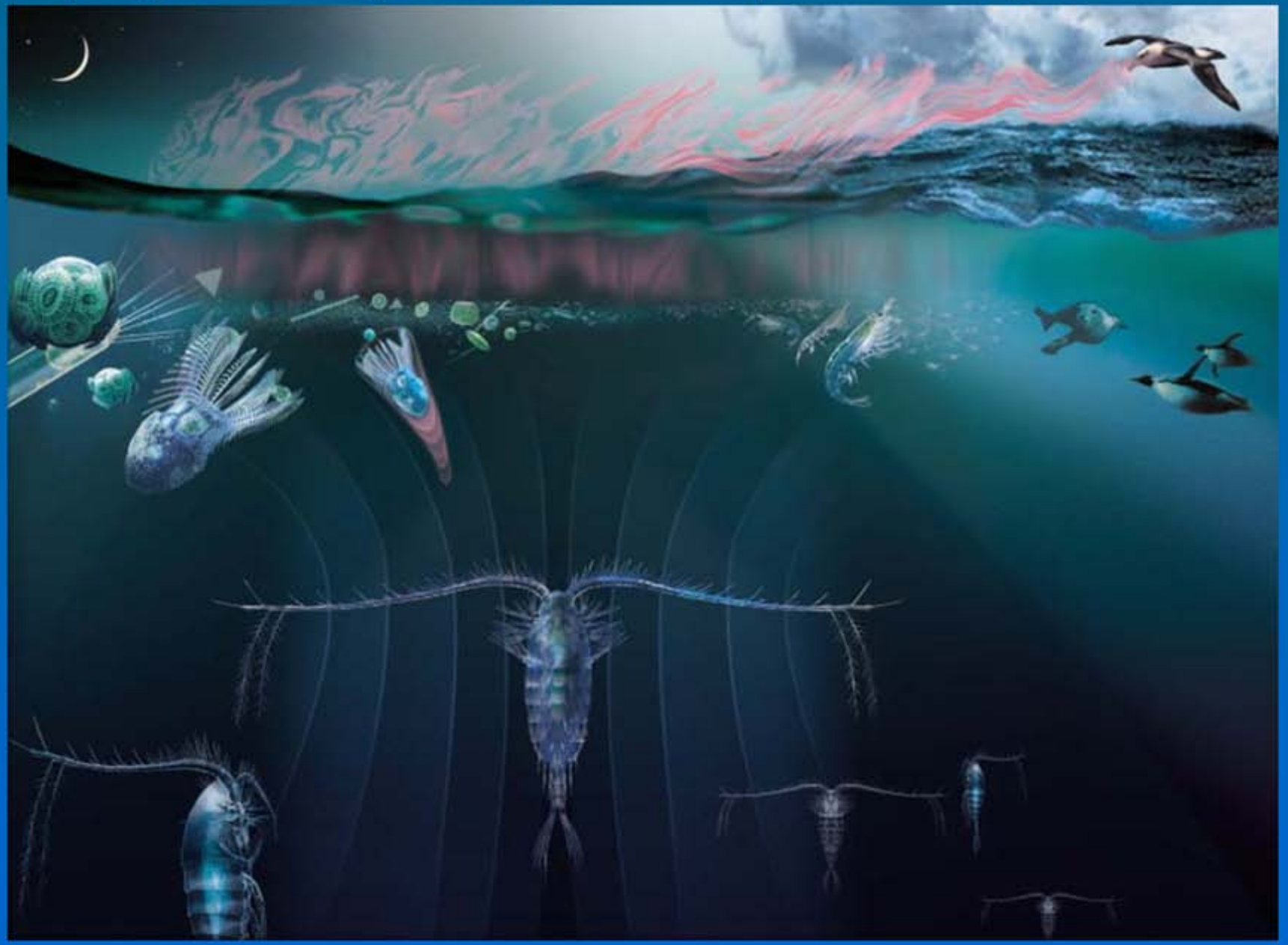
Methanobacterium

Thanks to :

Eva F. Møller, Danish Institute for Fisheries

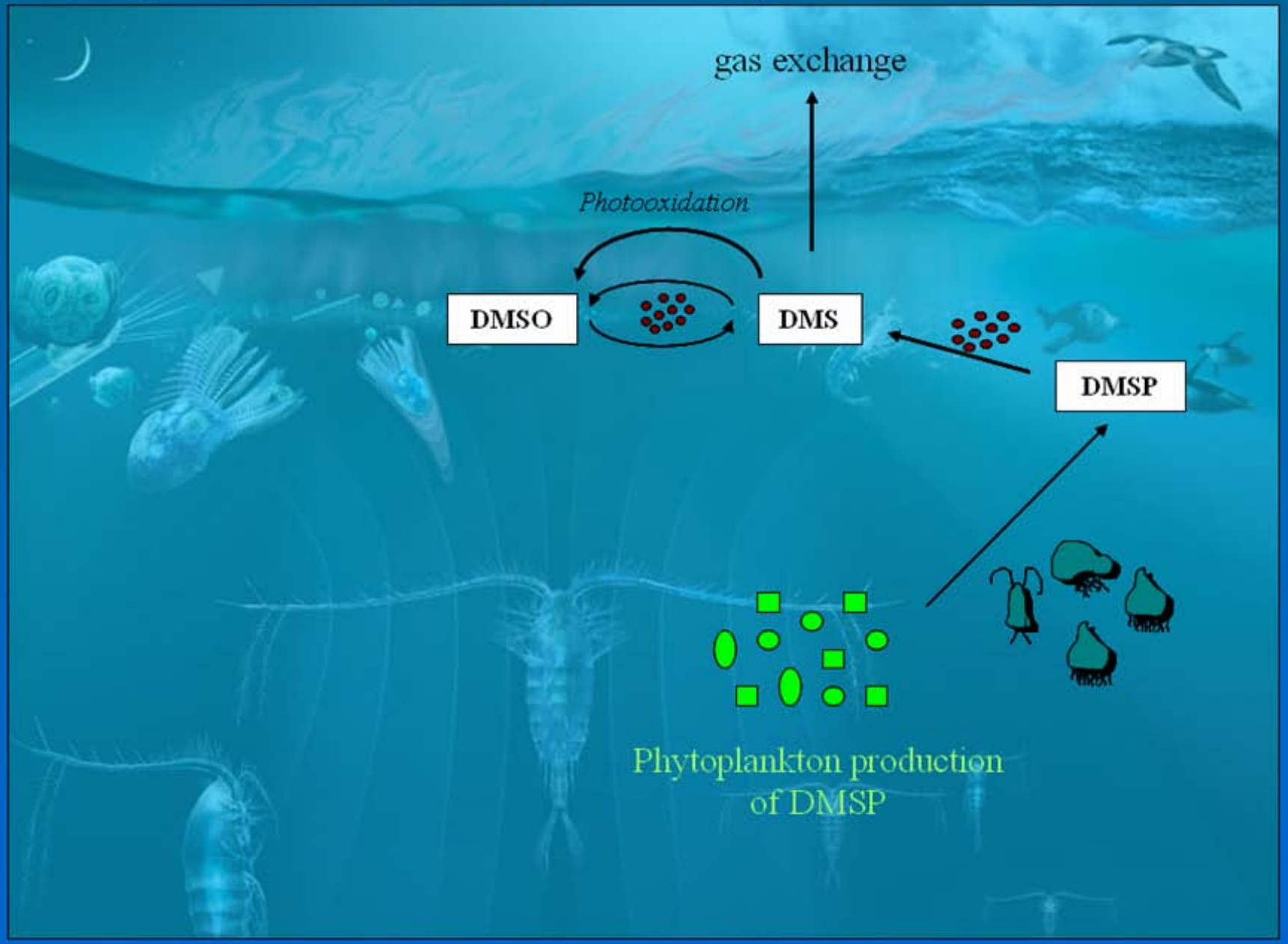
Albert Calbet, Institut de Ciències del Mar

Do pelagic methanogens compete with sulphate reducing bacteria?



Picture by Glynn Garrock

Do pelagic methanogens compete with sulphate reducing bacteria?



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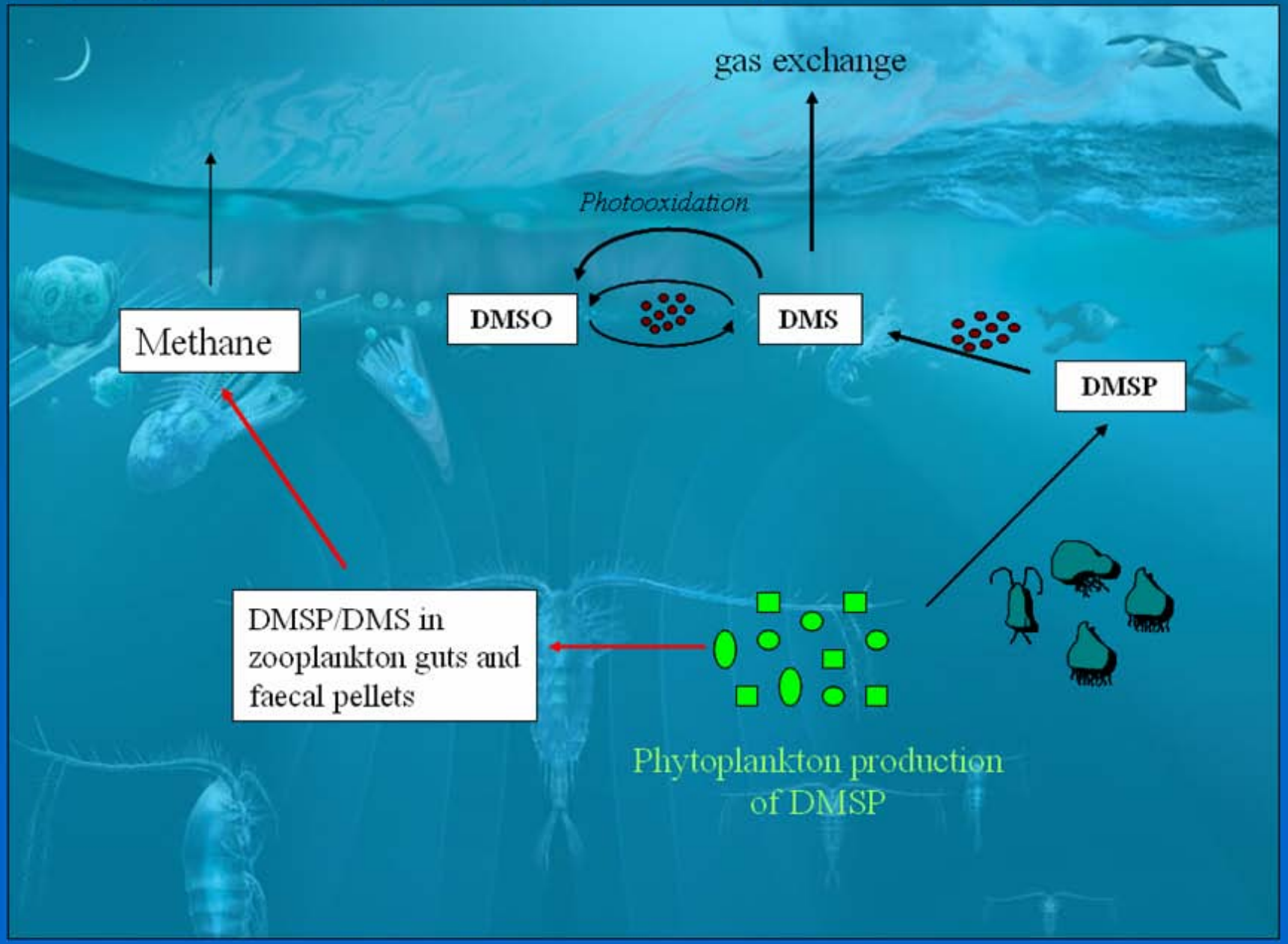

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Why is DMS important?

Steven Pinker's photos of blue sky sailboat

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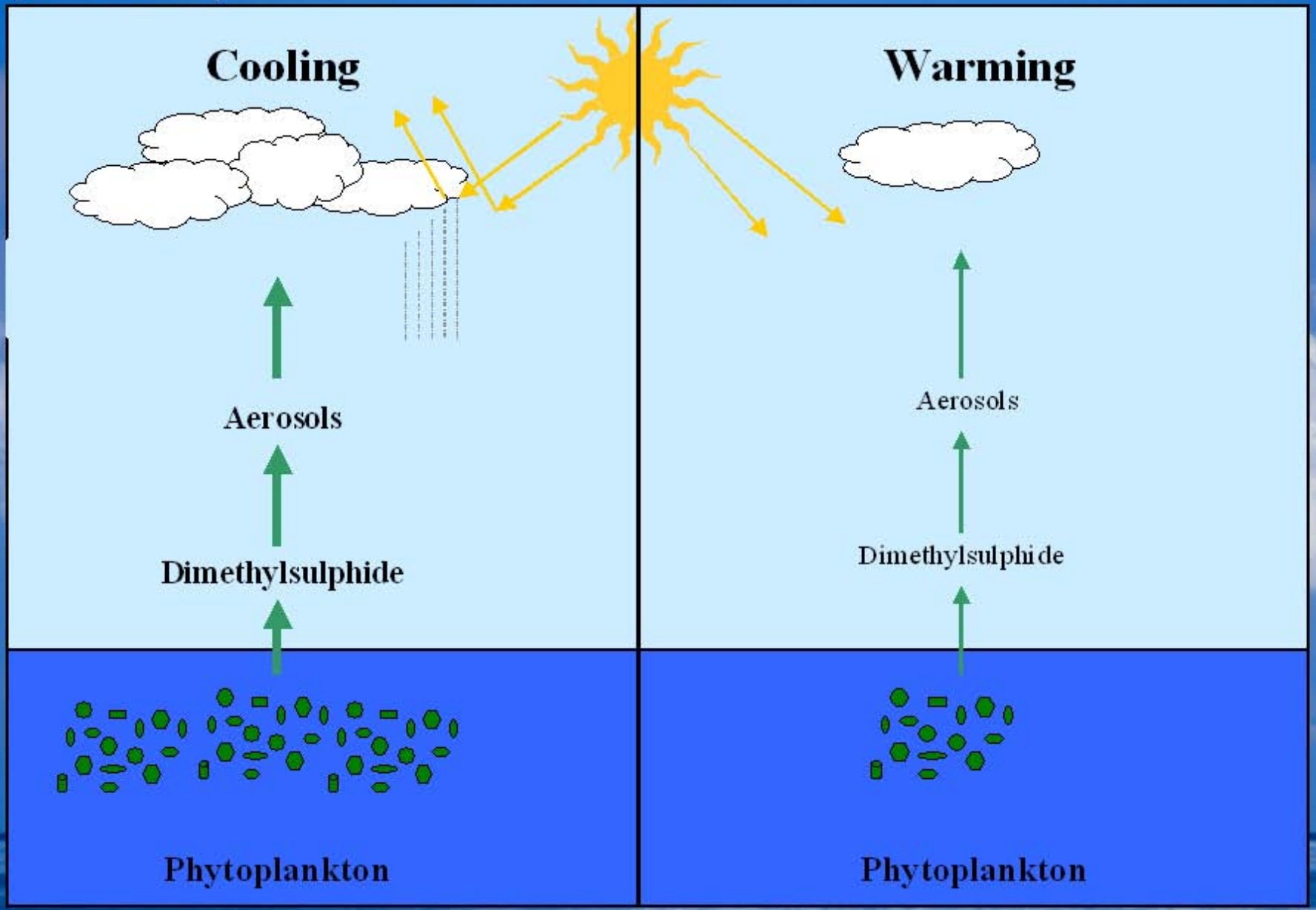
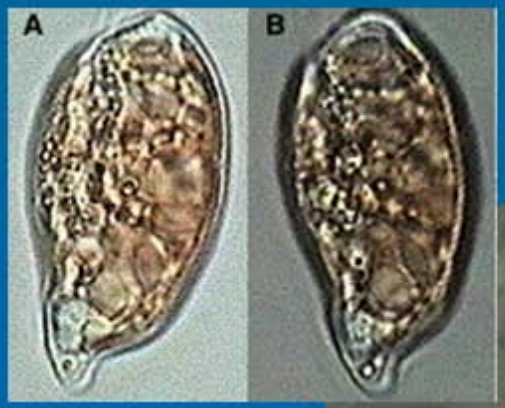


Steven Pinker's photos of blue sky sailboat

Methane measurements in slurry experiment

To collect faecal pellets

Zooplankton were starved for 24 hours, fed *Rhinomonas sp* and *Oxyrrhis marina* and left to defecate for 3 hours.



Pellets collected, examined under light microscope and counted.

For slurry experiments used either:

- 600 faecal pellets or
- 1g wet weight sedimenting particulate material

Incubated for several days in gas tight crimp top vials (nitrogen headspace)

Headspace analysed daily for methane using Gas Chromatograph fitted with a FID

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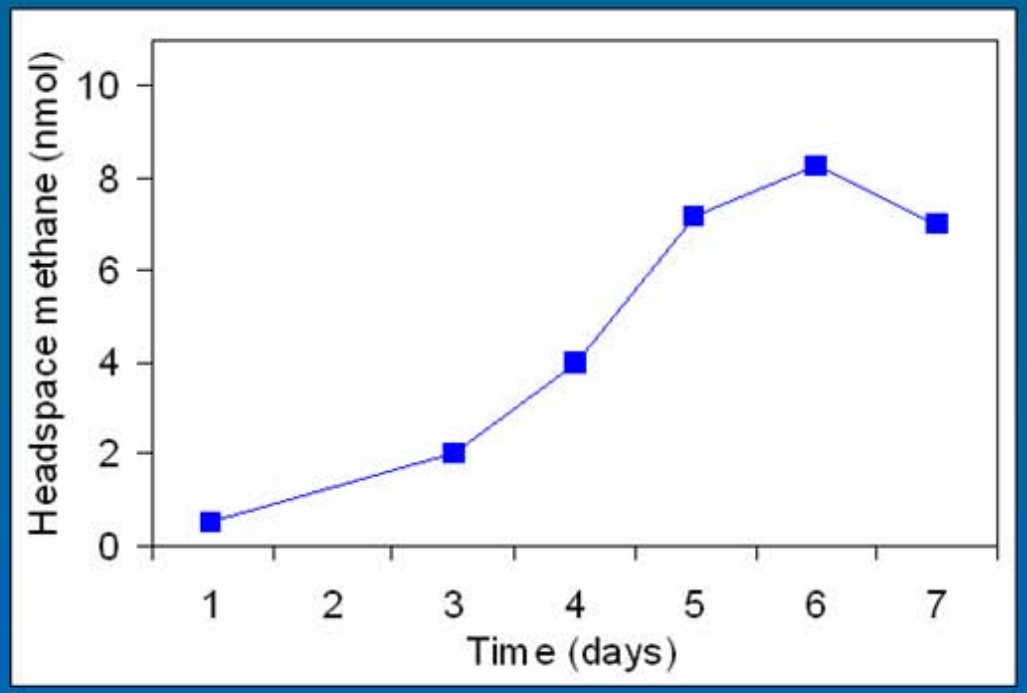
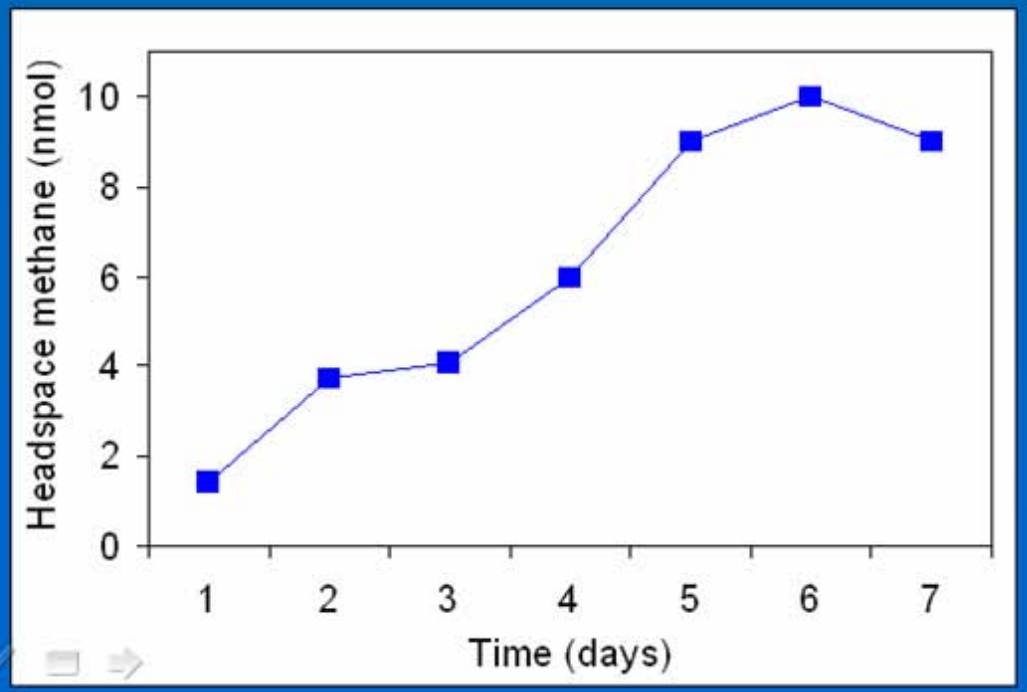
Are methanogens in the microsites viable and do they use DMS?

For zooplankton faecal pellets

≈20 pmol methane faecal pellet^{-1}





Sedimenting particles

For zooplankton faecal pellets

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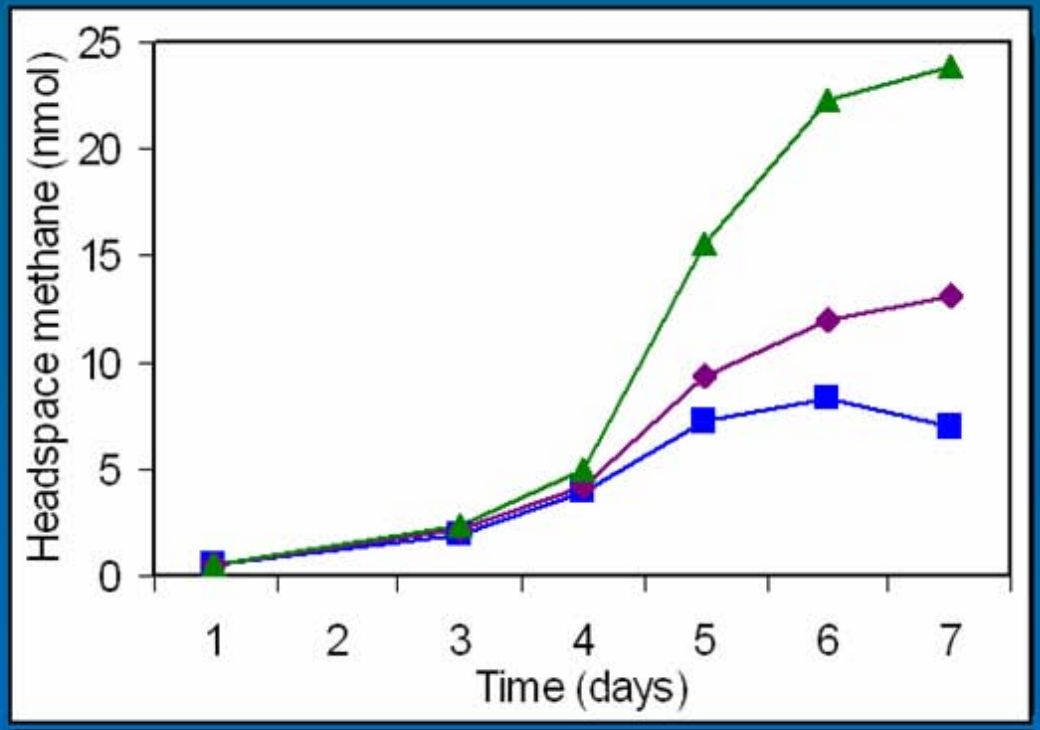
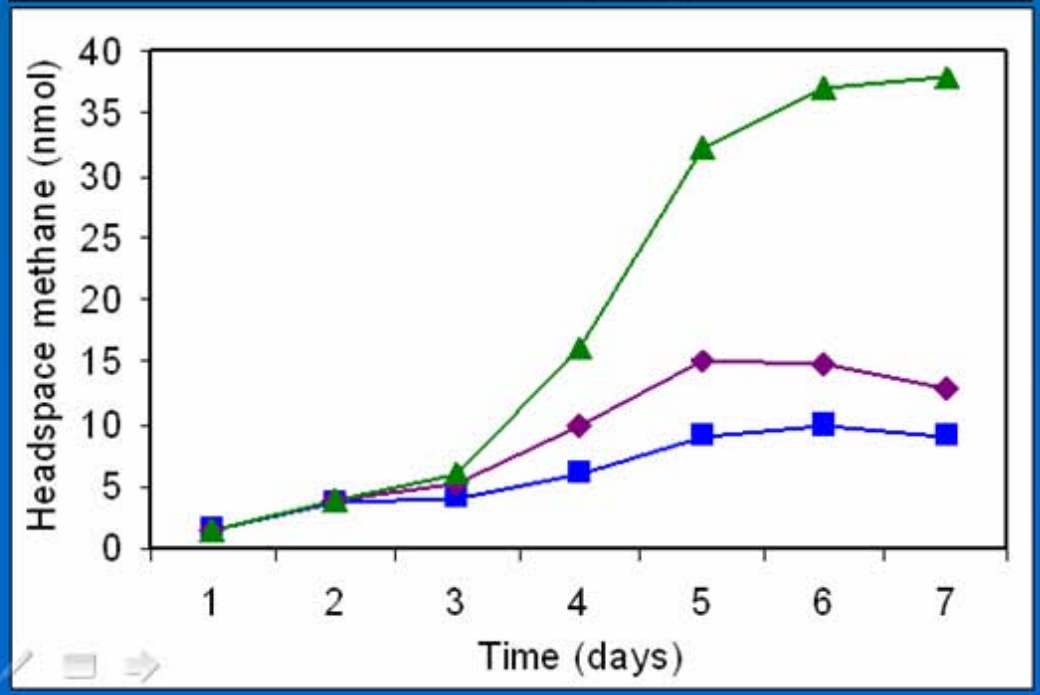




Sedimenting particles

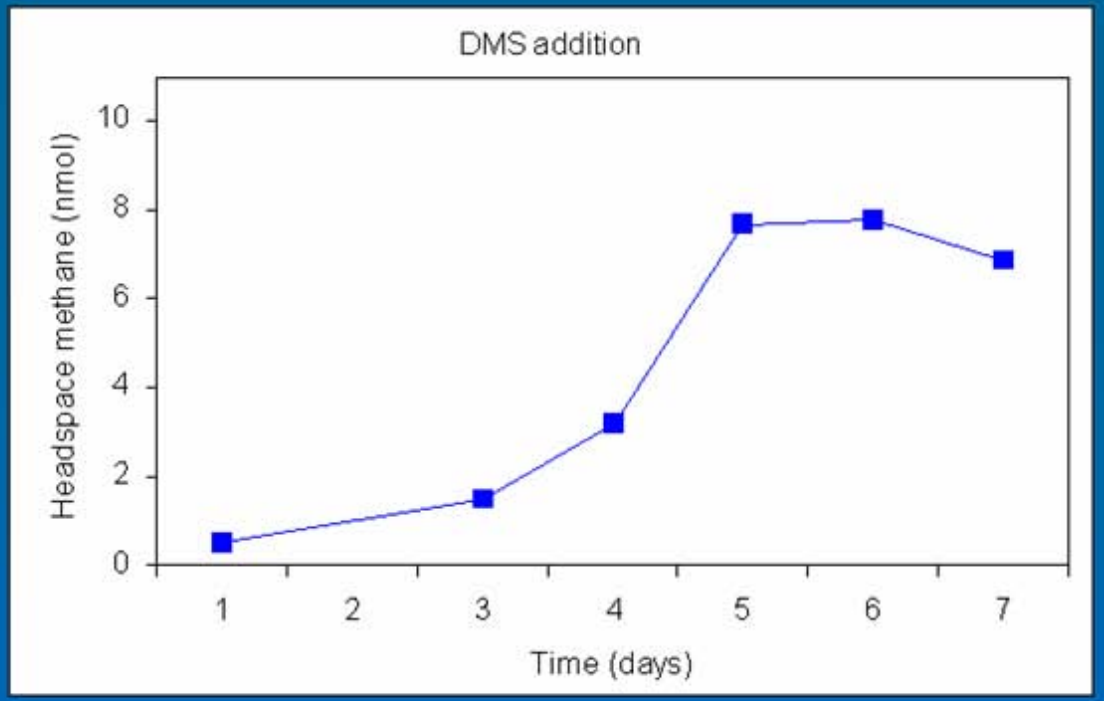
Plus DMS

Plus DMSP

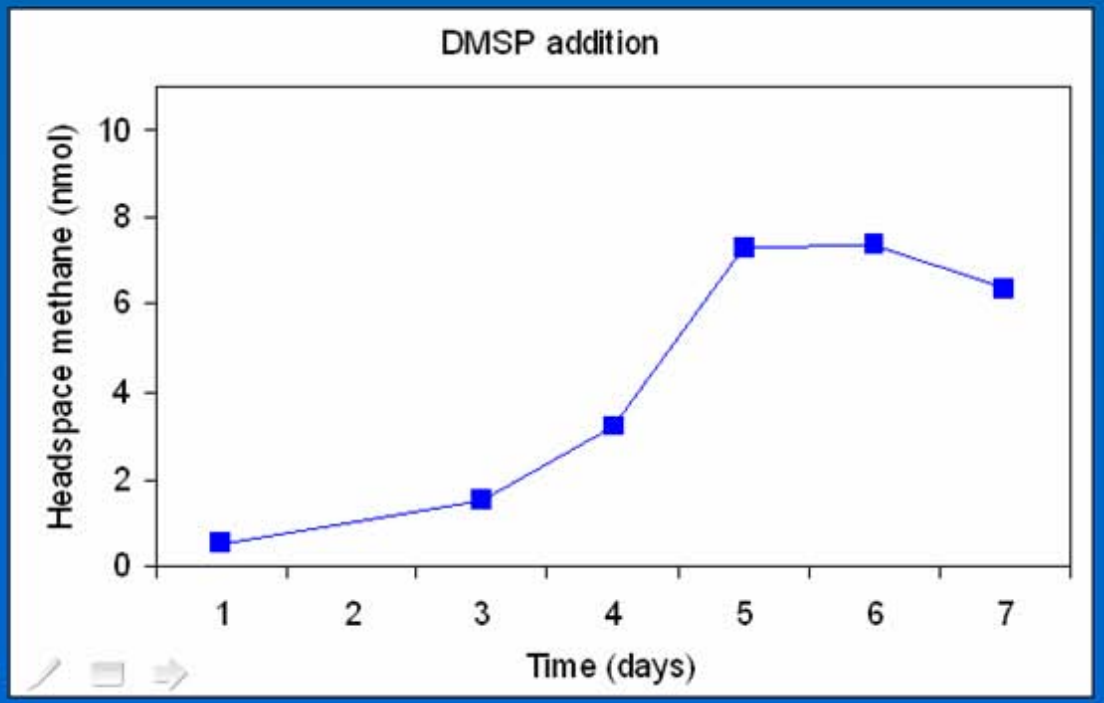
For zooplankton faecal pellets

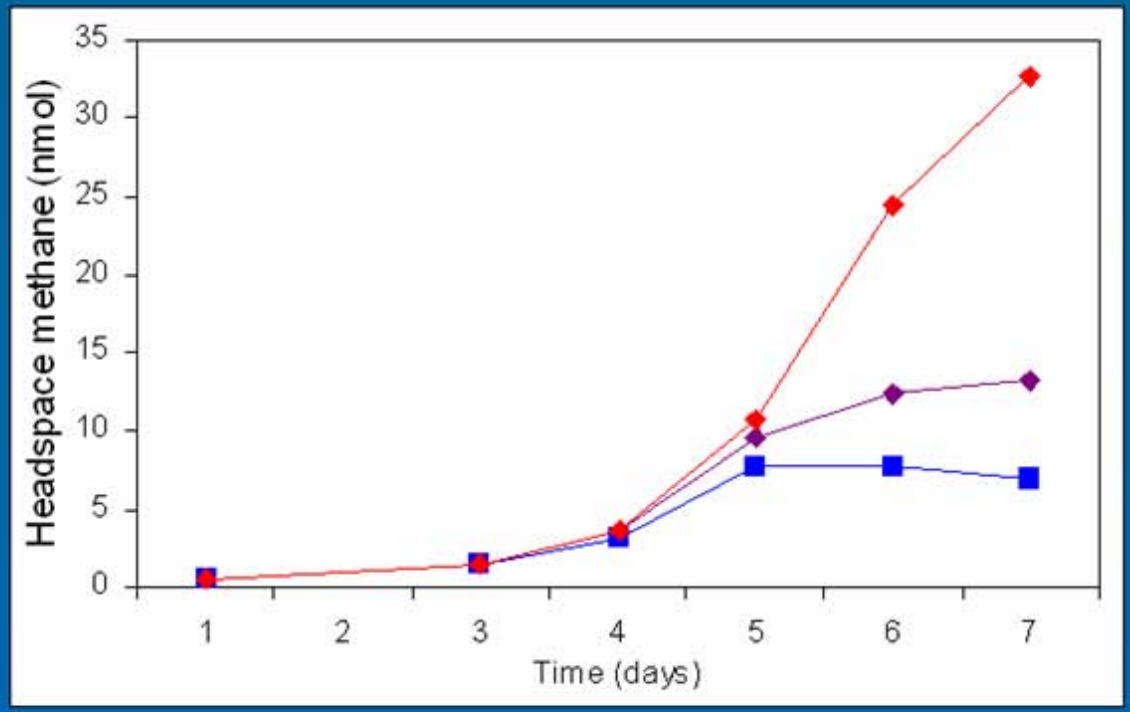
≈20 pmol methane faecal pellet^{-1}

Do other microbes play a role?



Sedimenting particles

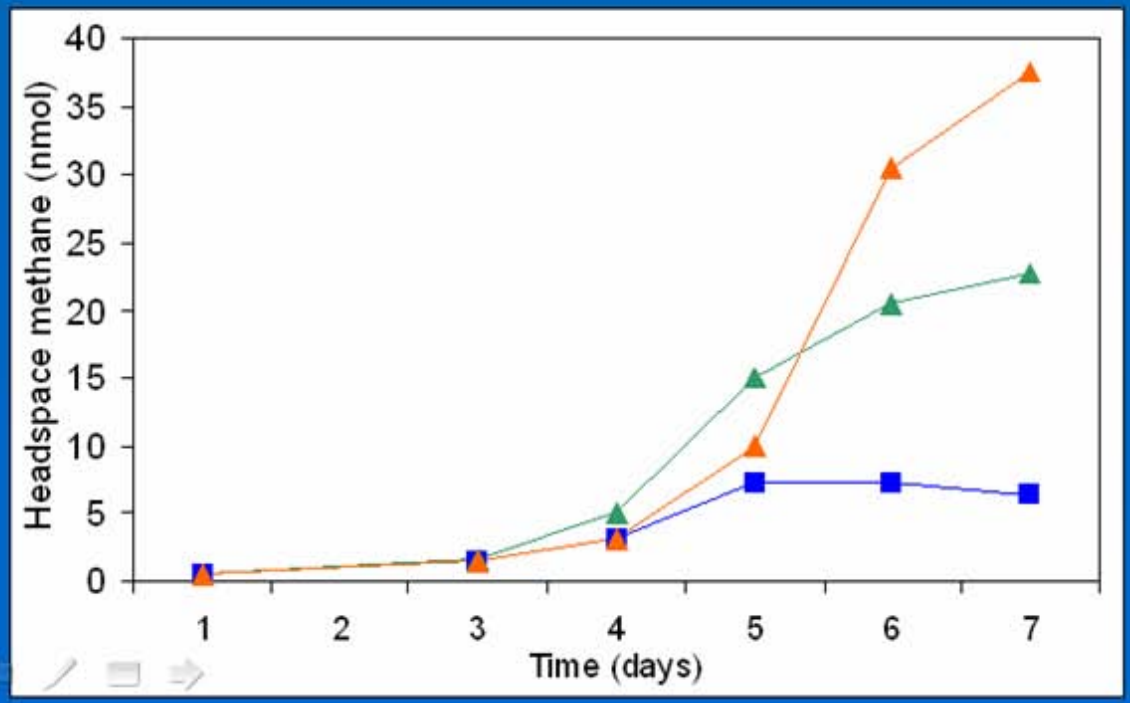




Sedimenting particles

Plus DMS

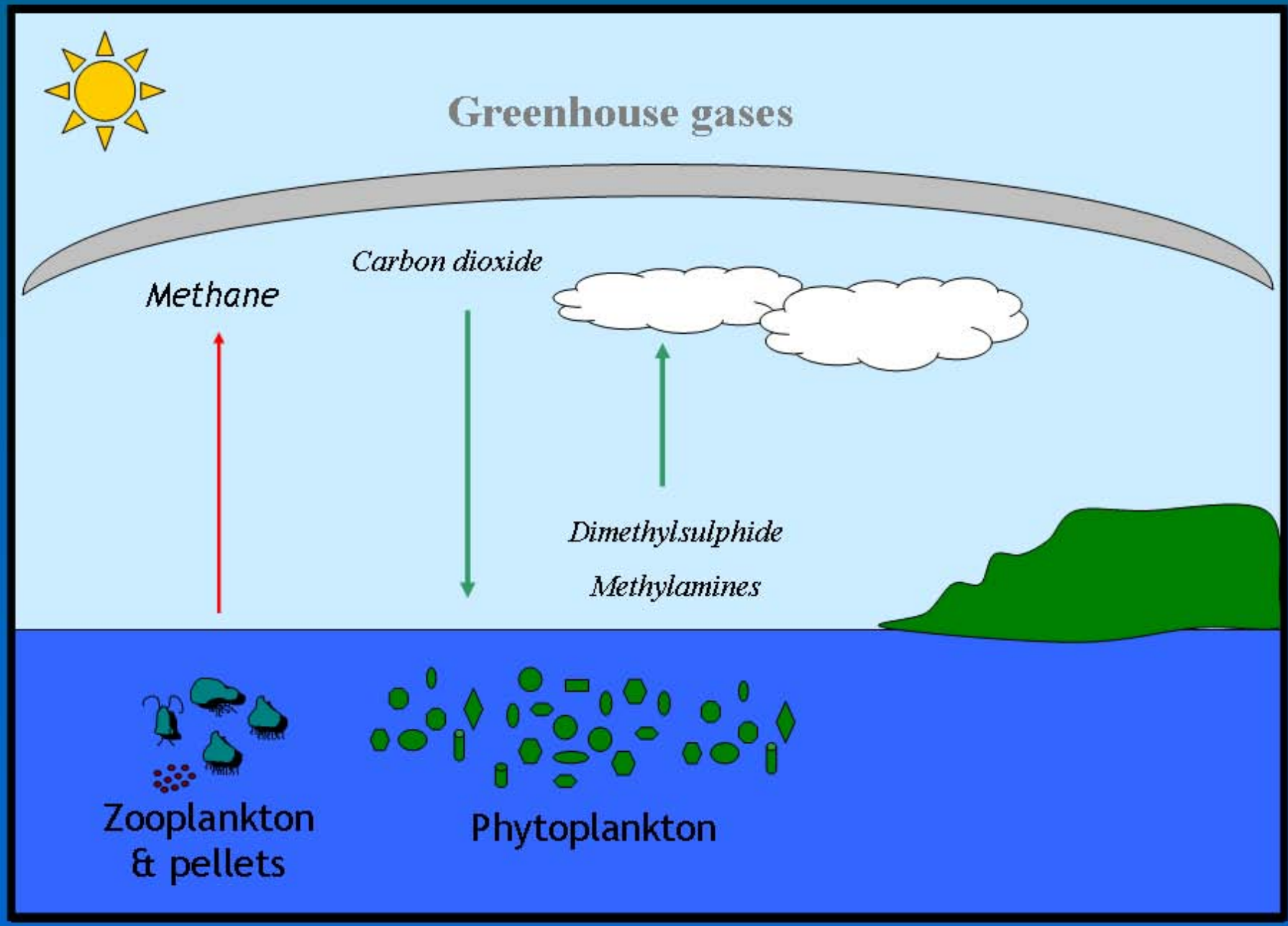
Plus DMS & antibiotics



Plus DMSP

Plus DMSP & antibiotics

How do marine phytoplankton influence the climate?



Significance of work

This is the first time methanogens have been identified in cultured zooplankton.

Both zooplankton faecal pellets and sedimenting material collected on the west coast of Scotland were shown to contain methanogens capable of utilizing DMS.

This is the first time methanogenium and methanobacterium related species have been found in pelagic waters.

- CO_2-reducing methanogens (could they also indirectly use DMS)

If DMS represent a substrate for methanogenic bacteria within the pelagic zone, we need to estimate the significance of this pathway in climate feedback models.

Now the work really starts!


Thank you
Acknowledgements:
Sam Wilson, Dave Green, Mark Hart, Kevin Purdy, Eva F. Møller and Albert Calbet