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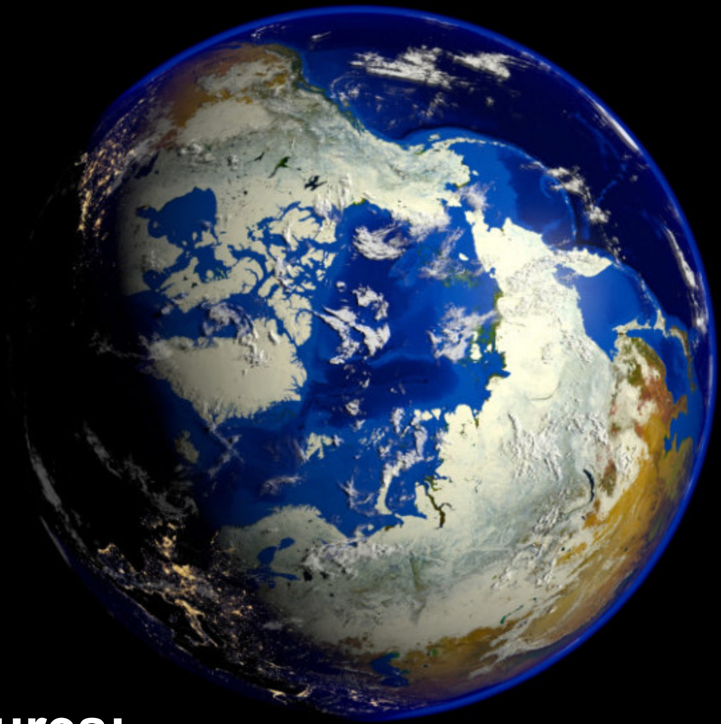
United Nations Environment
World Conservation Monitoring Centre

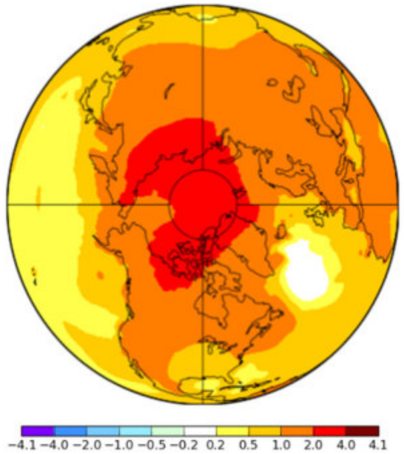


Arctic ecosystem futures: explorations with and evaluations of biodiversity models

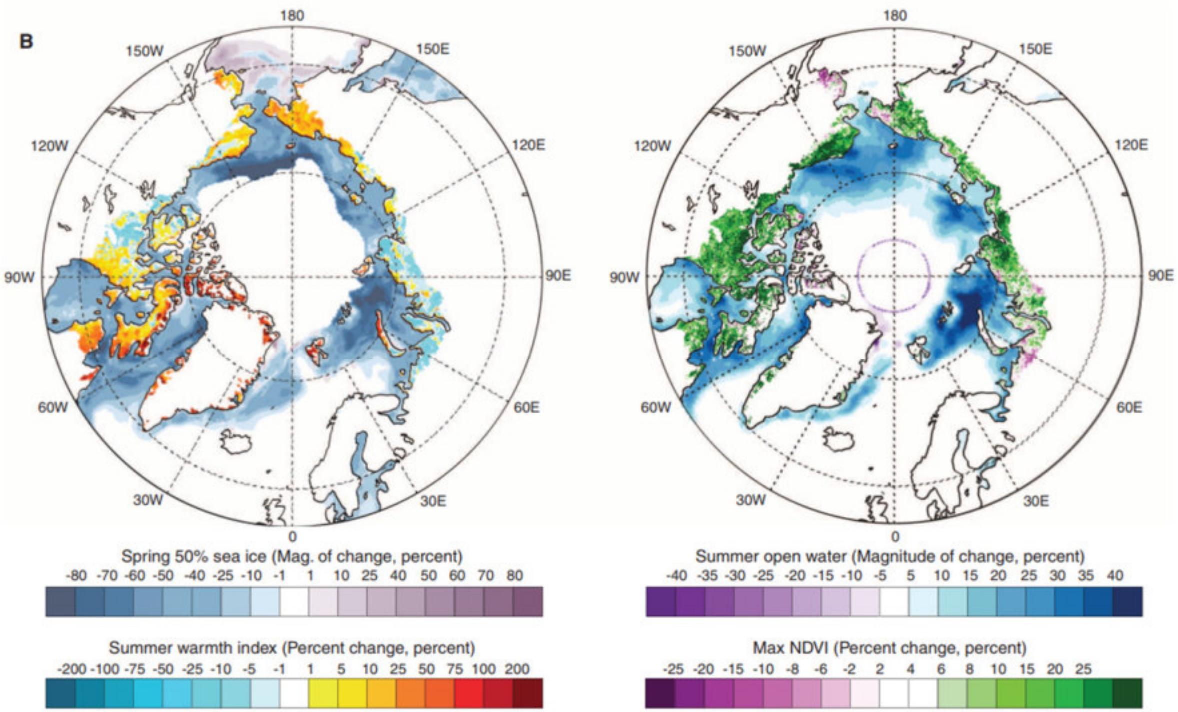
Fiona S. Danks/Mike Harfoot

Undergoing rapid change

2010-2017 Annual mean anomaly (°C) vs 1951-1980 mear



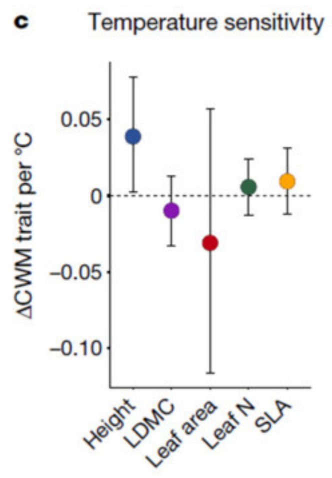
NASA-GISS



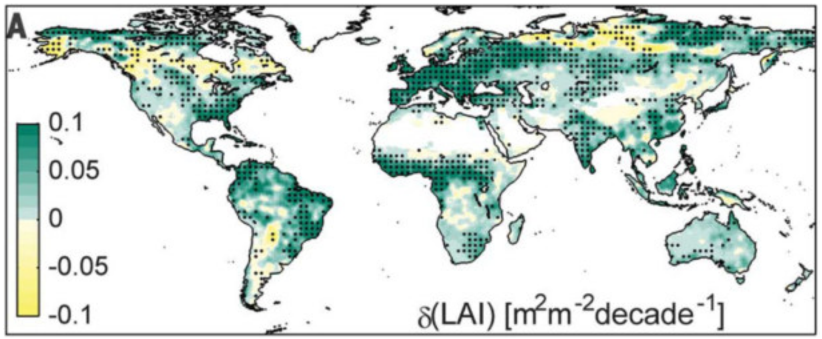
Post (2013) *Science*

Complex ecosystem responses

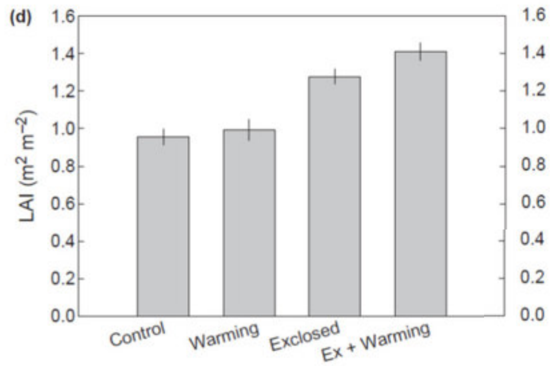
- Vegetation traits are changing as species turnover
- Complex changes in LAI across the Arctic
- Interactions with herbivores can be important



Bjorkmann (2018) *Nature*



Forzieri (2017) *Science*



Cahoon (2012) *GCB*

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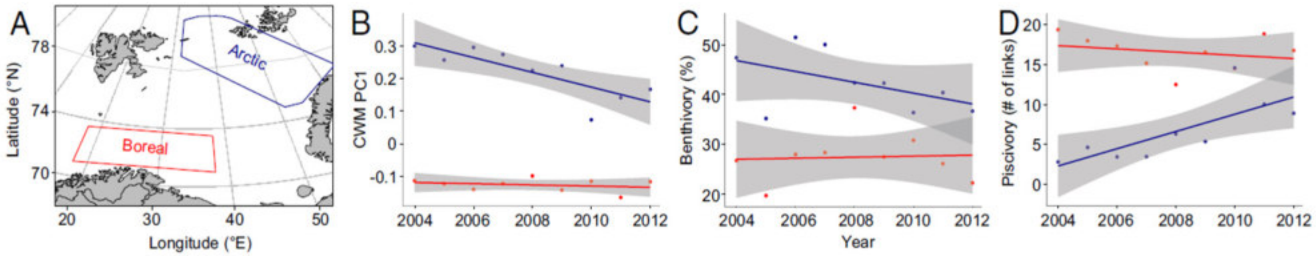
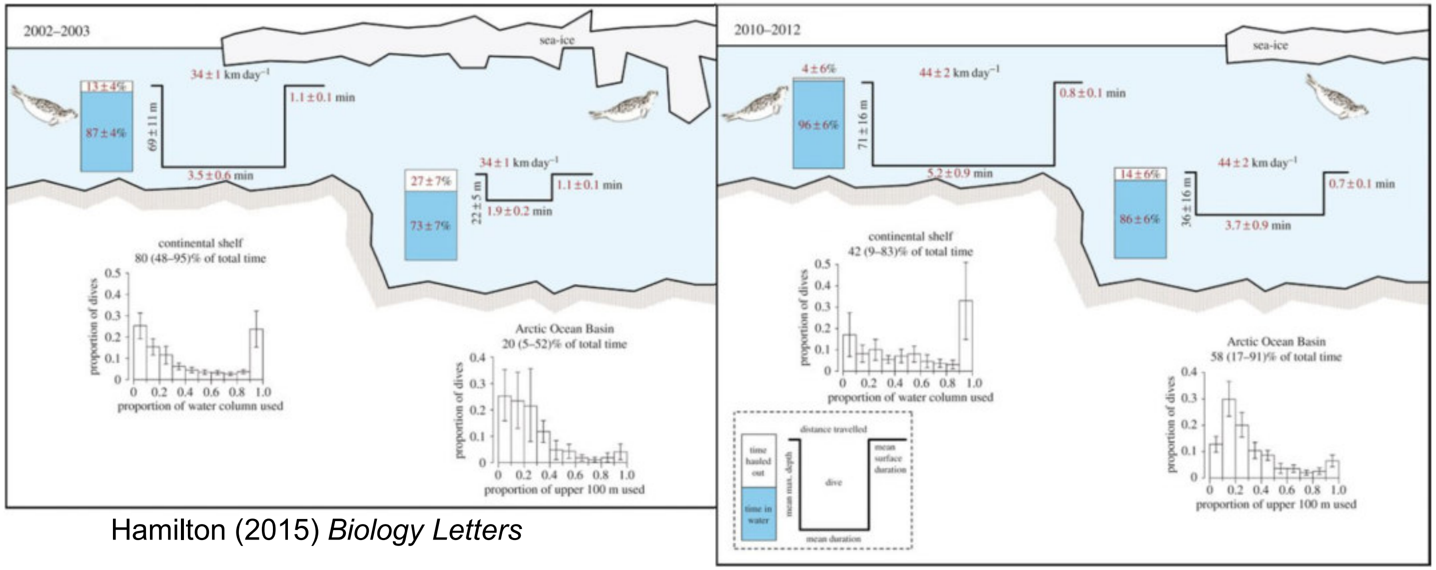
Marine changes

Marine plankton, fish, mammals and birds are undergoing substantial changes



Frainer (2017) *PNAS*



Hamilton (2015) *Biology Letters*

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Ecosystem futures

- Characterised by complex, non-intuitive outcomes
- Statistical models are likely insufficient to capture these changes. Need sophisticated models, probably including mechanism, which also capturing whole ecosystems.

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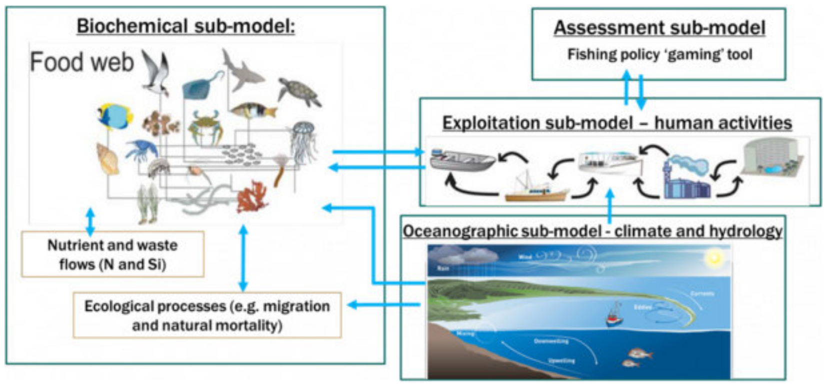
Current models - marine

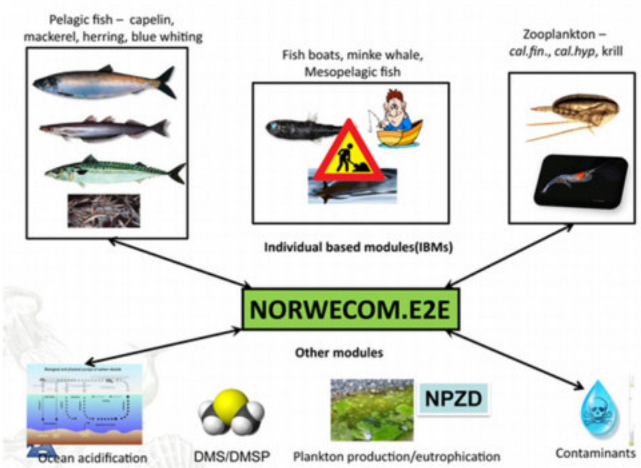
Models exist that link physical and chemical changes to ecosystem responses, e.g.

Atlantis



Fulton *et al.* (2004) *Ecological Modelling*

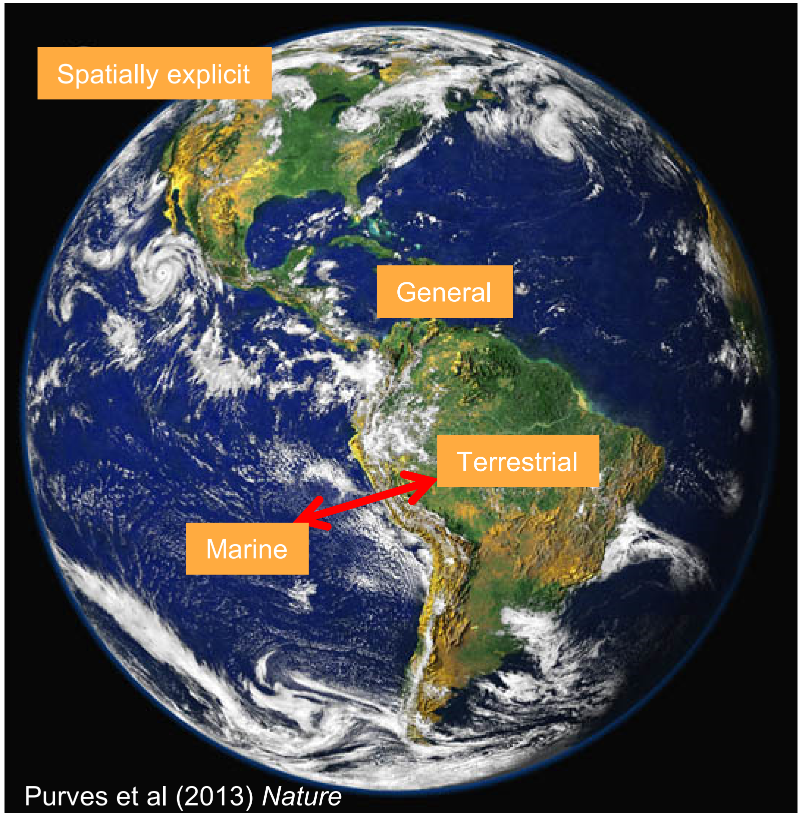
NORWECOM.E2E



Skaret (2014) *Progress in Oceanography*

Current models - terrestrial

- In the terrestrial realm there are vegetation models e.g. LPJ-Guess or HYBRID.
- But there are few models that mechanistically model animal communities.
- Madingley is one which has the potential to model autotrophs and heterotrophs interacting with each other in both marine and terrestrial environments, allowing interlinkages across realms to be captured.



The Madingley Model

Balanced consideration of all trophic levels

Properties emerge

Open

Reproducible

Inspirational

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Emergent Global Patterns of Ecosystem Structure and Function from a Mechanistic General Ecosystem Model

Michael B. J. Harfoot[1,2*¤], Tim Newbold[1,2*], Derek P. Tittensor[1,2,3*], Stephen Emmott[2], Jon Hutton[1], Vassily Lyutsarev[2], Matthew J. Smith[2], Jörn P. W. Scharlemann[1,4], Drew W. Purves[2]

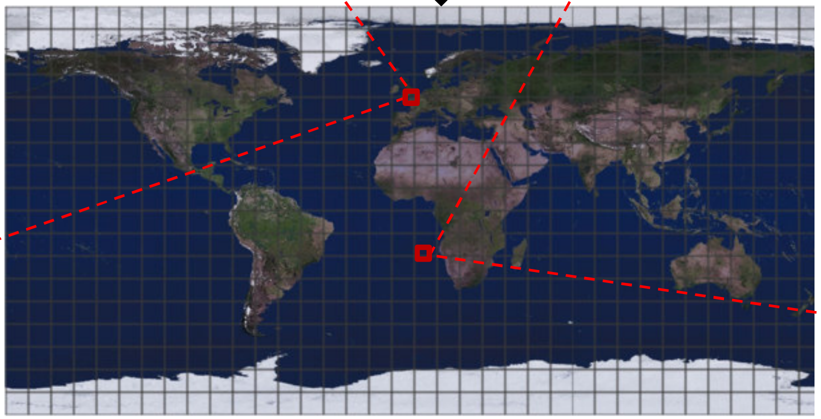
April 2014 | Volume 12 | Issue 4 | e1001841

The Madingley Model

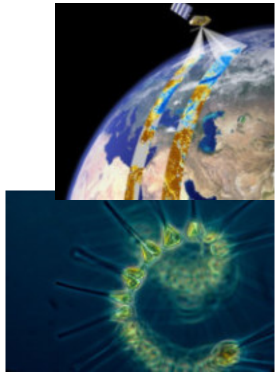
Realistic geography, ocean circulation, environmental conditions (air & ocean temperature, precipitation)

Terrestrial: data constrained carbon model (Smith *et al.*, 2013 Biogeosciences)

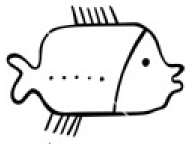
+



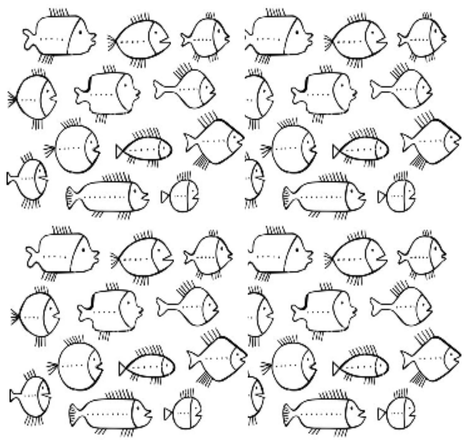
Marine: remotely sensed phytoplankton concentration



Agents: Trait & cohort-based approach

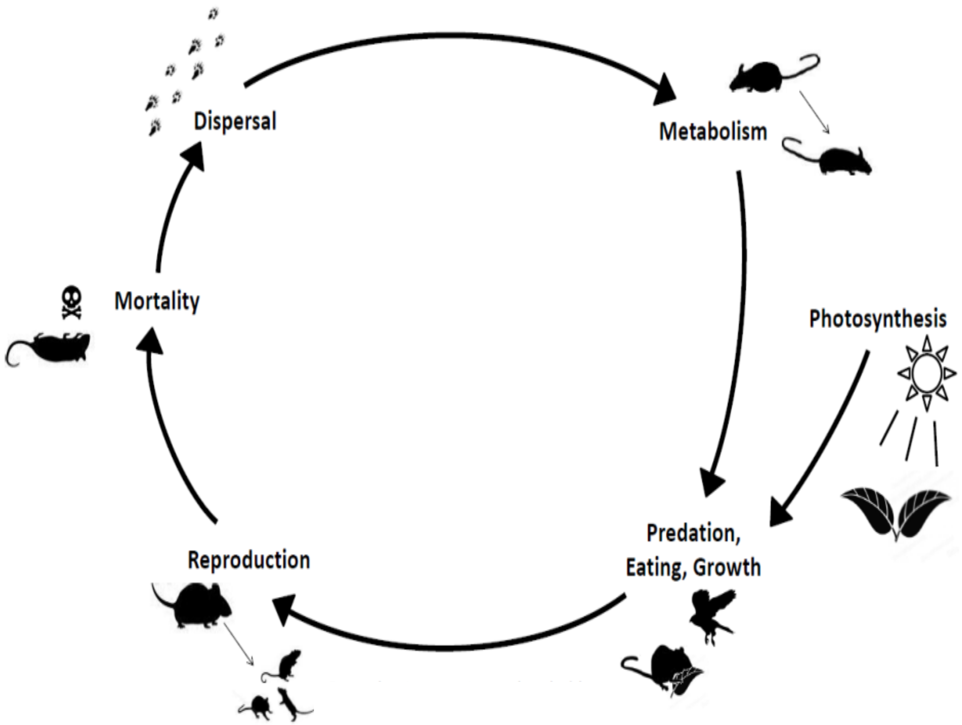


Herbivore / omnivore / carnivore
Ectotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Juvenile body mass
Adult body mass
Current body mass

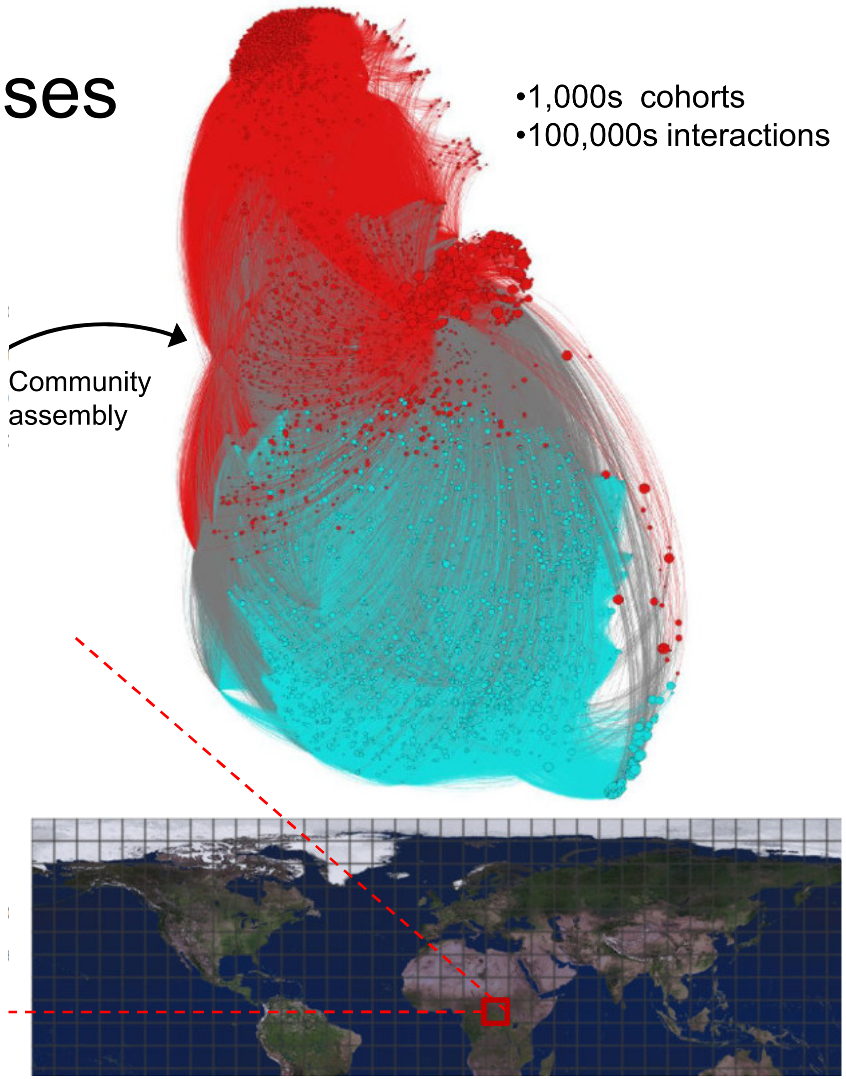


Herbivore / omnivore / carnivore
Ecotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Adult body mass
Juvenile body mass
Current body mass
Abundance

Ecological processes

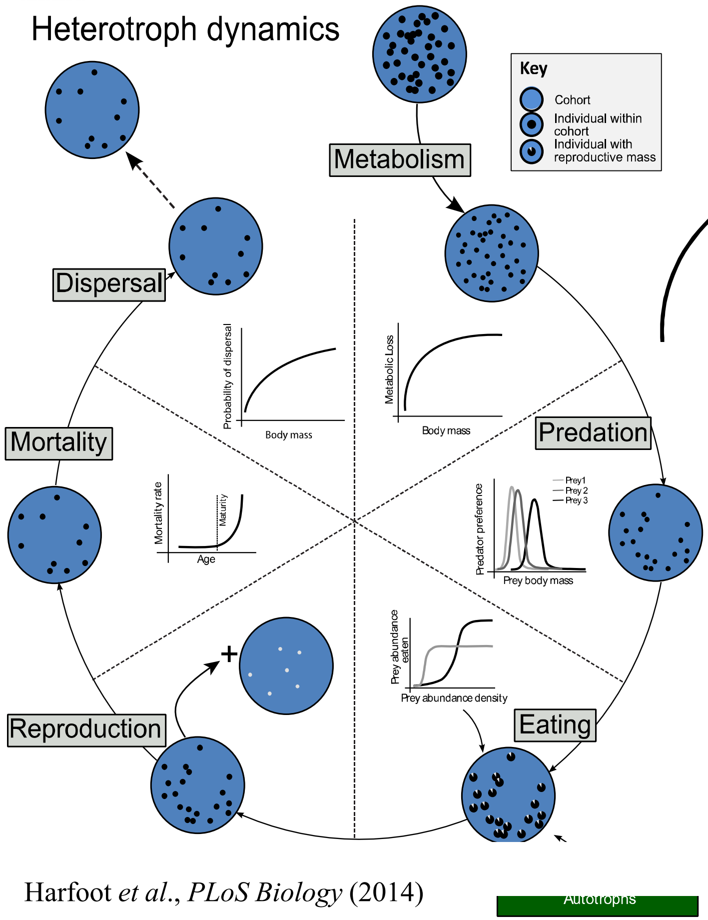


Harfoot *et al.*, *PLoS Biology* (2014)



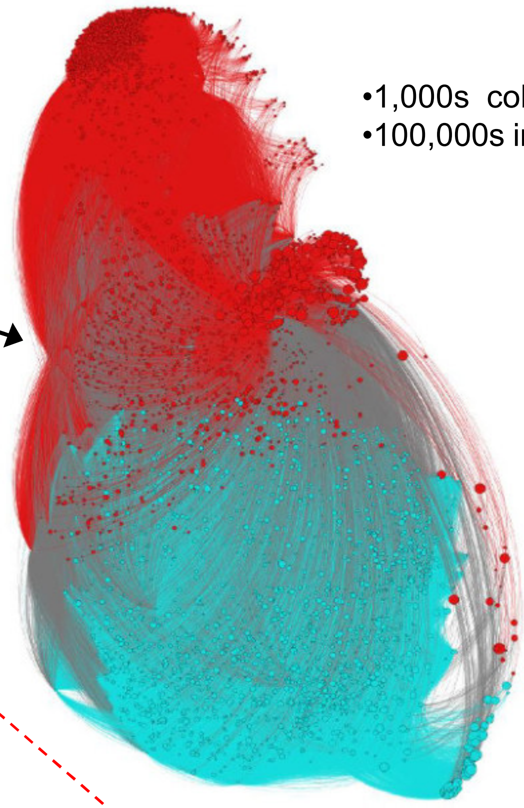
- 1,000s cohorts
- 100,000s interactions

Ecological processes

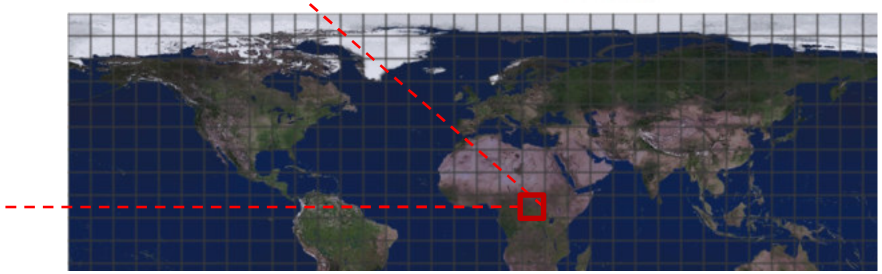


Harfoot *et al.*, *PLoS Biology* (2014)

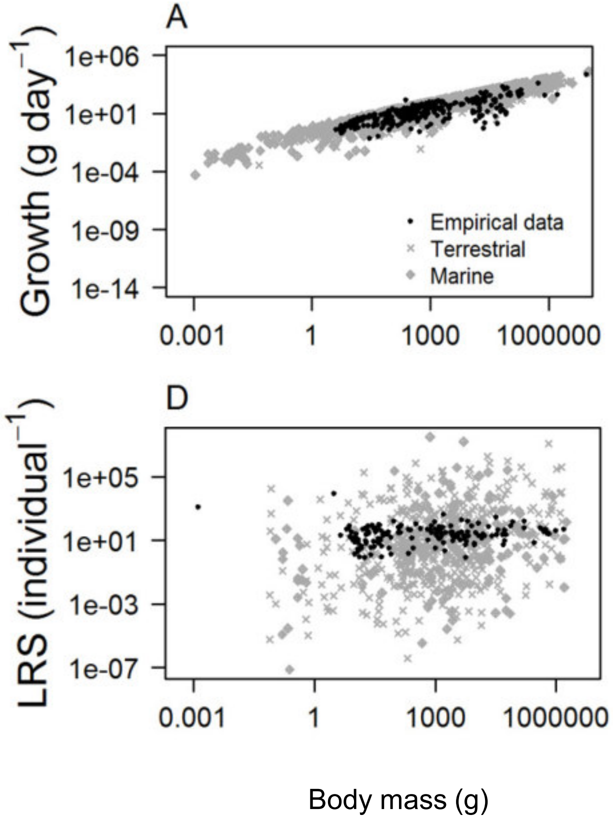
Community assembly



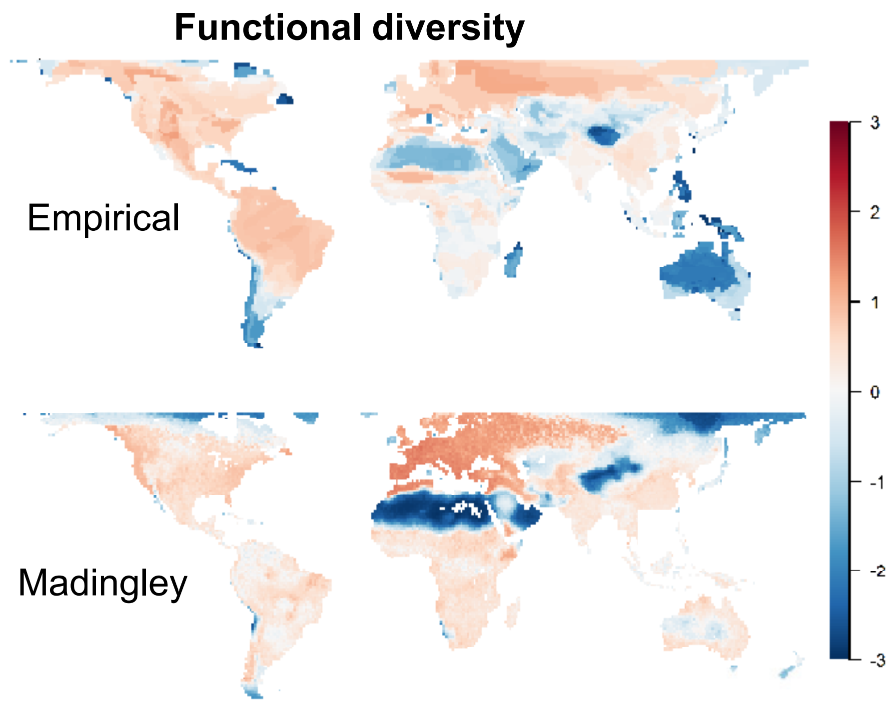
- 1,000s cohorts
- 100,000s interactions



Emergent patterns are broadly consistent



Harfoot *et al.*, *PLoS Biology* (2014)



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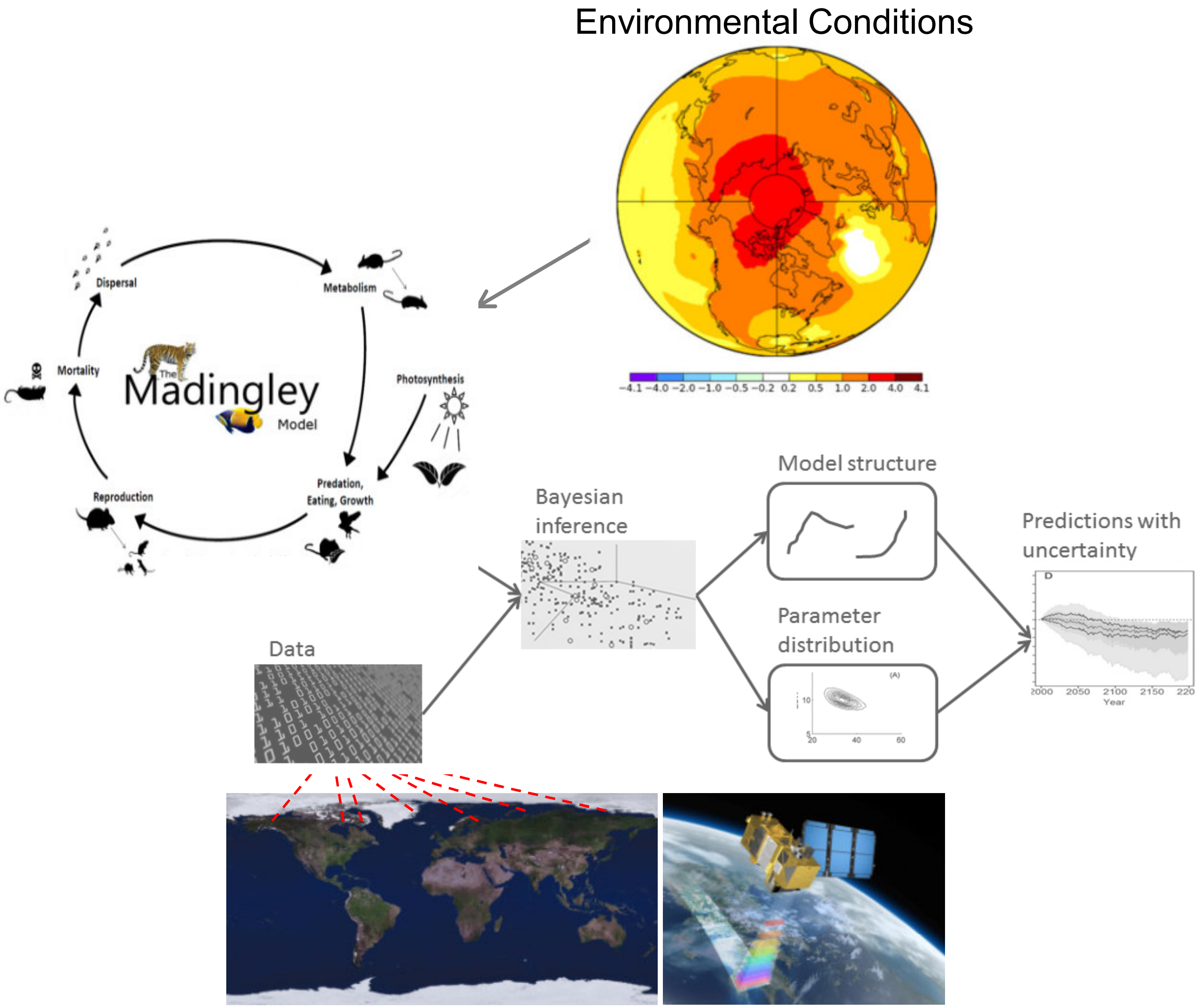

Advancing Arctic Ecosystem Modelling

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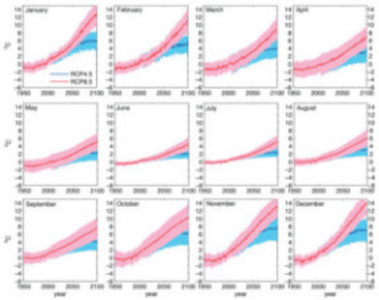
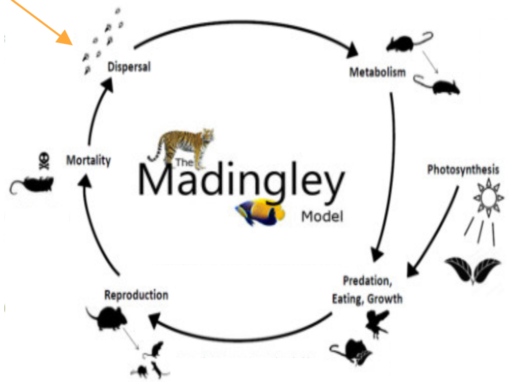
Ecological forecasts

- The pace of change in the Arctic means it is uniquely well placed to evaluate model performance:

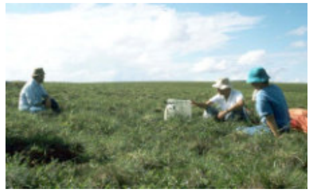


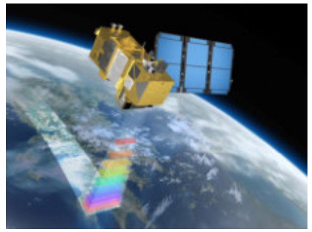


+ others e.g. DGVMs / SDMs

Forecast:
2-5 years

Evaluate





Conclusions

- There is a pressing need to understand Arctic ecosystem futures prior to further pressures (e.g. land conversion, fisheries) expanding substantially
- The rapid pace of change in combination with the complexity of ecosystem responses make Arctic systems valuable for developing better ecological models.
- In particular, process-based models might be important tools here to capture whole ecosystem changes.

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WCMC
United Nations Environment
World Conservation Monitoring Centre
The Madingley Model
www.madingleymodel.org
Thank you!
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