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Traits of benthic fauna: from observations to community models

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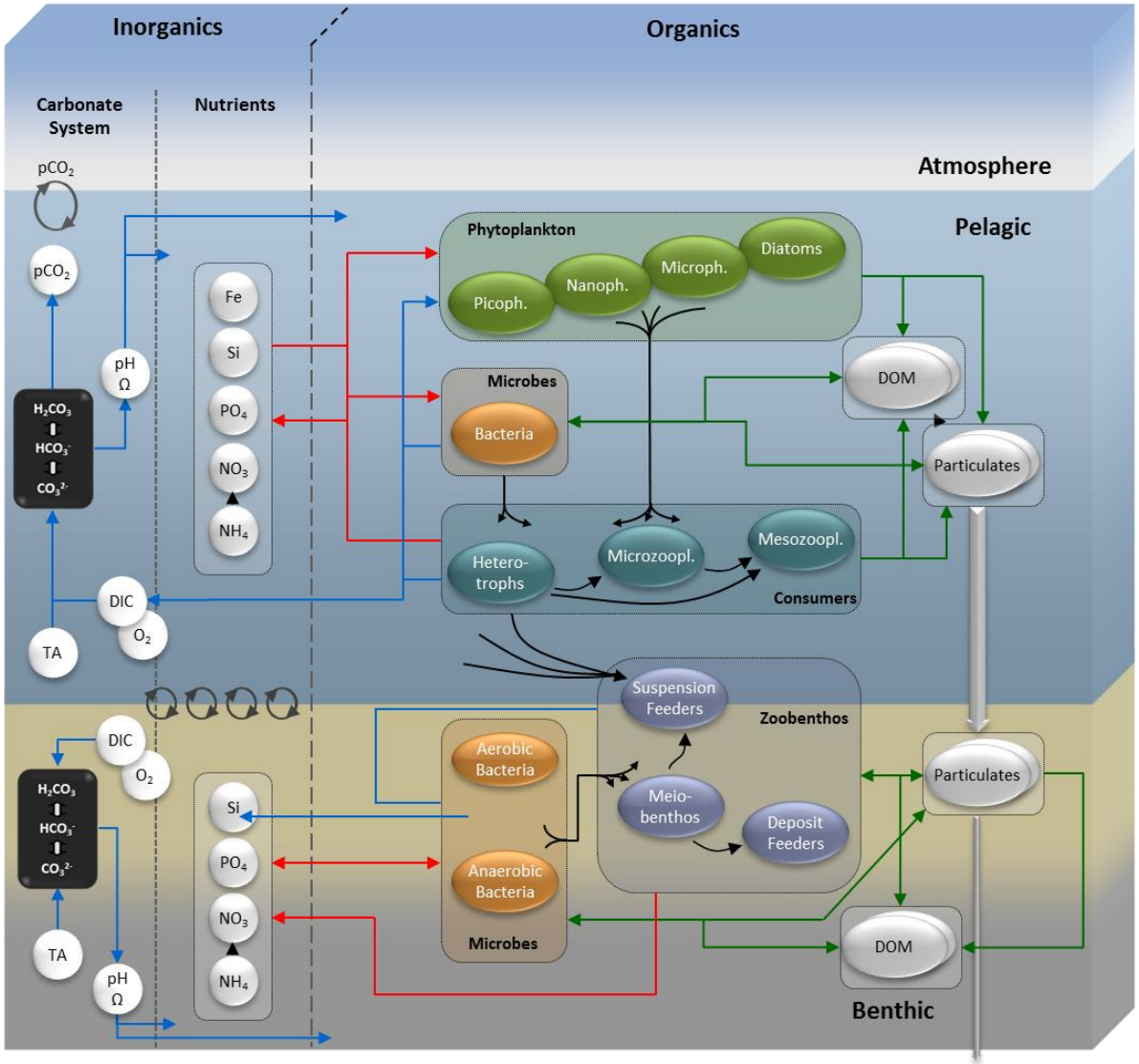
Context: ERSEM



Bütenschon et al. Geosci Model Dev Disc 2015, http://www.shelfseasmodelling.org

Context: ERSEM development

unicellular eukaryote
- phototrophy
- silica use
- calcification
- phagotrophy
- variable stoichiometry

original groups:
- nanophytoplankton
- microphytoplankton
- diatoms
- heterotrophic nanoflagellates
- microzooplankton

prokaryote
- phototrophy
- DOM uptake
- variable stoichiometry

original groups:
- picophytoplankton
- pelagic/benthic bacteria

pelagic metazoan
- predation
- fixed stoichiometry

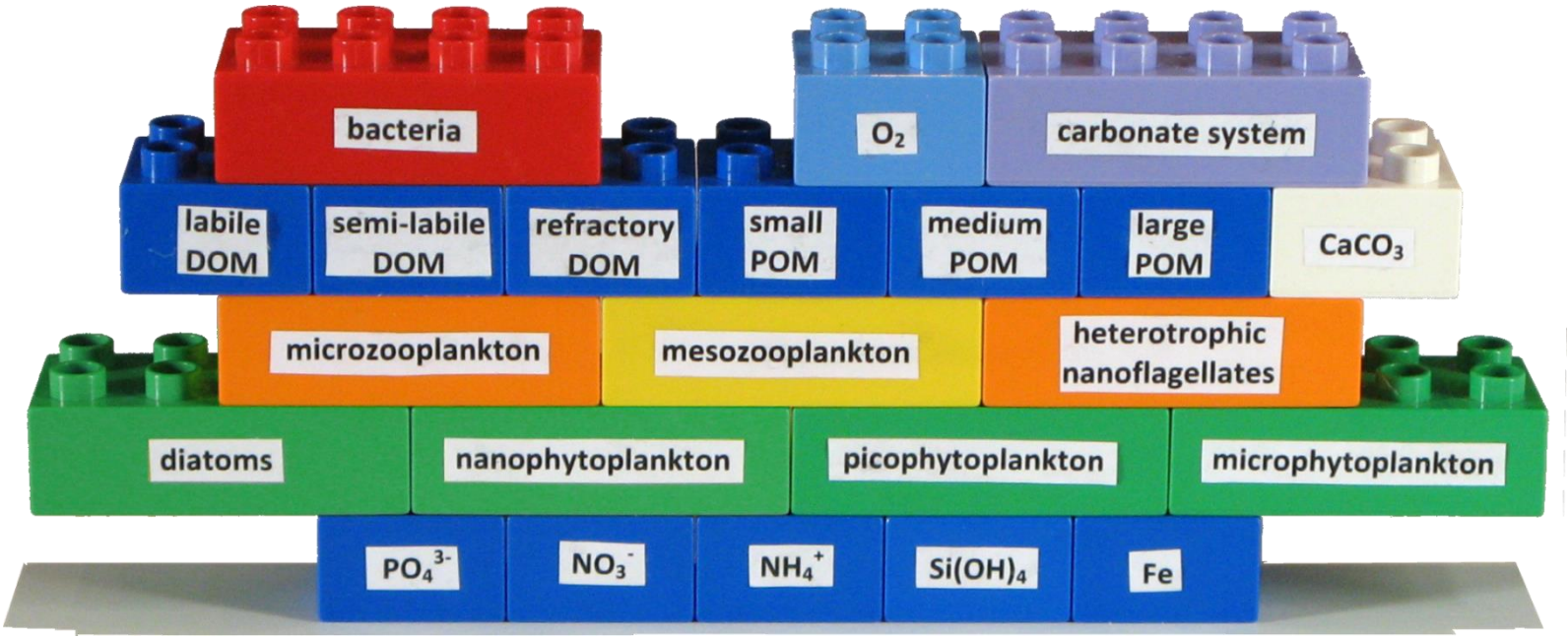
original groups:
- mesozooplankton

benthic metazoan
- predation (pelagic or benthic prey)
- fixed stoichiometry

original groups:
- suspension feeder
- deposit feeder
- meiobenthos

Bütenschon et al. Geosci Model Dev Disc 2015, http://www.shelfseasmodelling.org

Context: ERSEM development




passive particle


calcium carbonate


oxygen


carbonate system


phytoplankton


predator with variable stoichiometry


predator with fixed stoichiometry


bacteria

Bruggeman & Bolding Env Mod & Software 2014

The benthos: why do we care?

- Habitat for key species
  - commercially valuable: bivalves, crustaceans
  - structurally important: kelp, sea grass
- Feeding ground for fish
  - e.g., flatfish
- Key role for decomposition and nutrient supply
  - supplies 72.3% of pelagic phosphorus, 71.4% of nitrogen in English Channel (Proctor et al., 2003)
  - tightly linked to bioturbation/bioirrigation by benthic fauna

The Marine Ecosystem Research Program

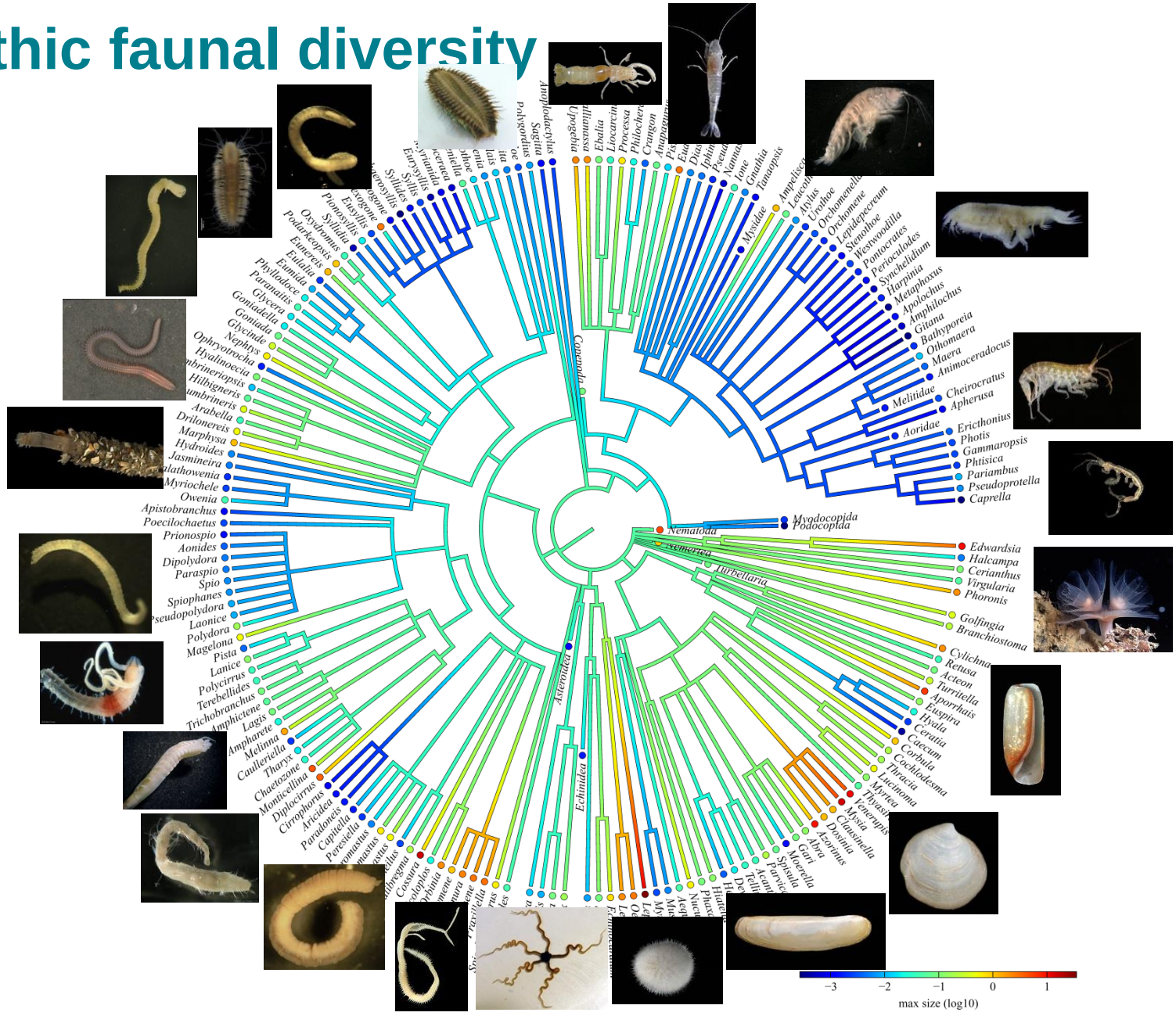
Marine Ecosystems Research Programme

… will address key knowledge gaps in marine ecosystem research. By bringing together existing data and targeted new data, the programme scientists will integrate these data with current models and knowledge of ecosystem services within a common framework, in order to improve our understanding of the whole UK marine ecosystem.

For benthic fauna:

- Understanding its variation in space and time…
  - test against existing time series, new field surveys
- …and its link to biogeochemical cycling…
  - kelp consumption
  - benthic-pelagic fluxes (O_2, CO_2, nutrients)
- …in order to assess impact of management scenarios
  - trawling bans
  - Marine Protected Areas

Benthic faunal diversity



Benthic faunal traits – thoughts

Table 1 The eight biological trait categories used in our analysis, with individual traits belonging to each category where relevant, and the importance of each trait category to macroecological analyses. A full definition of individual traits, together with additional information on their importance, is given in Table S2.

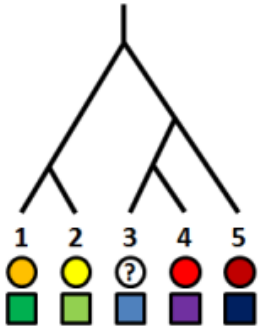
Trait categories	Individual traits	General importance
Body size	Maximum linear dimension (mm)	Key life history and macroecological trait (Gaston & Blackburn, 2000; Hildrew *et al.*, 2007), correlates with other traits, e.g. metabolic rate (Brown *et al.*, 2004), and response to disturbance, e.g. (Tillin *et al.*, 2006)
Diet	Major components of diet (e.g. plankton, detritus, invertebrates, fish)	Determines trophic structure, energy flow and nutrient cycling within communities
Feeding method	Mode of food capture (e.g. grazer, predator, filter feeder)	Influences inter-specific interactions, nutrient and energy cycling and predicts response to disturbance
Reproductive timing	Reproductive frequency (no. of breeding attempts per year); reproductive duration (length of breeding season); reproductive season (time of year of breeding season)	Determines annual productivity, as well as changes in phenology as a response to climate change (e.g. Edwards & Richardson, 2004)
Fecundity	Annual fecundity (number of eggs/young produced in a reproductive event); egg size (diameter of eggs/size of young)	Related to rate of population increase (e.g. Jennings *et al.*, 1998; McGill *et al.*, 2006) and thus to (meta)population dynamics and response to environmental change
Larval dispersal	Larval development mode (presence of a planktonic larval stage); larval duration (duration of the larval period; scored as 0 for live-bearers)	Influences geographic range size (Jablonski, 1986) and the relationship between distribution and abundance (Foggo *et al.*, 2007)
Adult dispersal	Adult movement method (mode of movement, e.g. crawling, swimming, burrowing, sessile); adult migration (existence of significant post-recruitment horizontal movements outside typical daily movements)	Important in determining large-scale colonization and extinction dynamics in response to changing environmental conditions, which is key to structuring macroecological relationships (Freckleton *et al.*, 2005)
Longevity	Adult life span (maximum recorded life span); age at maturity (minimum recorded age at maturity)	Influences population dynamics through effects on reproductive strategy and response to disturbance (Jennings *et al.*, 1998)

Tyler et al. 2012; Glob Ecol Biogeogr

Benthic faunal traits – available data

- wet weight
  - UK Western Channel Observatory: species totals
  - Irish Sea samples: individual weights
- ash-free dry weight : wet weight
  - Brey et al. 2010; http://www.thomas-brey.de/science/virtualhandbook
- size at maturity, mass-specific growth rate at birth
  - Hirst & Forster 2013 Proc Roy Soc B
- feeding mode, motility
  - PML internal

Getting at traits through phylogeny



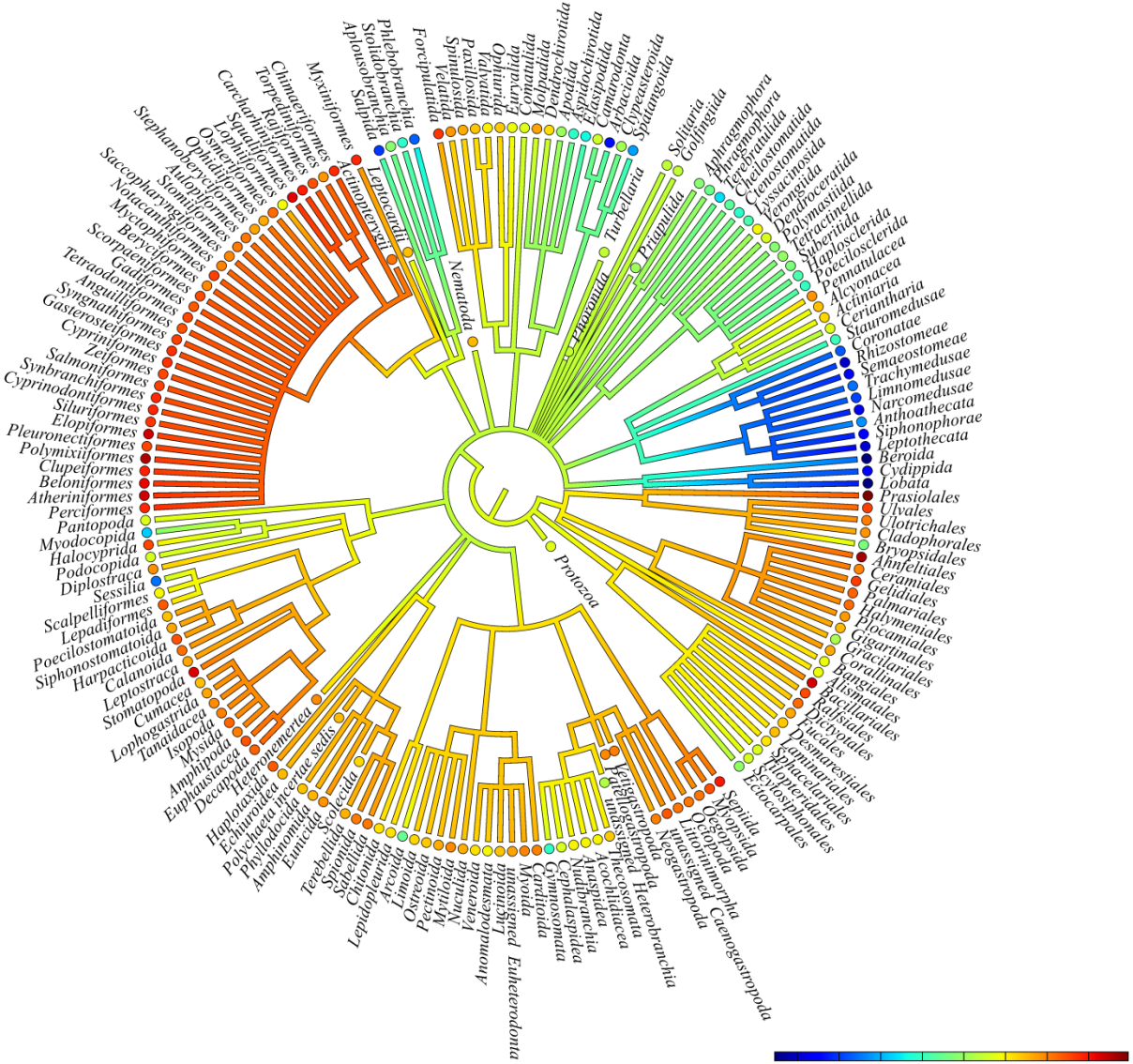
PhyloPars

- "phylogeny-aware regression", separates
  - *general patterns* (e.g. allometric scaling)
  - *random jumps* (evolutionary innovations)
- Enables trait value *inferences*

- Phylogeny: WoRMS World Register of Marine Species taxonomy – not phylogeny!
  - access web service API for taxonomic classification
- Aim: fit scale factors for distances between ranks
  - phylum –class – order – family – genus – species

Bruggeman et al. (2009 Nucleic Acids Res)
http://www.ibi.vu.nl/programs/phylopars/; http://www.rphylopars.org/

Ash-free dry weight : wet weight

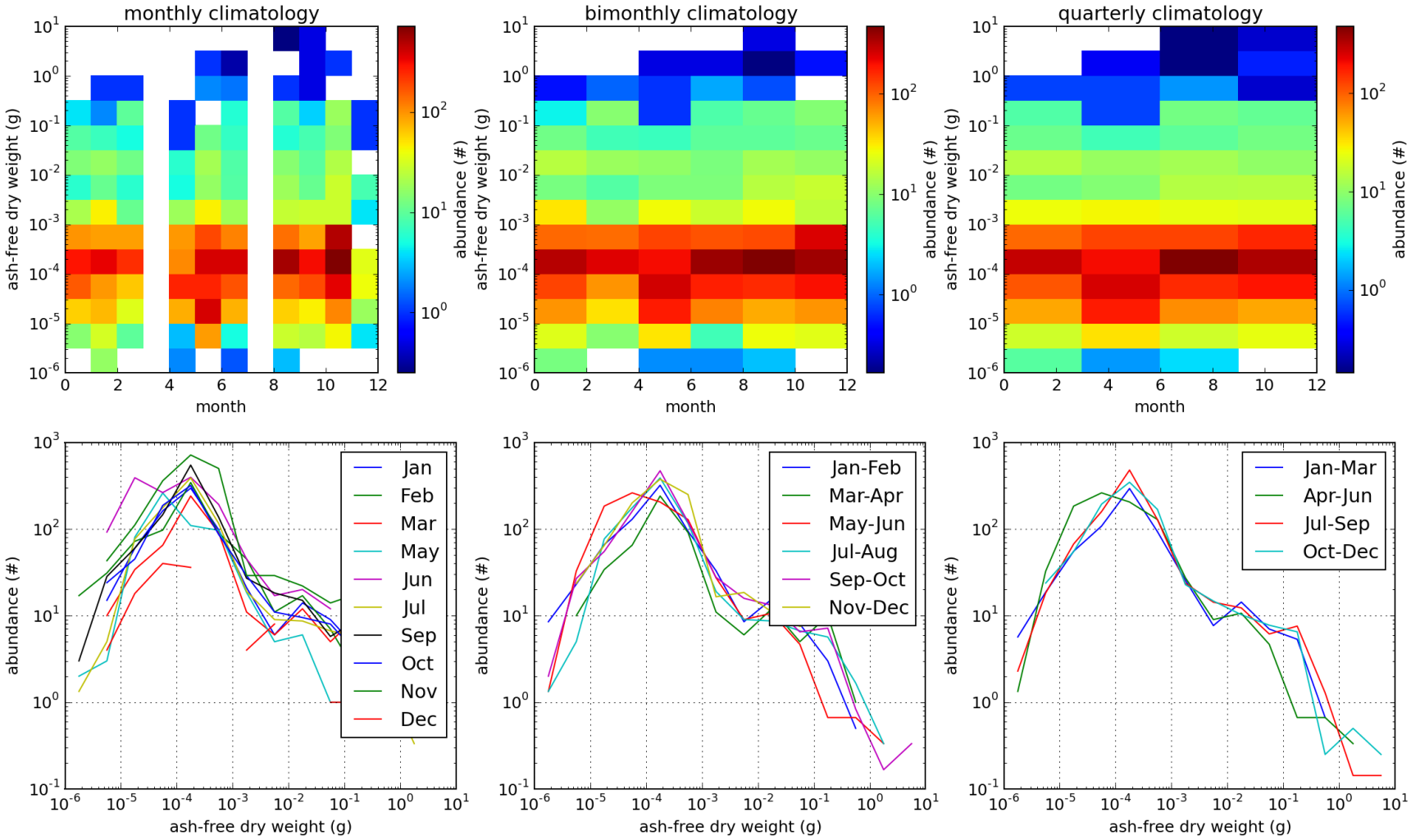


−2.0 −1.8 −1.6 −1.4 −1.2 −1.0 −0.8 −0.6

AFDM/WM (log10)

http://www.thomas-brey.de/science/virtualhandbook

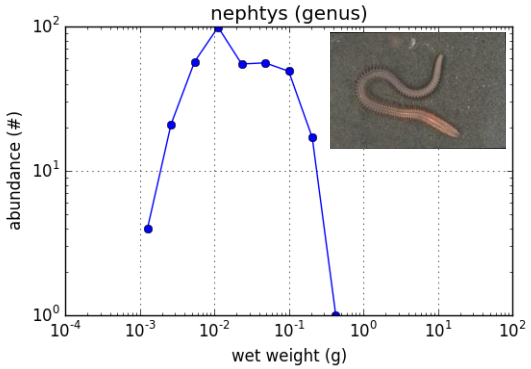
Observed size spectra: Western English Channel

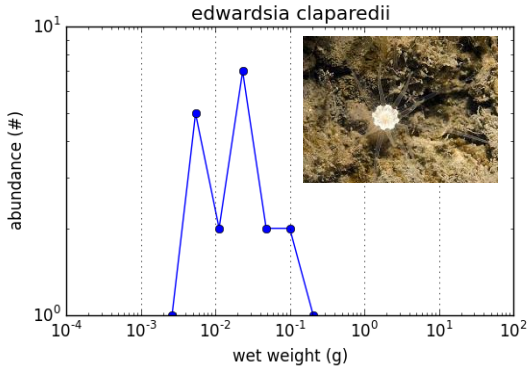


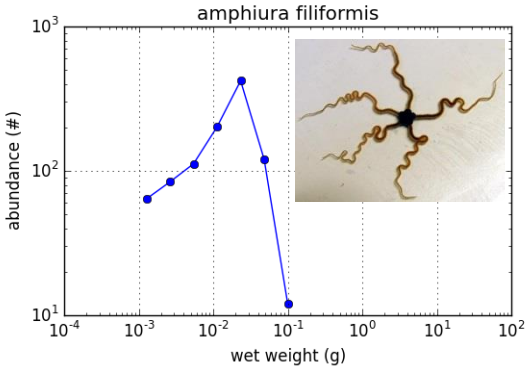
Western Channel Observatory data; Ana Queiros

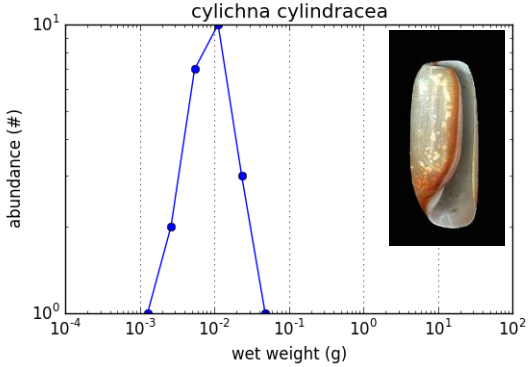
Intraspecific size

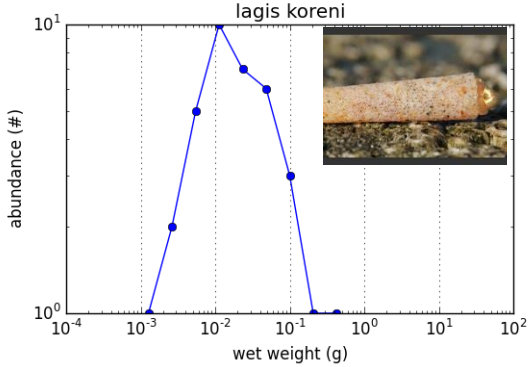
Irish Sea samples; Jan Geert Hiddink

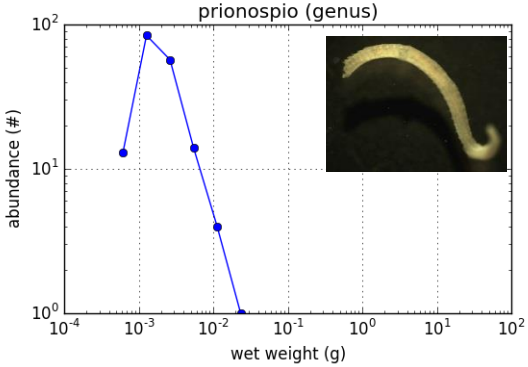


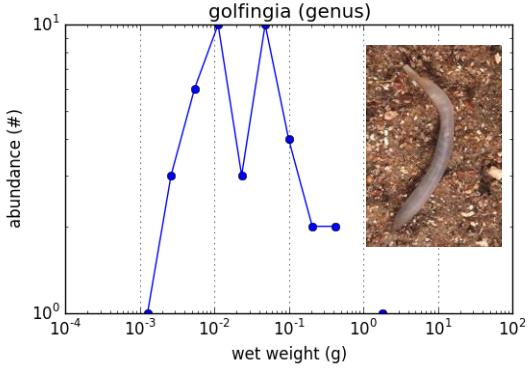


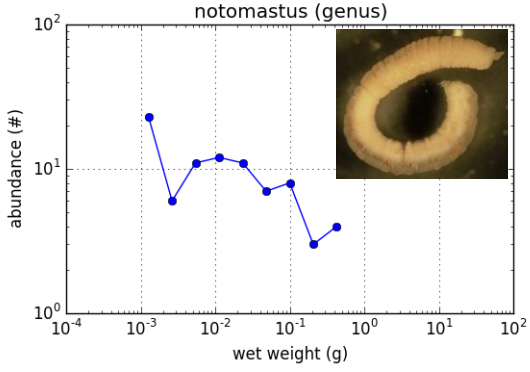


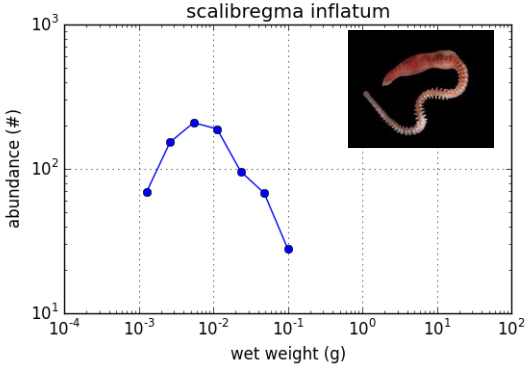




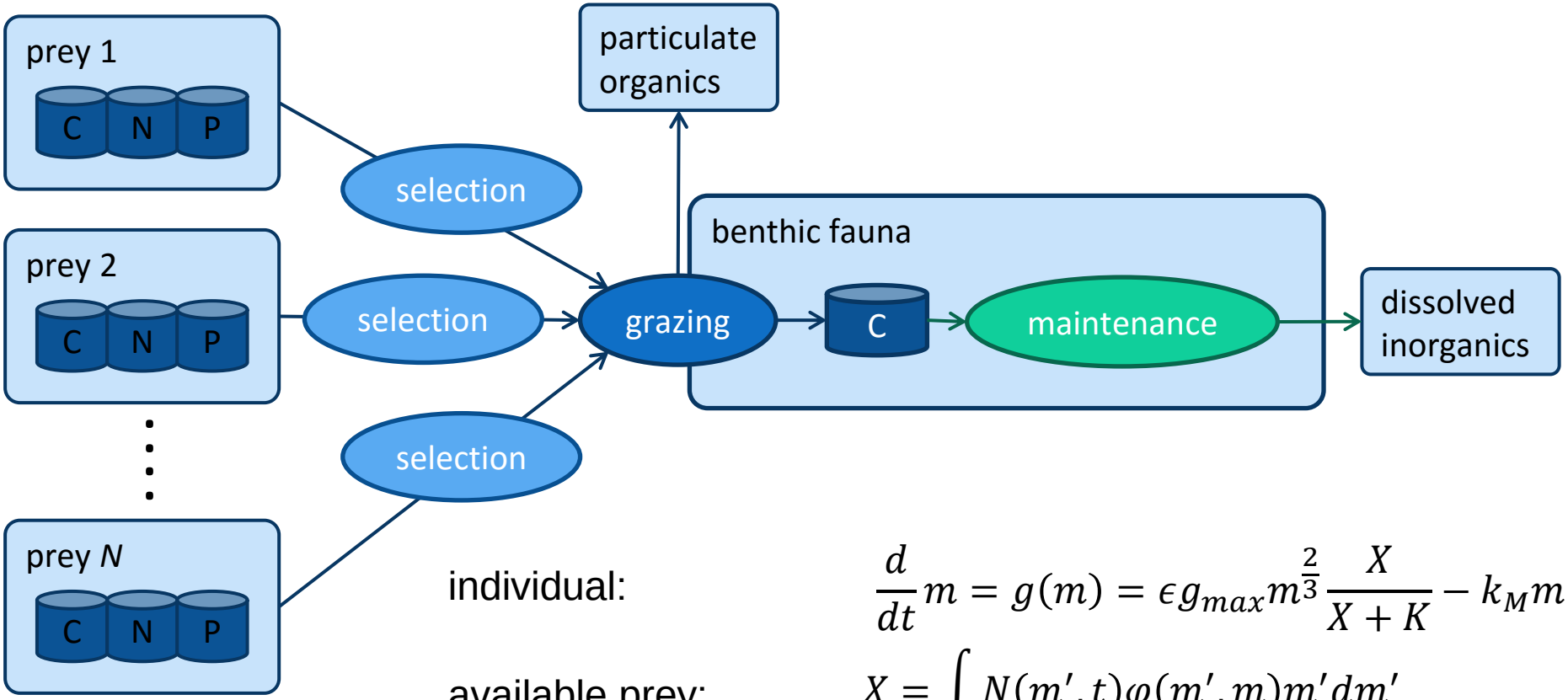








Proof of principle – a stripped down metazoan



individual: $$\frac{d}{dt}m = g(m) = \epsilon g_{max} m^{\frac{2}{3}} \frac{X}{X+K} - k_M m$$

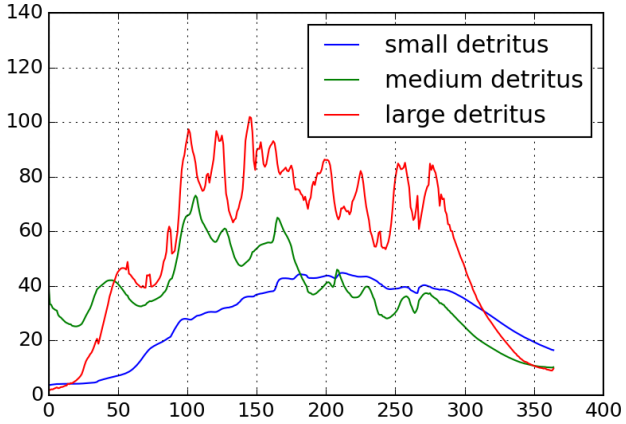
available prey: $$X = \int N(m',t)\varphi(m',m)m'dm'$$

grazing selectivity: $$\varphi(m, m_{prey}) = e^{-\frac{\left(\ln\frac{m}{\beta m_{prey}}\right)^2}{2\sigma^2}}$$

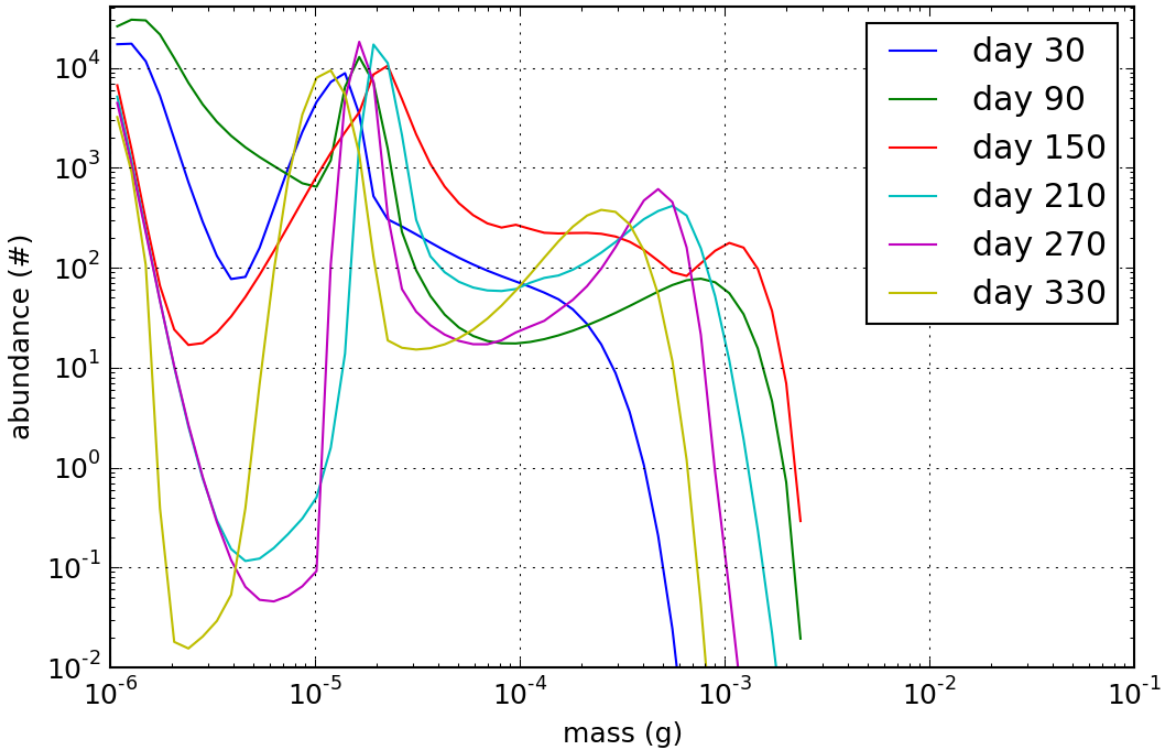
structured population: $$\frac{\partial}{\partial t}N(m,t) = \frac{\partial}{\partial m}(Ng) - hN$$

Initial model results

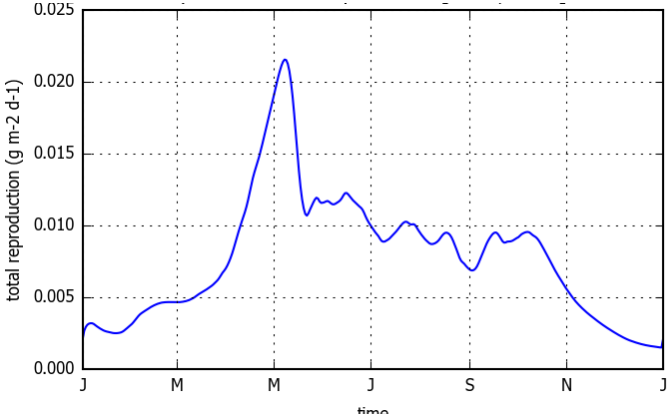
Forcing: detritus fluxes



Result: bimonthly size spectra

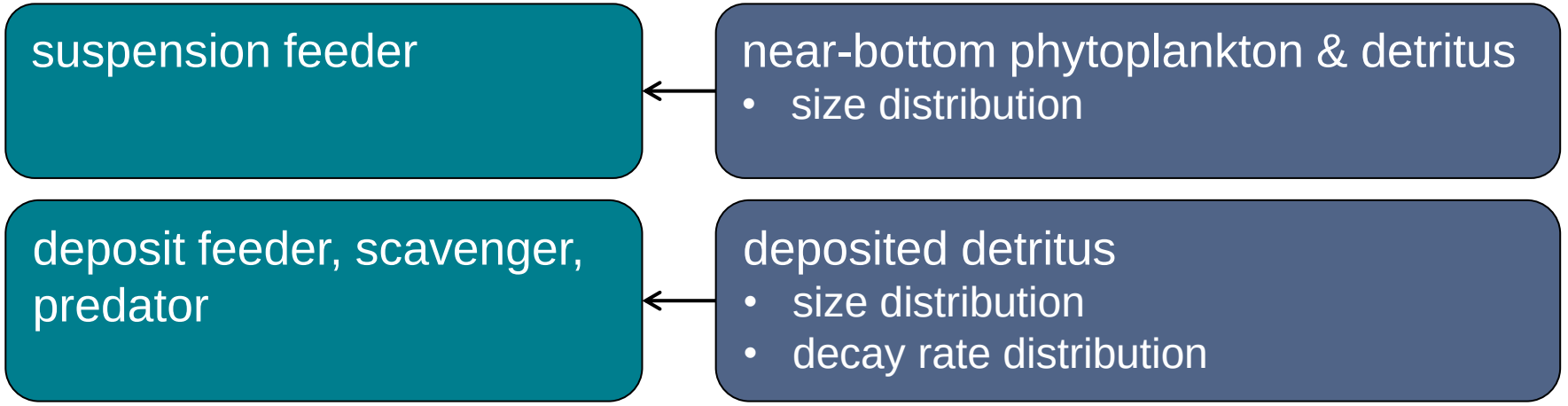


Result: reproduction



Way forward

- Feeding mode and food traits…



- Reproduction (pelagic larvae)
- Impact on biogeochemical cycles
  - Bioturbation/bioirrigation
- Habitat (substrate, vertical structure of sediment columns)
- Space
  - 1D water columns
  - 3D high resolution UK shelf model

Thank you

Marine Ecosystems Research Programme

NERC SCIENCE OF THE ENVIRONMENT

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Duplo (reluctantly) provided by