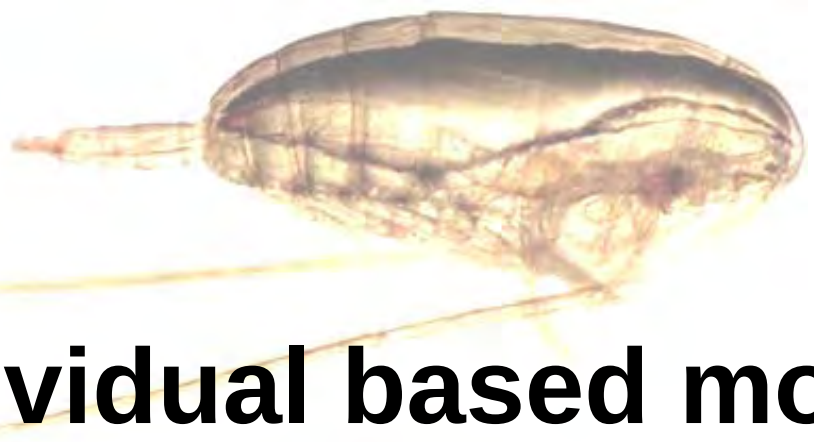

An individual based model with emergent life history and behaviour for *Calanus finmarchicus*

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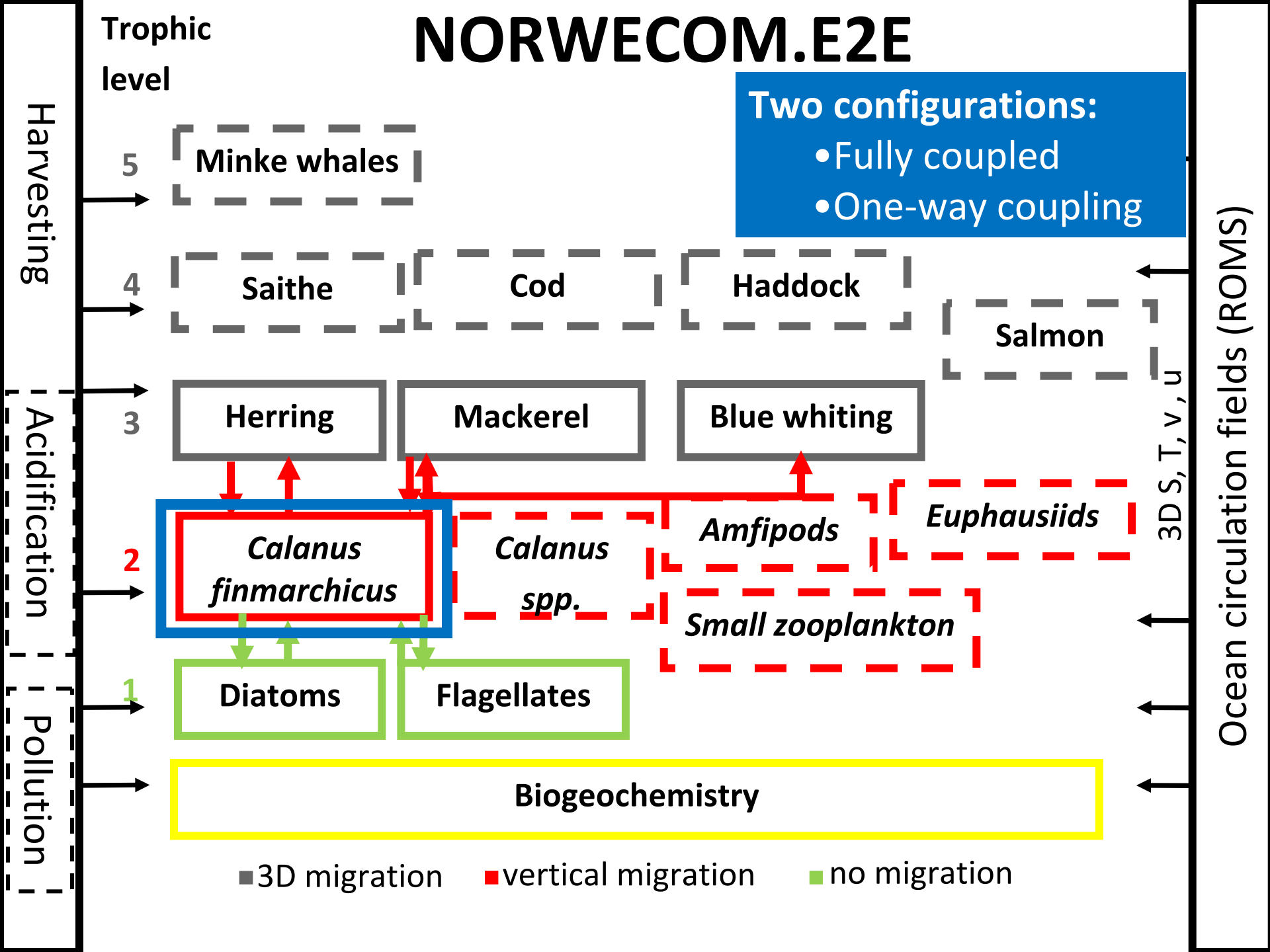
Background

- A lot of interest in end to end modelling of marine ecosystems

- End to en models:
  - Aims to represent the entire food web and the associated abiotic environment
  - Integrate physical and biological processes at different scales
  - Two-way interaction between ecosystem components
  - Dynamic forcing effect of climate and human impacts at multiple trophic levels

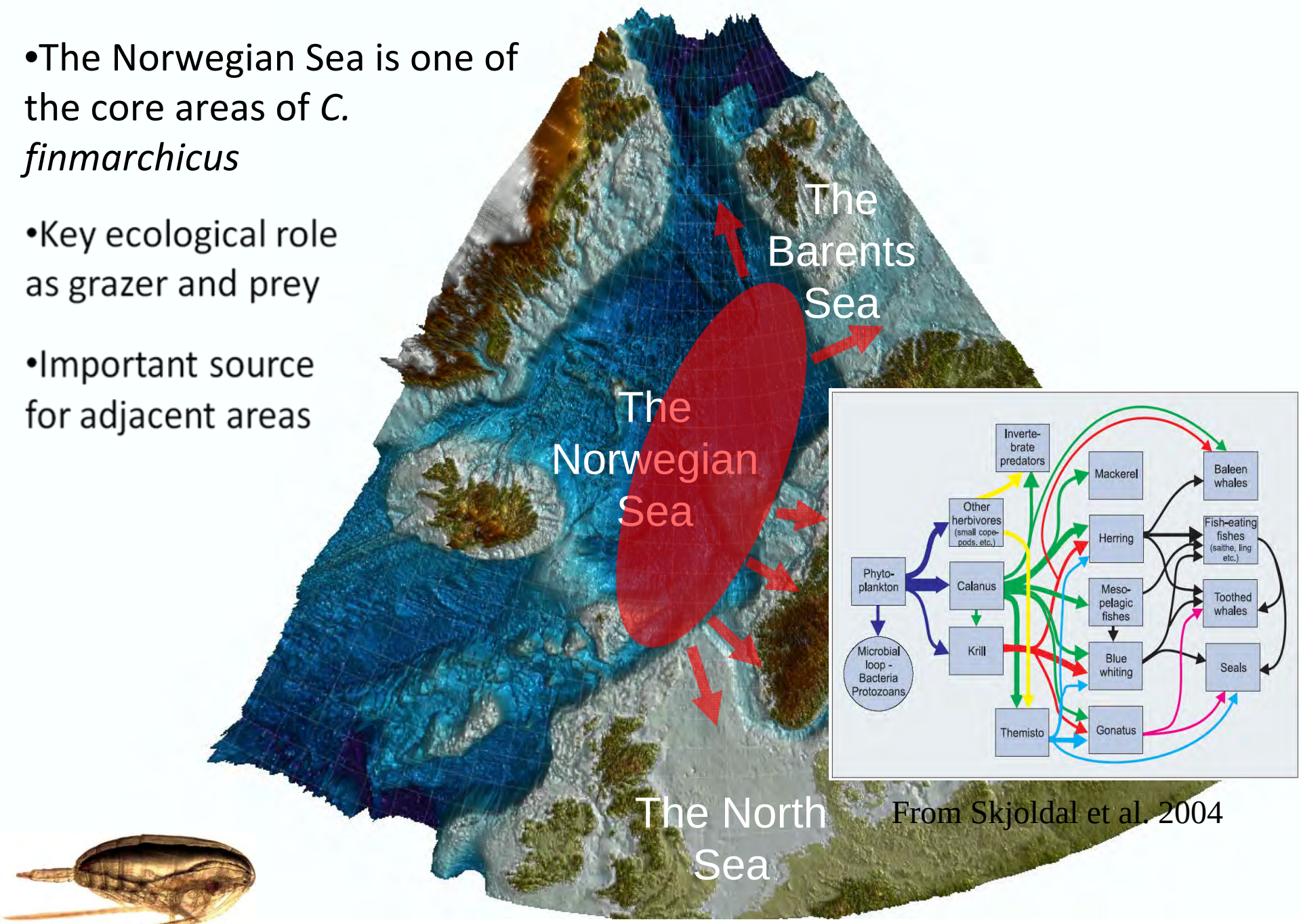
(Travers et al 2007)


NORWECOM.E2E
Trophic level
Two configurations:
•Fully coupled
•One-way coupling
5
Minke whales
4
Saithe
Cod
Haddock
Salmon
3
Herring
Mackerel
Blue whiting
2
Calanus finmarchicus
Calanus spp.
Amfipods
Euphausiids
Small zooplankton
1
Diatoms
Flagellates
Biogeochemistry
Harvesting
Acidification
Pollution
3D S, T, v , u
Ocean circulation fields (ROMS)
3D migration
vertical migration
no migration

Objectives

- Present IBM with emergent life history and behaviour for *C. finmarchicus*
- Model simulations to look at:
  - Effect of inter-annual variability on traits
  - Impact of different predation levels on traits
- Show implementation of the *Calanus* model in the fully coupled NORWECOM.E2E system focused on the Norwegian Sea

- The Norwegian Sea is one of the core areas of *C. finmarchicus*
- Key ecological role as grazer and prey
- Important source for adjacent areas



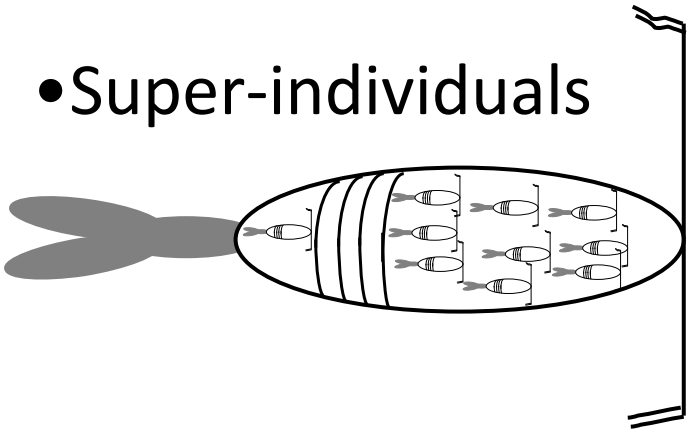
From Skjoldal et al. 2004

Individuals

Attributes

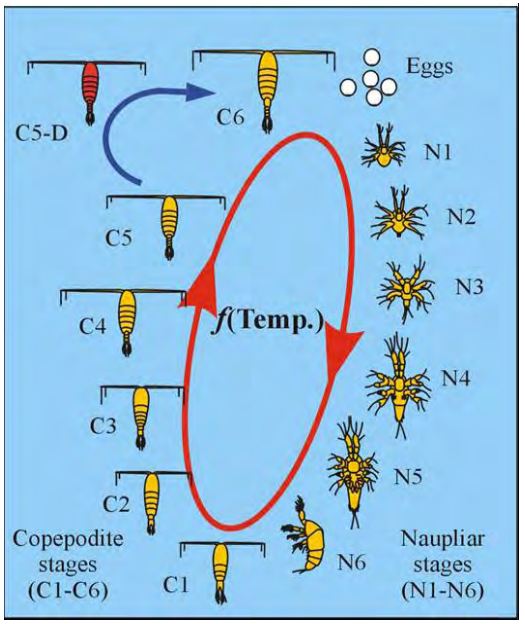
- Stage
- Structural weight
- Fat content
- Position
- Depth

- Super-individuals



Strategies

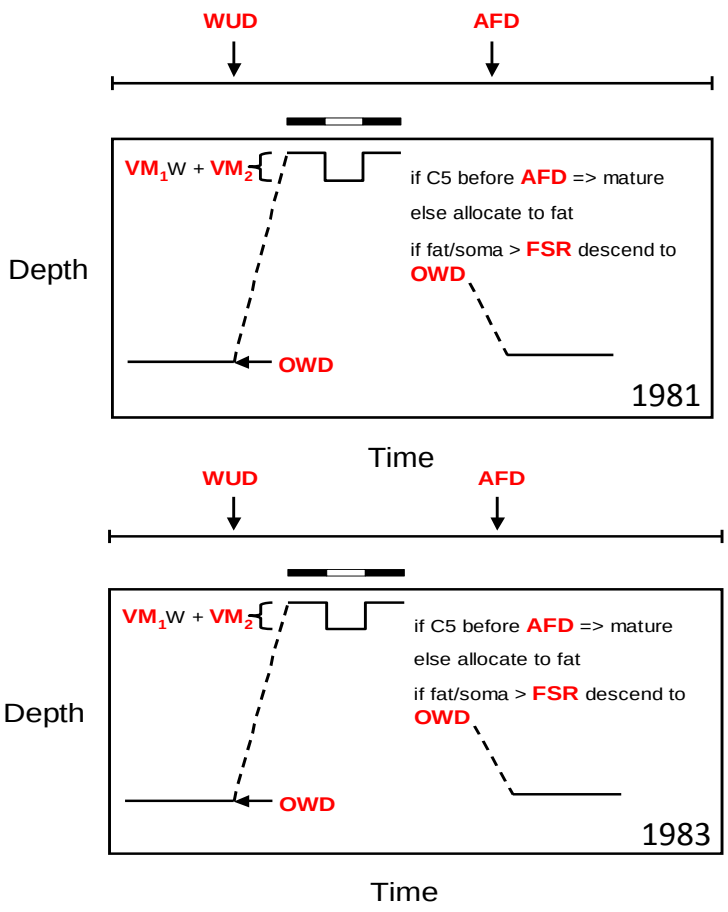
- Overwintering depth (OWD)
- Wake up day (WUD)
- Allocation to fat date (AFD)
- Fat to soma ratio (FSR)
- Vertical migration (VM1,VM2)

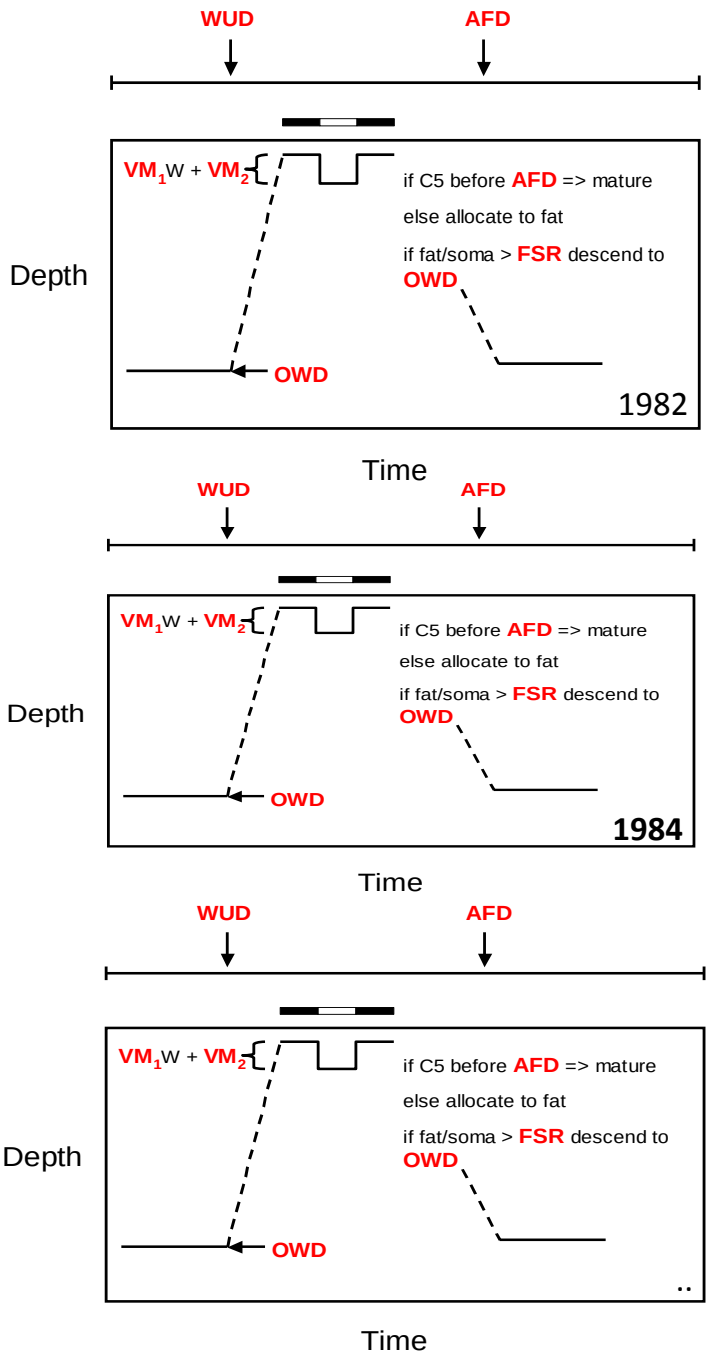


From http://pulse.unh.edu/

Model structure

- The life of super-indviduals is simulated using life history traits to control actions at key points





- Traits are inherited by offspring and adapted through selective growth and survival
- Recombination and mutations add variability to traits

Processes

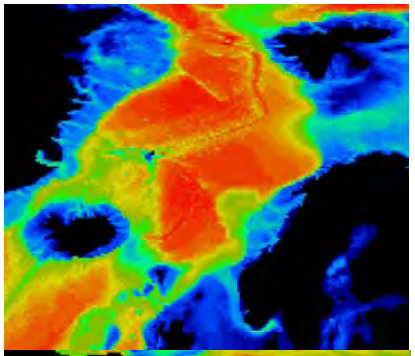
- **Feeding:** functional response (Campbell 2001)
- **Growth:** bioenergetics (Carlotti & Wolf 1998)
- **Mortality:** predation, starvation, spawning
- **Reproduction:** mature adults above size thres.
- **Vertical movement:** ontogeny, dvm
- **Horizontal movement:** Runge-Kutta
- **Fitness based resampling:** Super individuals are resampled to a fixed initial population size at the start of the year to keep population size in check
- **Fitness:** internal number*weight

Environment

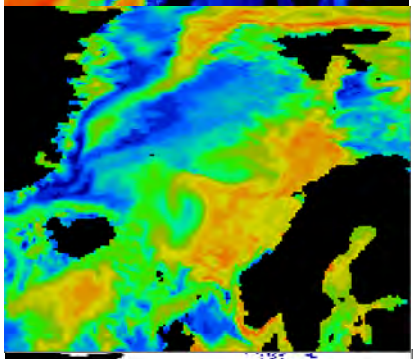
- Model grid 181x153
- 20x20 km squares
- 1 m vertical resolution

- Input data:
  - Temperature
  - Currents
  - Light
  - Food
  - Predators

Bathymetri



Diatoms & flagellates



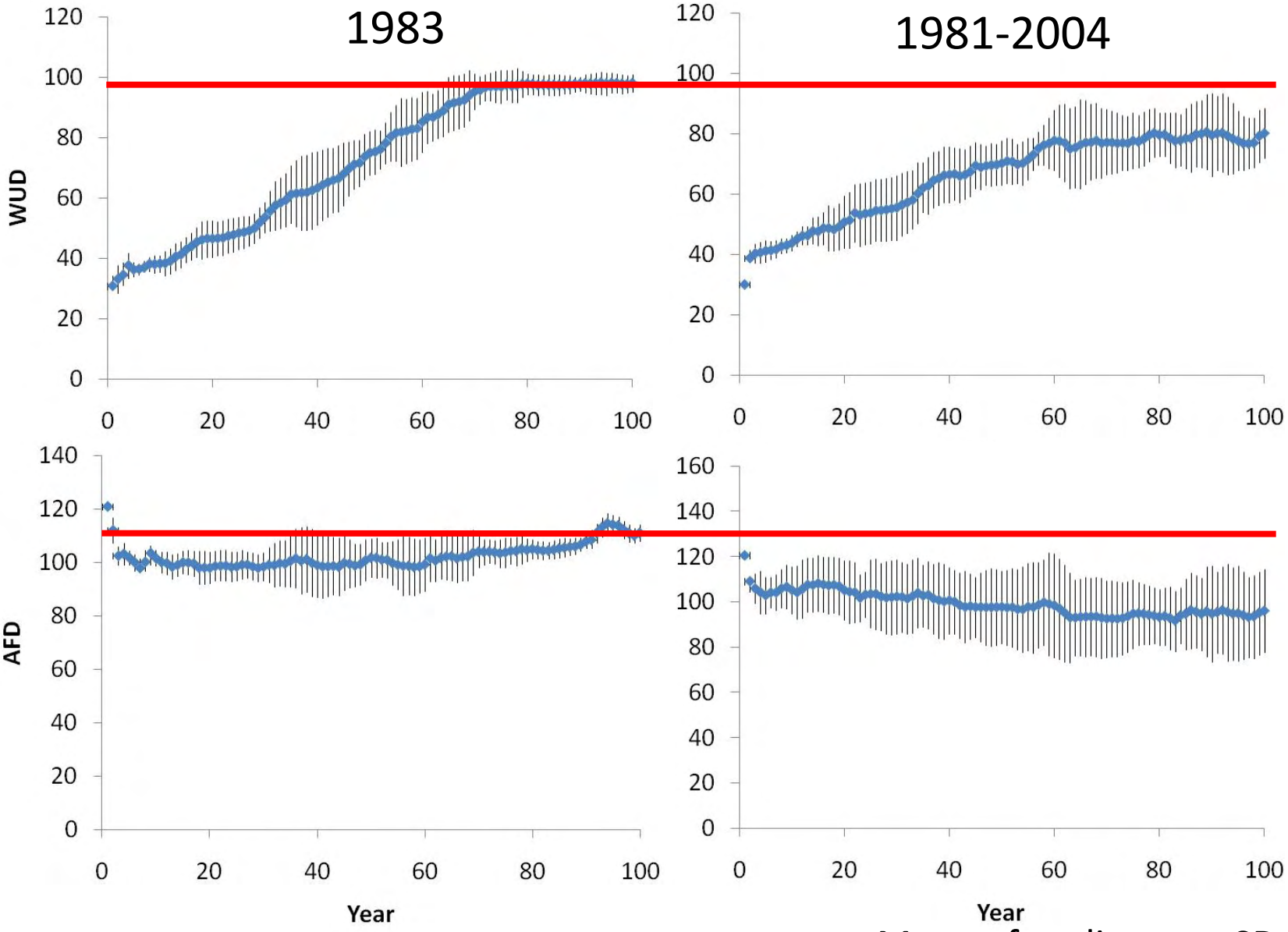
Pelagic fish

Invertebrate predators

Results

Trajectories of trait evolution

- Fixed forcing year 1983
- Multiple forcing years 1981-2004



Mean of replicates ± SD

Results

”Genetic” variation in traits within simulations

	WUD	FSR	AFD	OWD	VM1	VM2
Multiple years	9.2	0.1	14.2	124.3	7.7	629.3
Fixed year	4.4	0.0	9.1	98.9	3.5	203.2

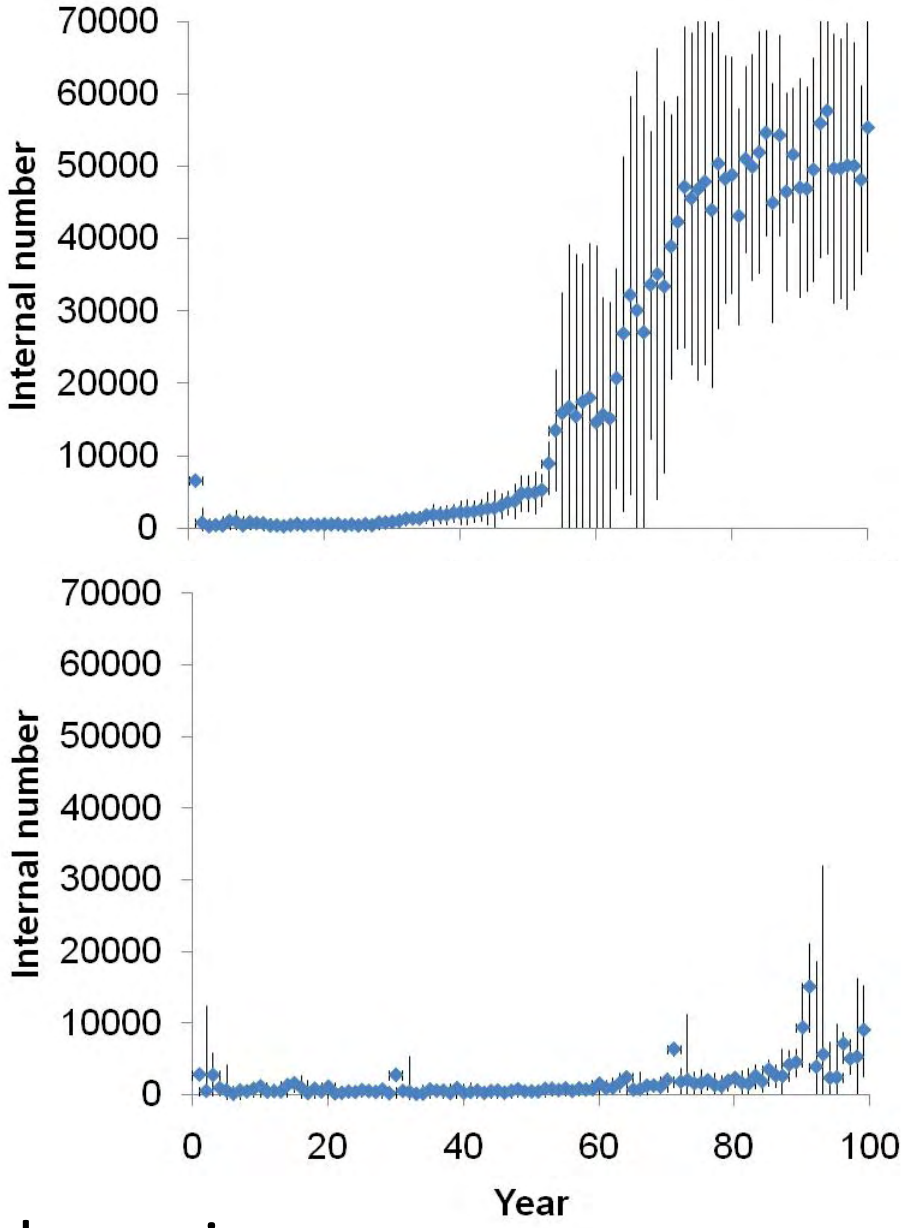
(Average standard deviation within replicate simulations)

- Standard deviation is 25-300% higher in simulations with interannual variability

Results

High vs. low fish density

- Low fish density
- High fish density

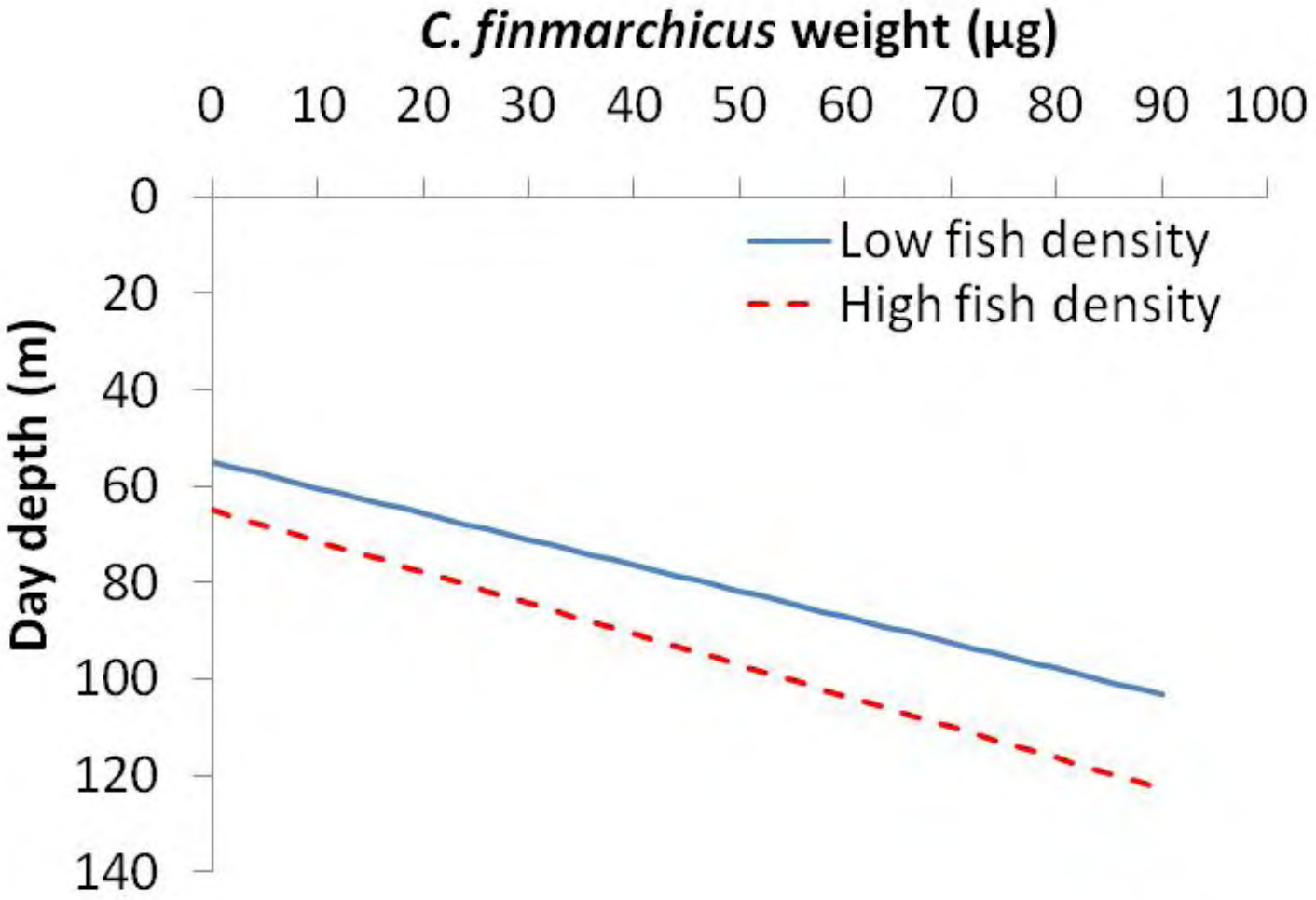


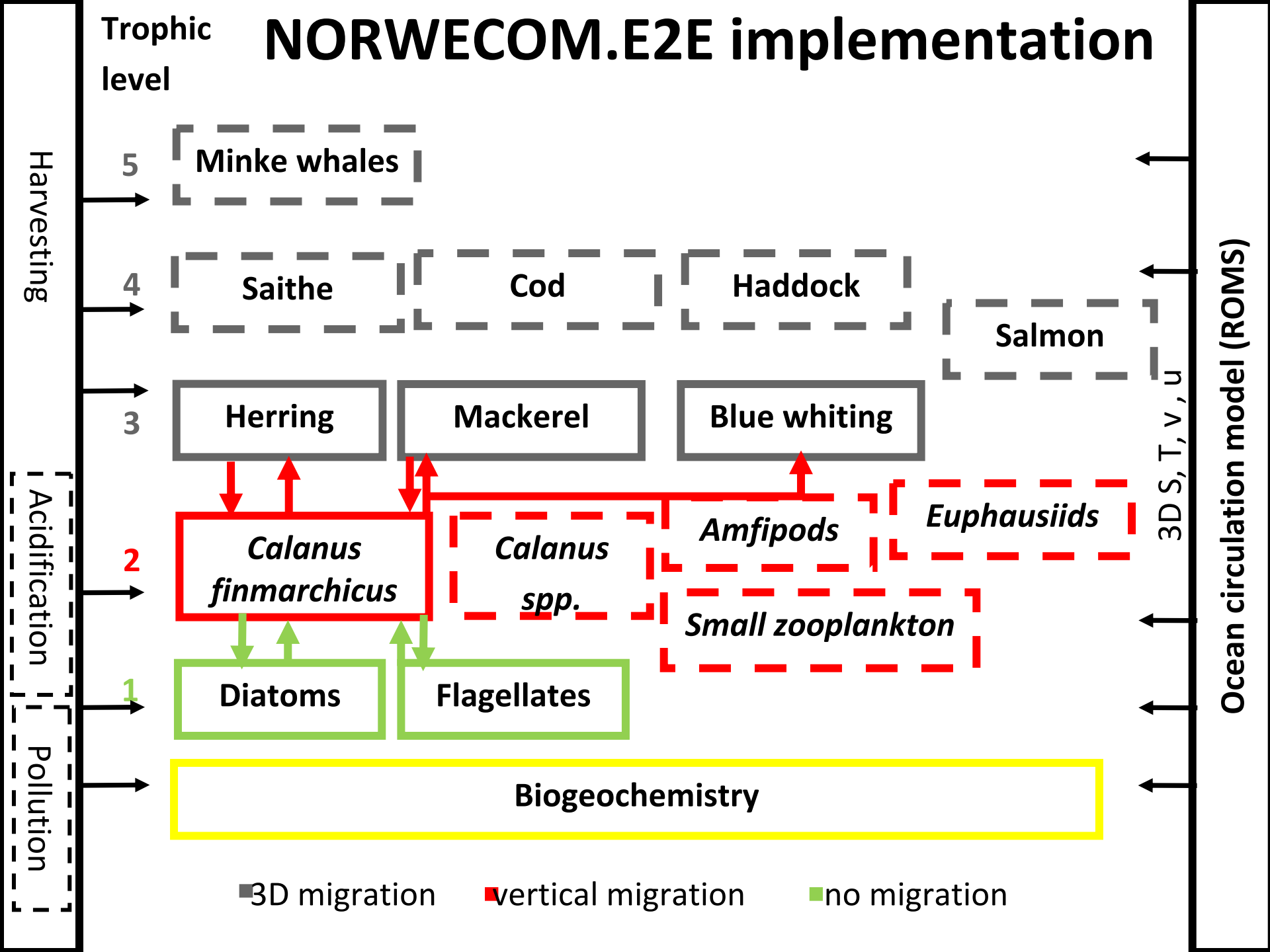
Population or ”fitness” dynamics

Results

Vertical migration

- Night depth at chlorophyll maximum
- Modelled day depth: $vm_1 + vm_2$*weight

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NORWECOM.E2E implementation
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Calanus spp.
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Diatoms
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Biogeochemistry
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Acidification
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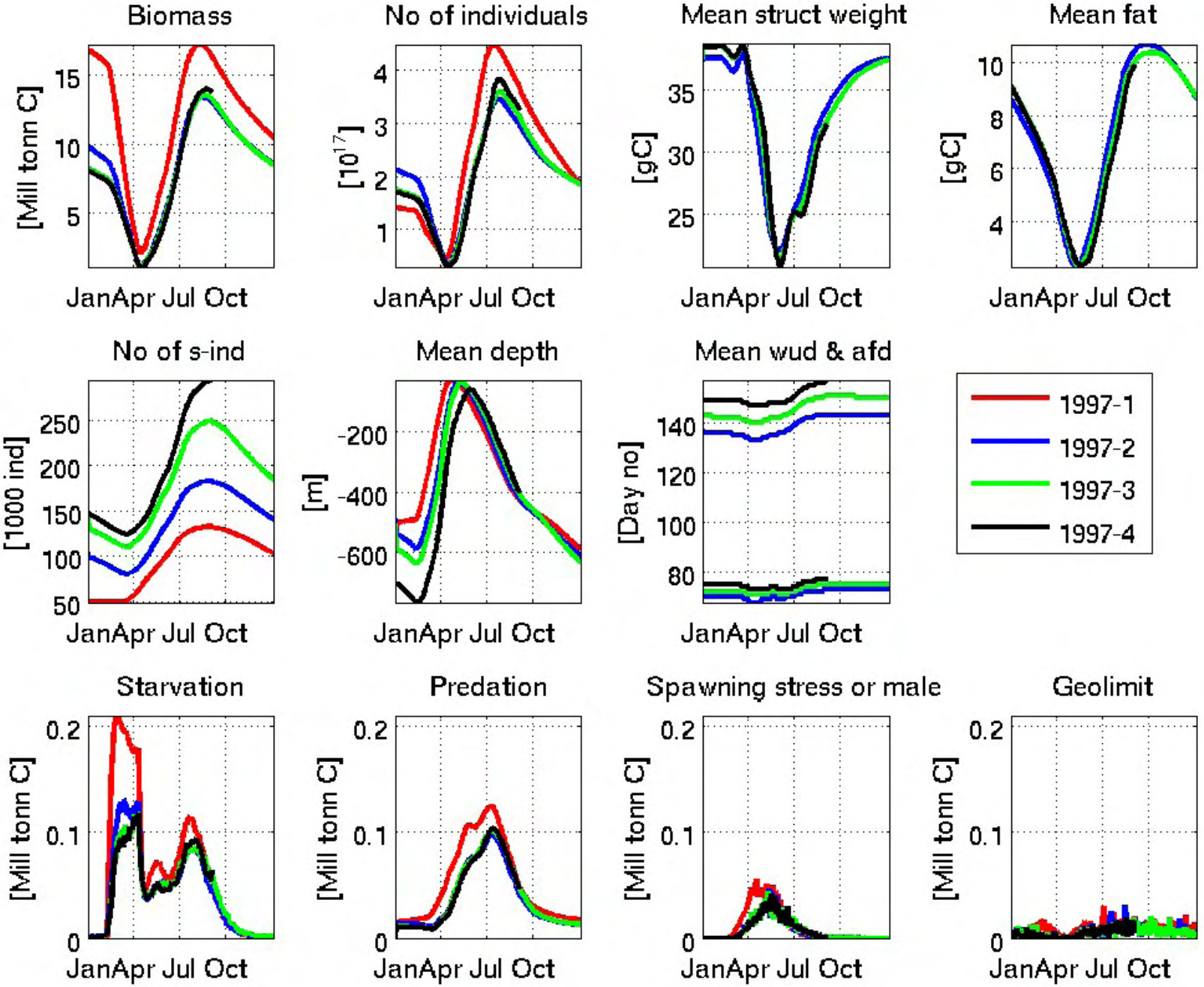
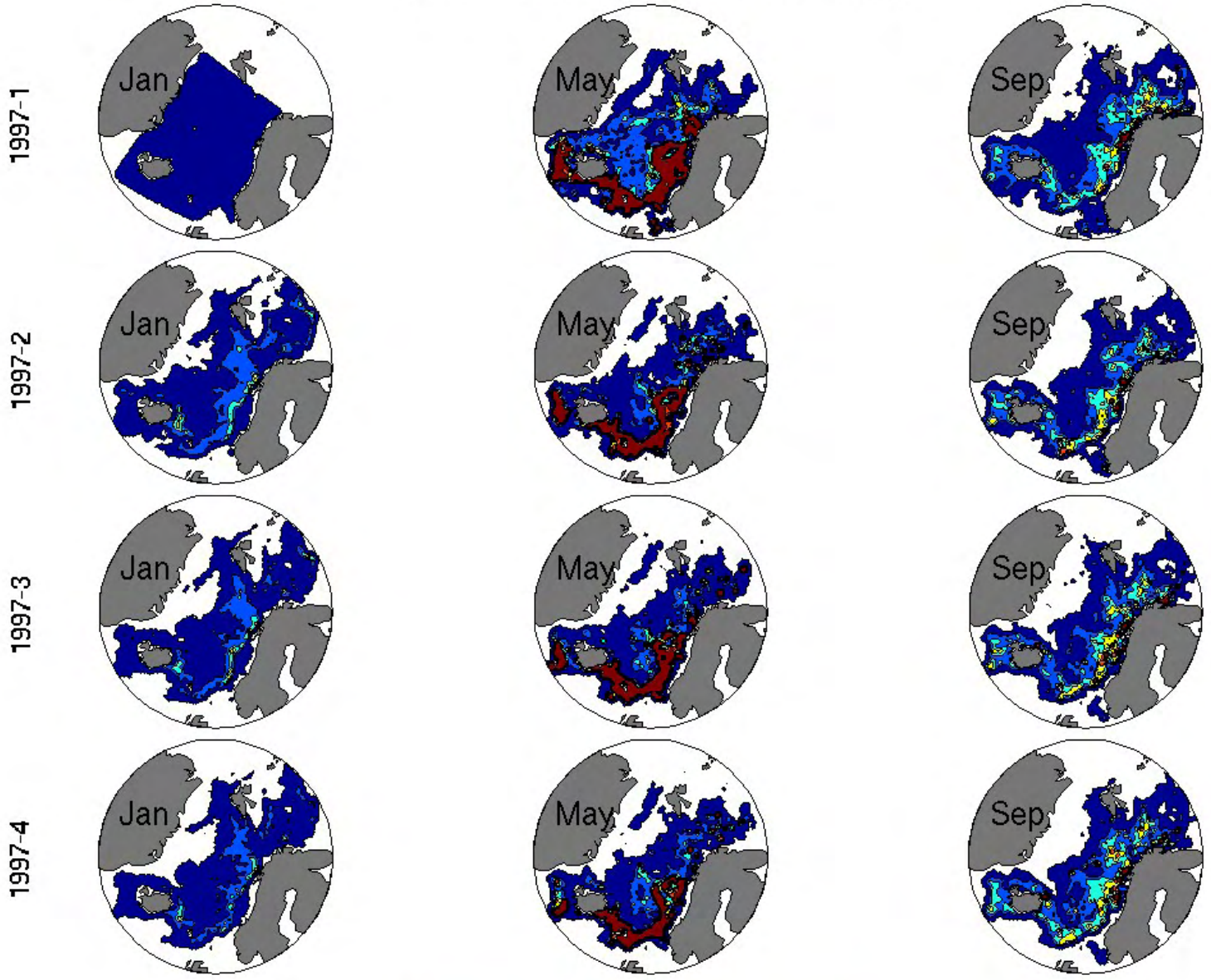
3D S, T, v , u
Ocean circulation model (ROMS)
3D migration
vertical migration
no migration

NORWECOM.E2E spin up over 4 years

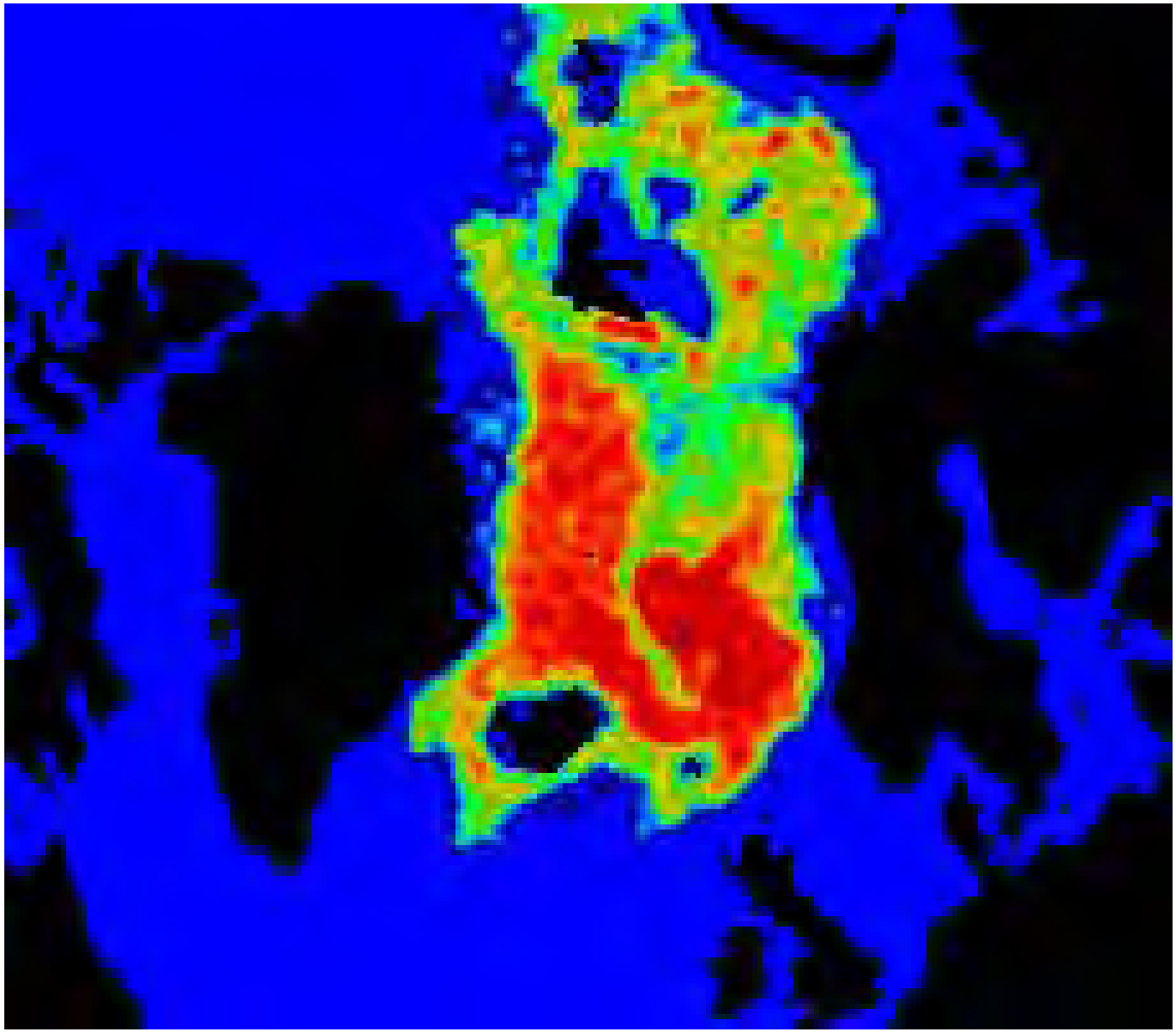


C. finmarchicus copepodite distribution (1000 m^{-2})



Results

Distribution of copepodites over one year from starting conditions



Conclusions

- The simulated population remains viable in the Norwegian Sea basin over hundreds of years
- The model resembles the spatial and population dynamics of *C. finmarchicus* – but more validation is needed and is underway
- The population generally adapts well after about 100 years, but maintains some ”genetic” variability
- Risk averse life histories emerged in the predator rich environment
- The offline *C. finmarchicus* model will be seamlessly coupled to the NORWECOM.E2E in future versions