UNDERSTANDING COPEPOD LIFE-HISTORY AND DIVERSITY USING A NEXT-GENERATION ZOOPLANKTON MODEL

Frédéric Maps
Andrew J Pershing
Nicholas R Record

1865 THE UNIVERSITY OF MAINE
Gulf of Maine Research Institute
NSF

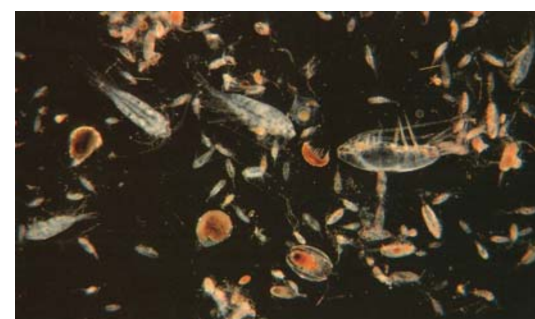
Introduction

> Copepods are especially important at high latitudes

> In the North Atlantic/Arctic, the small and ubiquitous *Pseudocalanus* and the large and often highly specialized *Calanus* genera dominate.

> Why? How? What about environmental changes? What about biodiversity in the wake of EC?

> Help from a new generation of numerical models.



Introduction

- Copepod models seem now as diverse as copepods are, but they all come down to **population** & **individual** based categories

- Improvements and innovation required:

  - **Develop mechanistic models (Predictive)**:
    need to develop functions of physiological processes based on fundamental principles, beyond empirical relationships

  - **Develop models for variable scales**:
    need to develop the ability to transfer information across these scales (IBM <-> Populations <-> Ecosystems)

  - **Develop models embedded in coupled NPZD-GCMs**:
    need to develop numerically “light” models

Mechanistic model

> **Develop mechanistic models:**

> Paradigm change: **mechanistic formulations** add both explanatory and predictability power!

> **Example**: development (stage duration) as f(T)

Belehradek: $D_i = a_i.(T+b)^c$

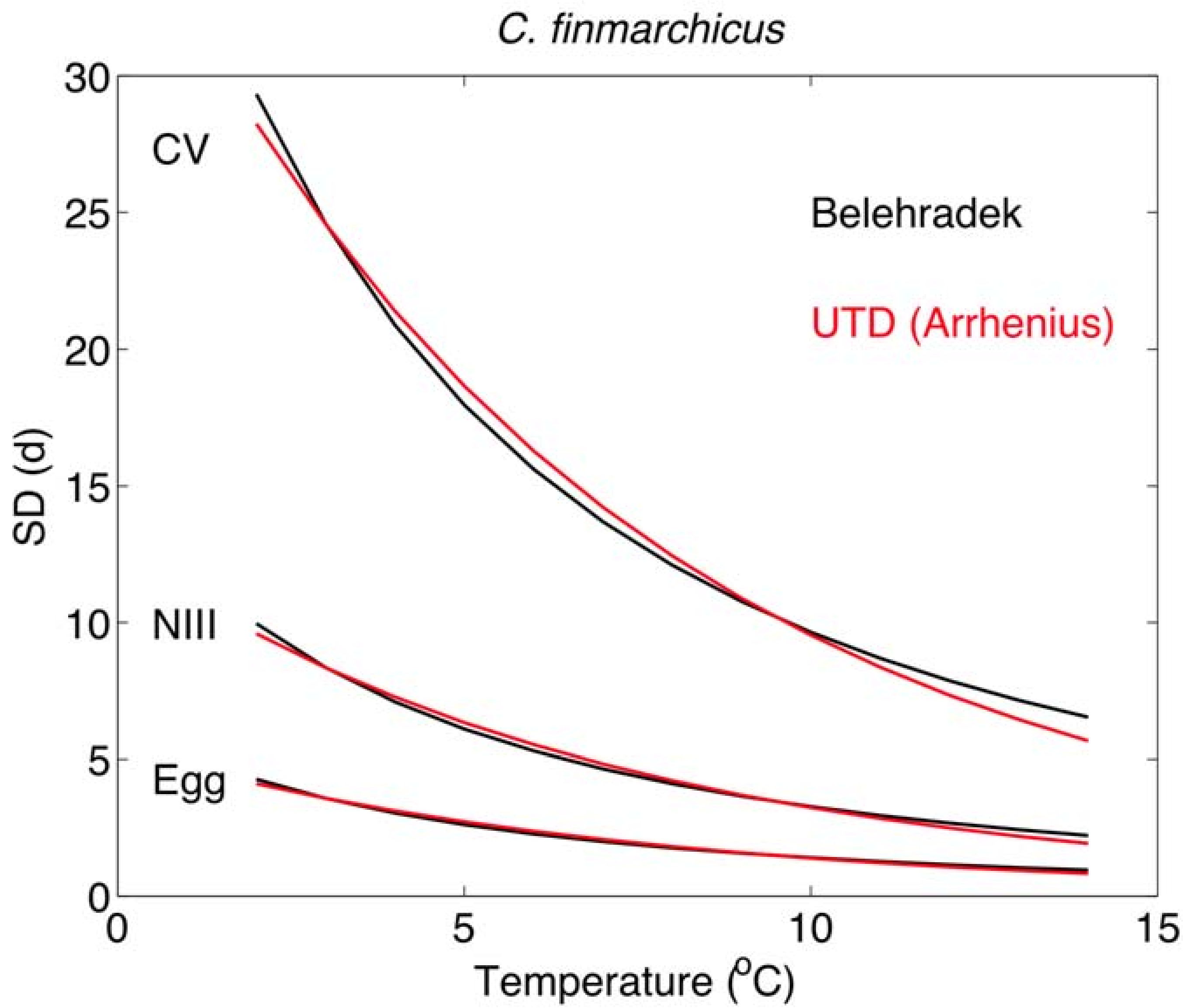
vs.

UTD : $D_i = d_i.\exp(-E.(T-T_0)/k.T.T_0)$

> *Any T dependent process obeys the mechanistic Arrhenius relationship*

UTD = Universal Temperature Dependence ~ Arrhenius, Gillooly et al. 2001

Mechanistic model



Mechanistic model

> **3 fundamental mechanistic formulations** to implement the essential physiological processes of a **compupod**

> **Universal Temperature Dependence** = response to temperature

> **Holling II** = response to food concentration

> **Quarter-power allometric rule** = scaling to body mass

> The physiological processes of a compupod are combinations of those functions

Mechanistic model

> **2 steps in building and validating the model:**

1. Fit the model with a genetic algorithm procedure to the growth trajectories of 4 calanoid species:

Pseudocalanus sp.

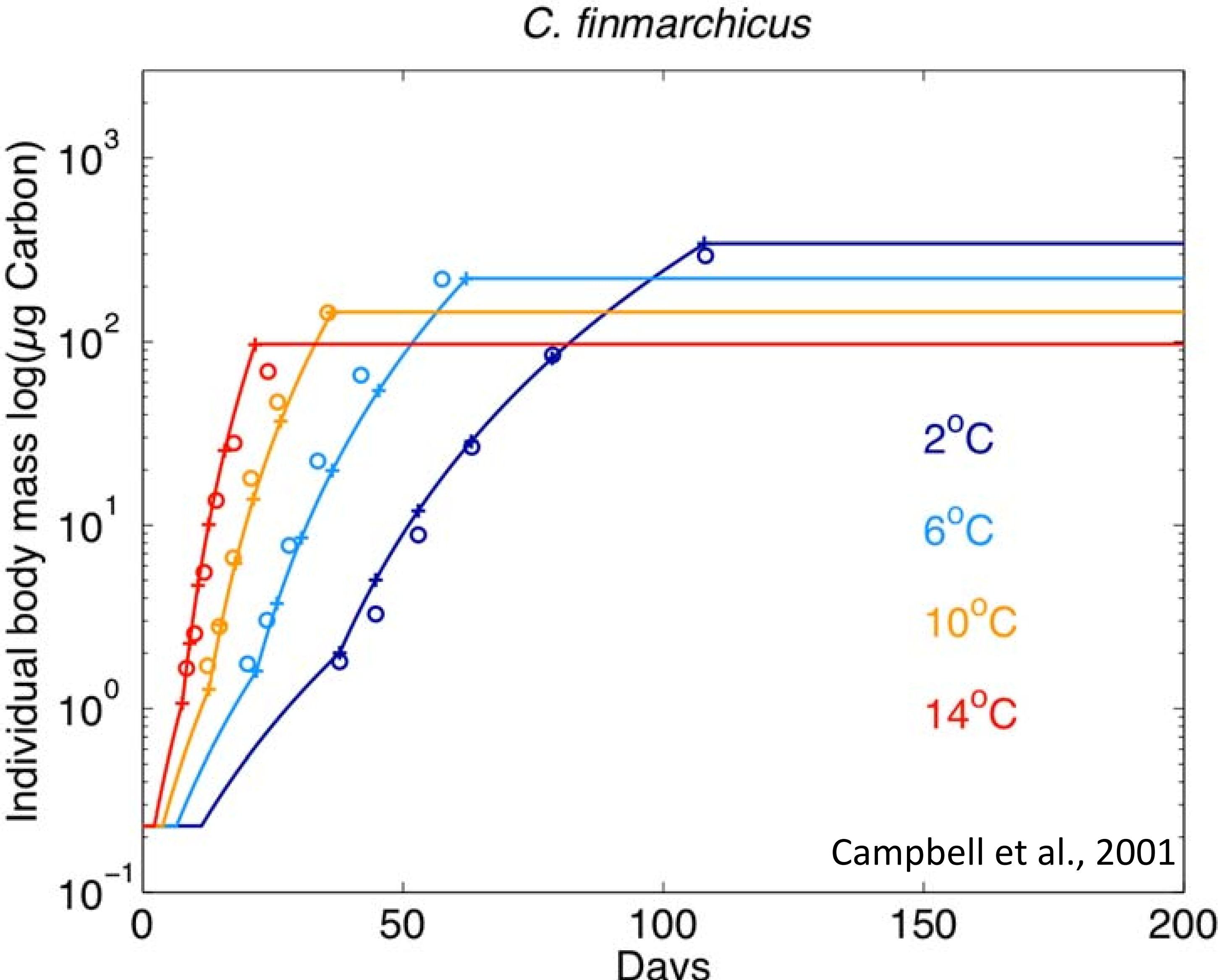
Calanus finmarchicus

C. glacialis

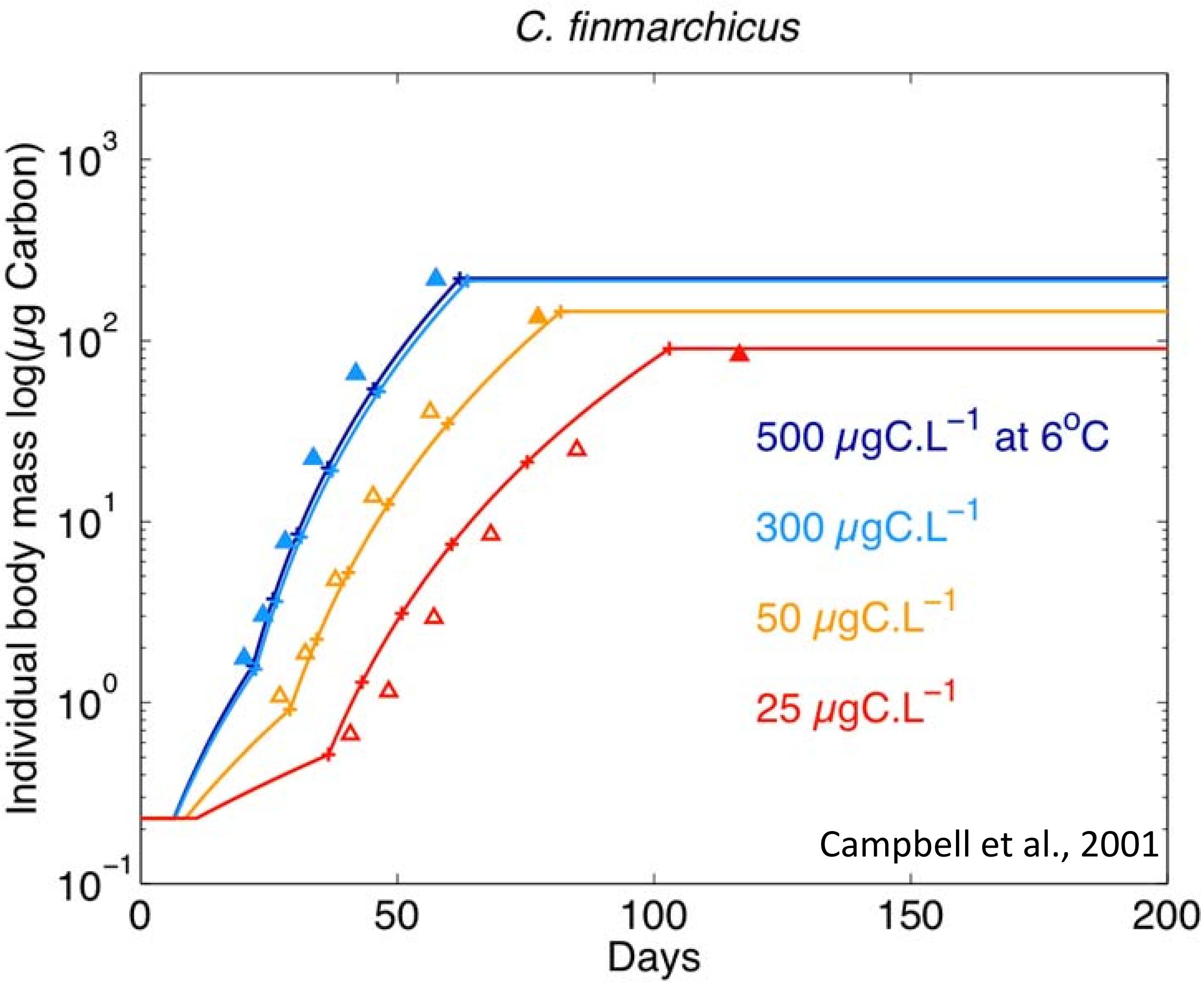
C. hyperboreus

> *Ensures that the mechanistic formulations yield the right functional forms*

Mechanistic model



Mechanistic model



Mechanistic model

> **2 steps in building and validating the model:**

2. Evaluate the physiological processes implemented in the model against other data from literature :

Ingestion rate (IR)

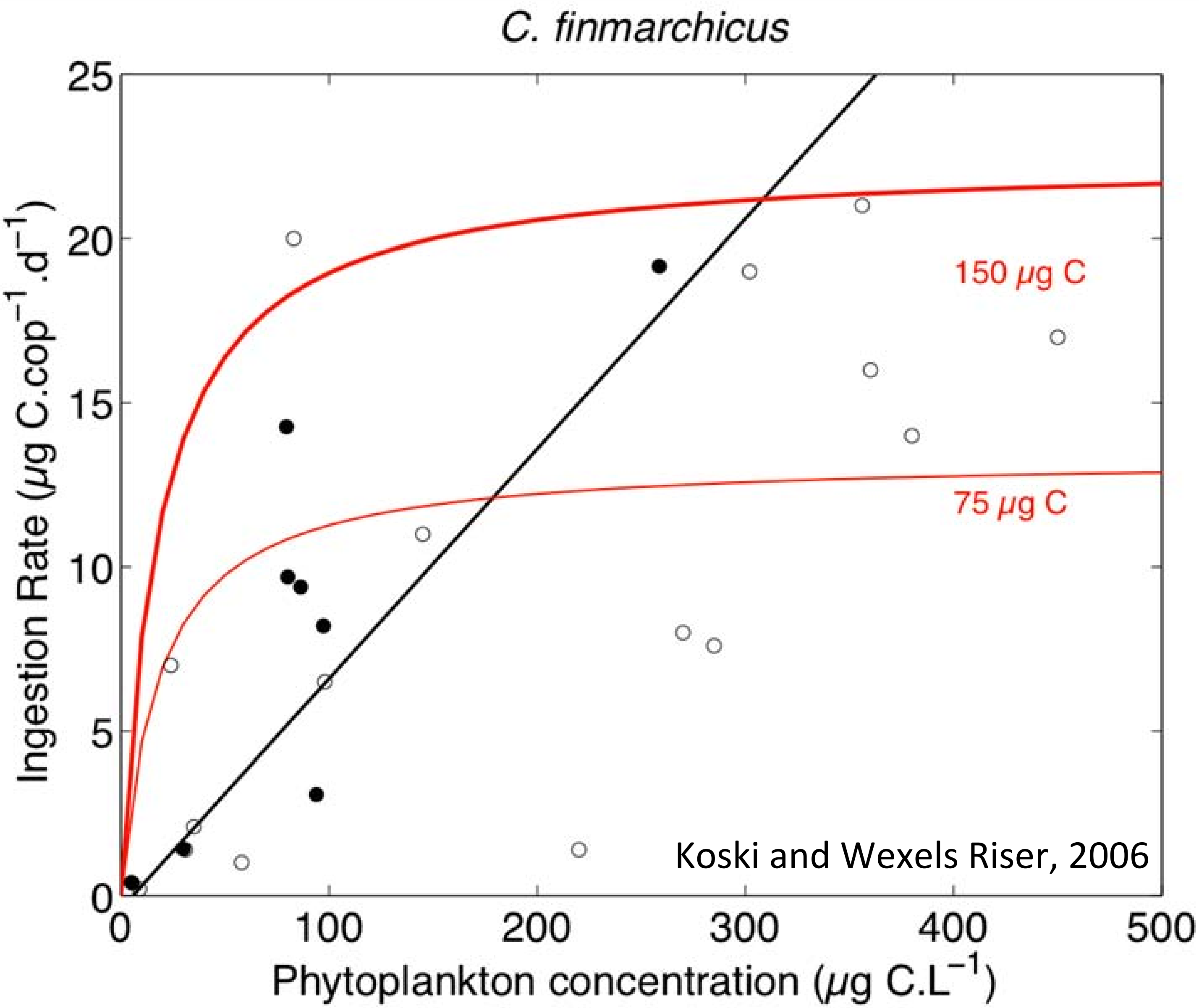
Maximum volume filtered (V)

Handling time^{-1} ~ gut clearance rate (GCR)

Egg production rate (EPR)

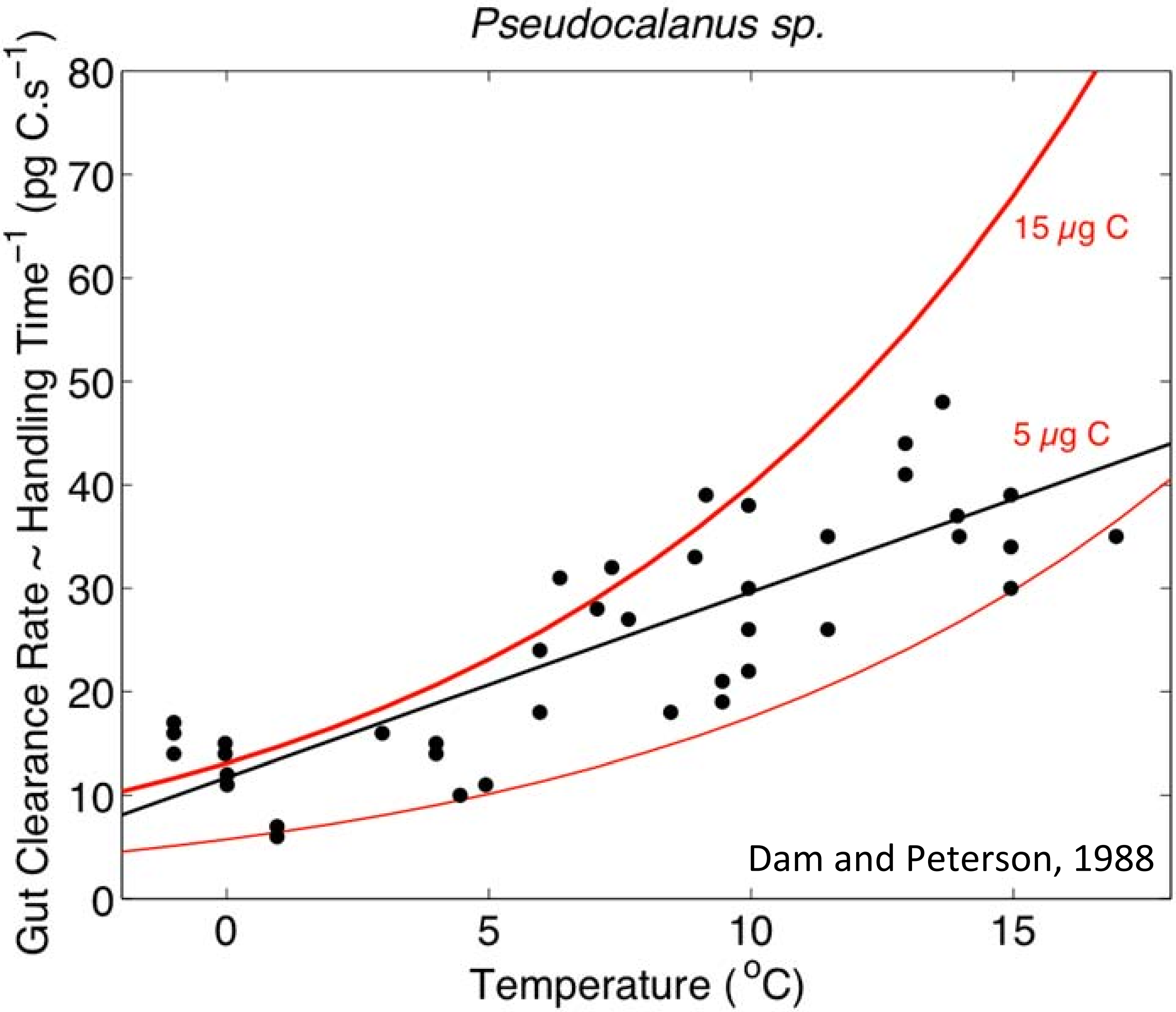
> *Ensures that the mechanistic formulations are right*

Mechanistic model

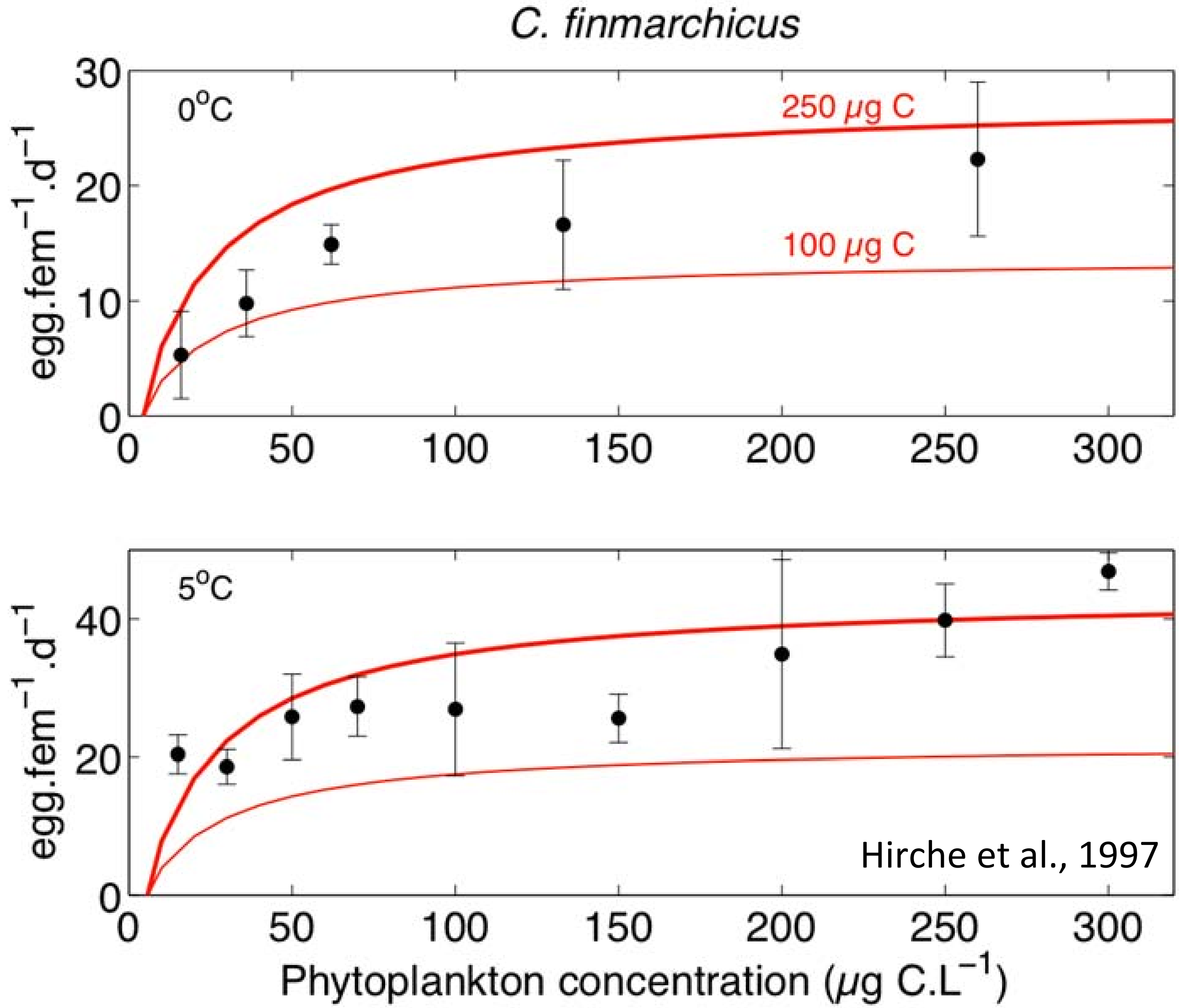


Koski and Wexels Riser, 2006

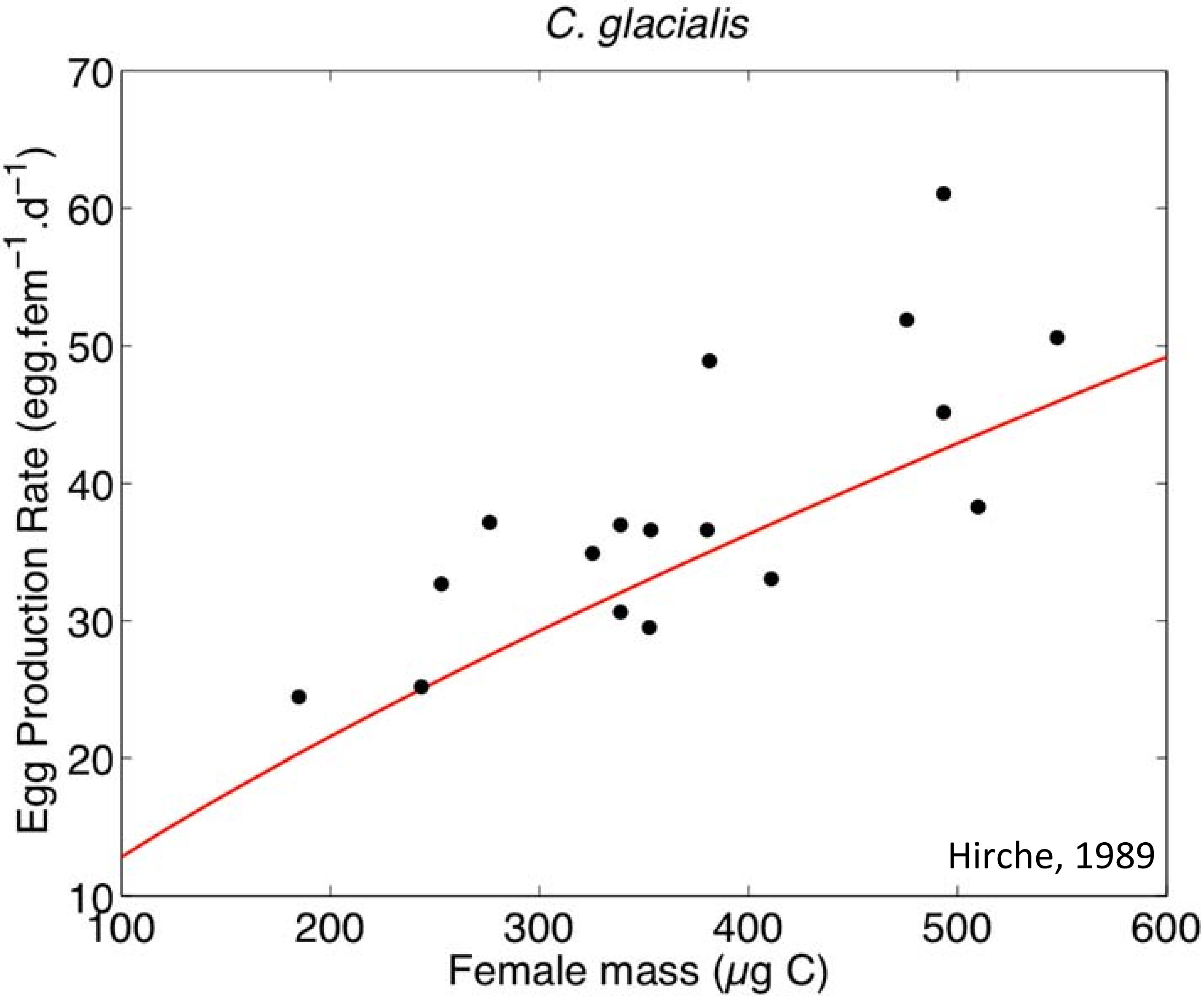
Mechanistic model



Mechanistic model



Mechanistic model

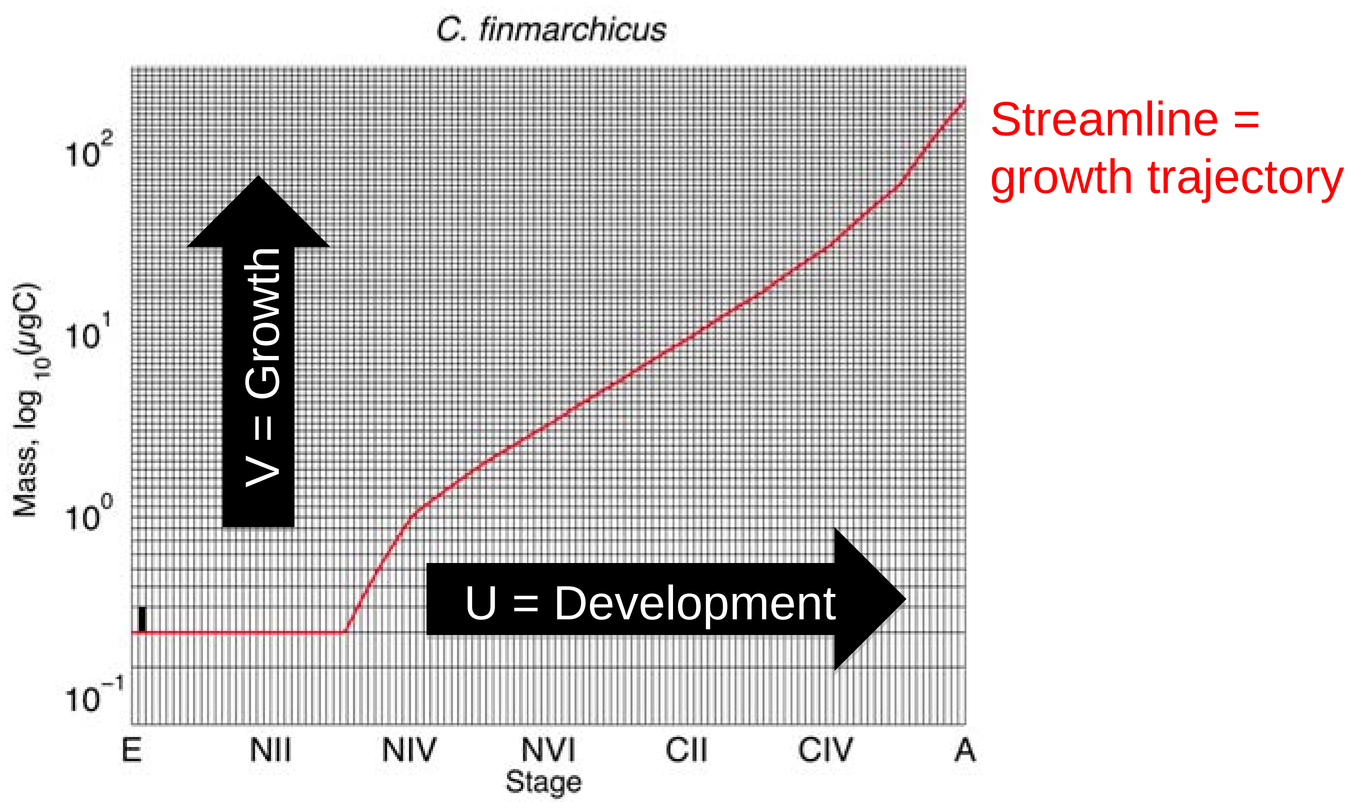


> Develop models integrating various scales

&

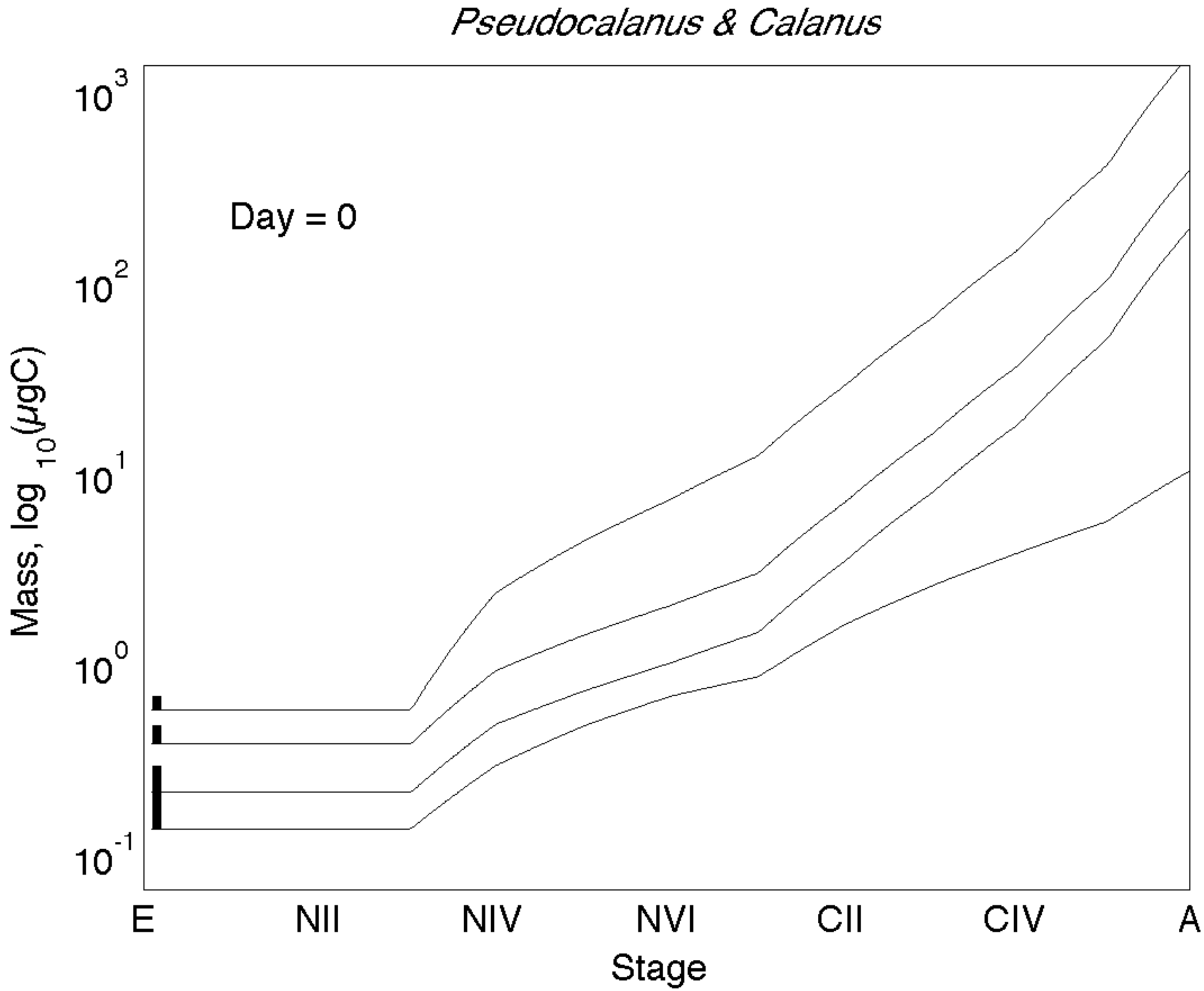
> Develop models coupled to NPZD-GCM:

Physical methods, PDEs in a 2-D stage & mass space



Maps et al., next generation zooplankton model

Integrative & coupled model



Integrative & coupled model

- Trade-off between development and growth:
  Grow FAST or grow BIG?
  - From the model, slow development and large egg mass are enough to make a *hyperboreus* vs a *glacialis*
  - What about *Pseudocalanus* vs *C. finmarchicus?*
  - Loose coupling between development and growth:
    is development allometric, lipids storage?
- Invisible hand of mortality…
  - Interact with critical life-cycle traits. Not just a closing term!
- To explore thoroughly those ecological implication, design numerical selection experiments

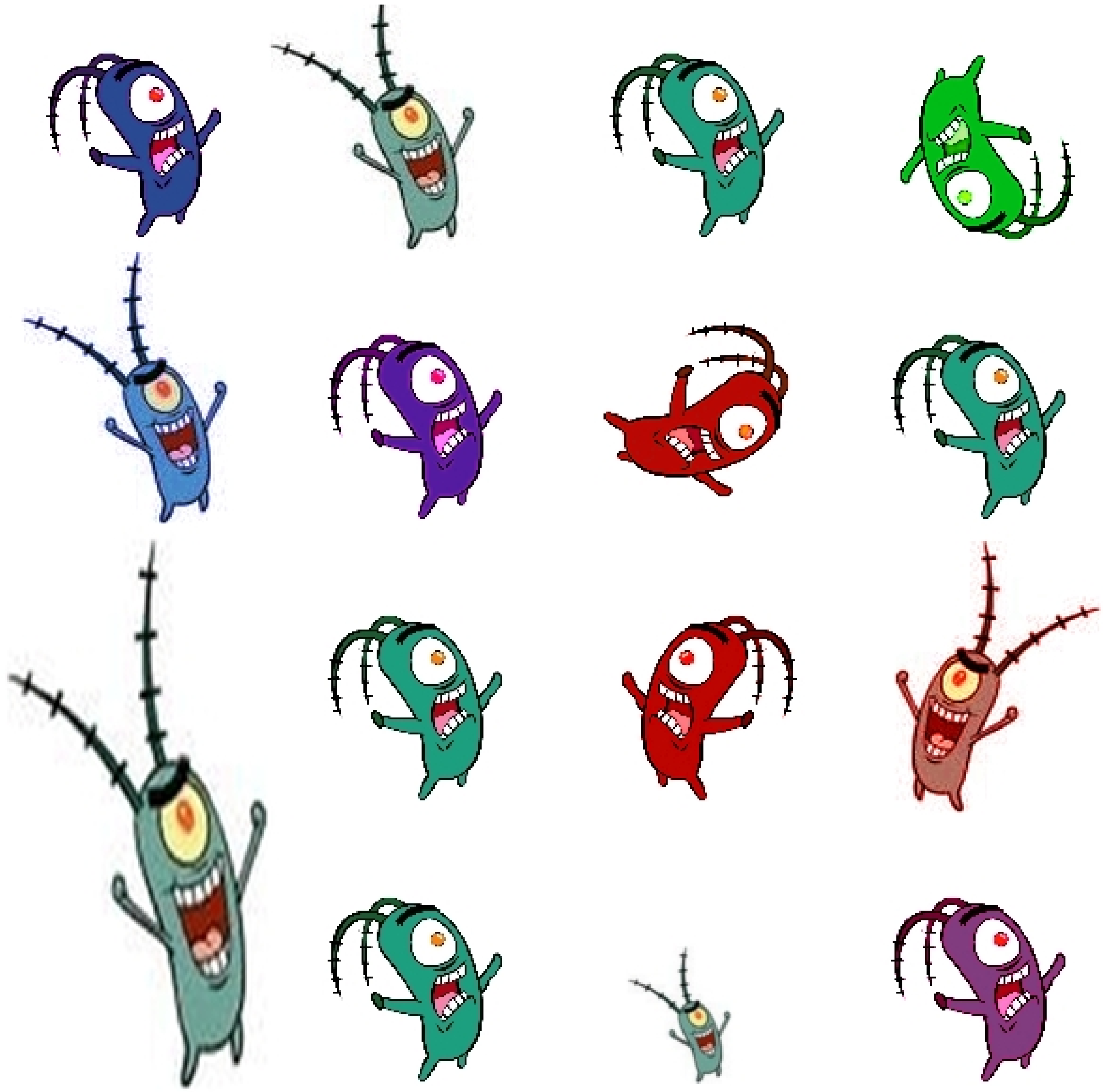
Selection experiments

> Intelligently designed compupod…

> Coupled physical-biological simulations: embedded in ROMS with CoSiNE for NPZD

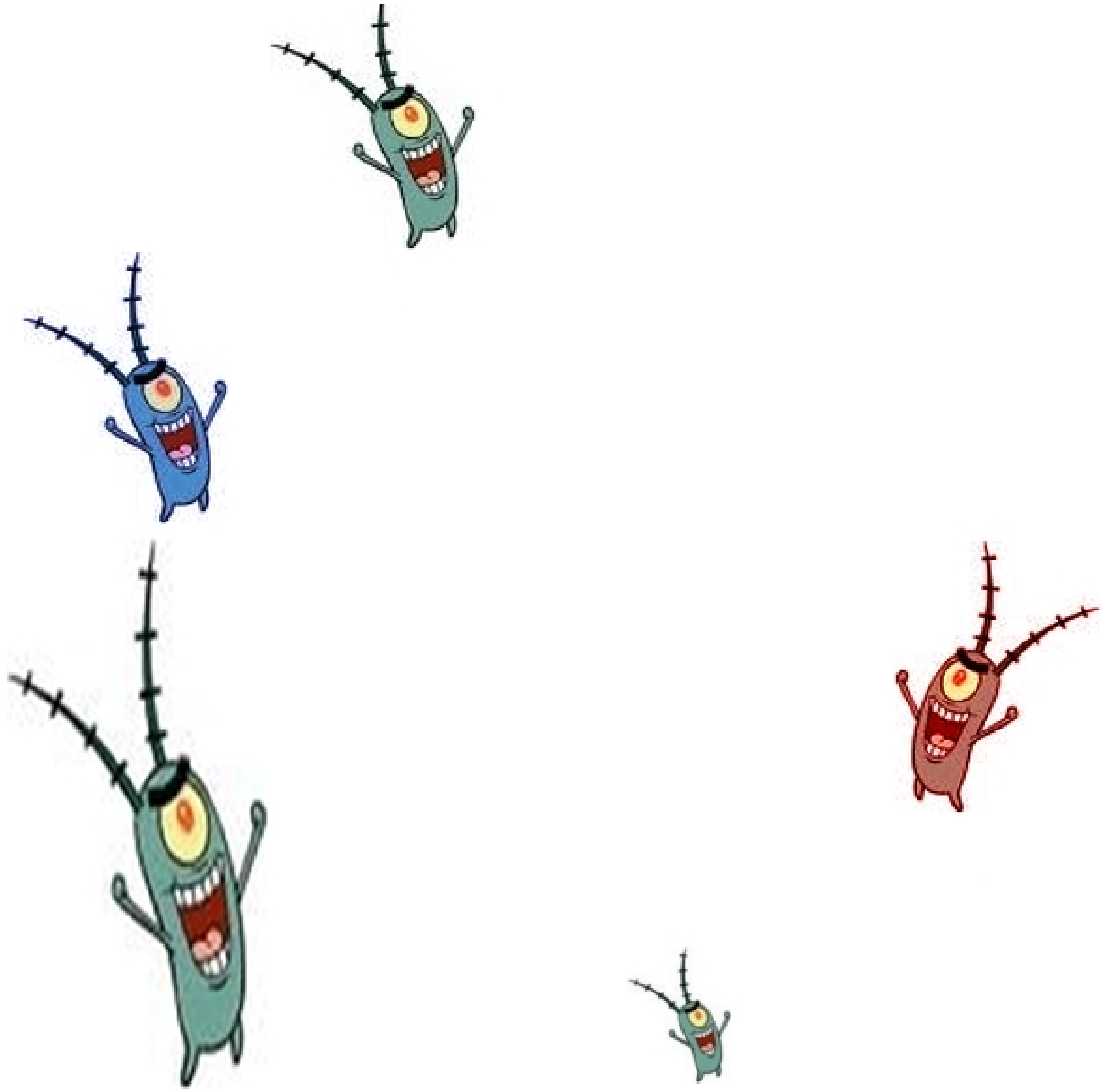
> Use of genetic algorithm (paramosome) to “select” species

> Paramosome



Selection experiments

> Selection by genetic algorithm



Future

- Future directions:
- Based on actual species:
  - Further interpret differences/similarities between species
  - Carefully define life-cycle traits modules (~ group of parameters)
- Numerically:
  - Add dimensions in the PDEs space? (Lipids, C&N…~DEB)
  - Mortality design & effects!
- Selection experiments:
  - Which species thrives where?
  - Implications for a changing ocean…


THANK YOU. GRACIAS.
1865 THE UNIVERSITY OF MAINE
Gulf of Maine Research Institute
NSF