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

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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.
> 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
> 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: \( D_i = d_i \exp\left( -\frac{E(T-T_0)}{kT.T_0} \right) \)

> **Any \( T \) dependent process obeys the mechanistic Arrhenius relationship**

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

SD (d)

Temperature (°C)

CV

Belehradek

UTD (Arrhenius)

NIII

Egg

Maps et al., next generation zooplankton model
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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.
> 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

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Mechanistic model

C. finmarchicus

Individual body mass (μg Carbon)

Days

500 μgC.L\(^{-1}\) at 6°C
300 μgC.L\(^{-1}\)
50 μgC.L\(^{-1}\)
25 μgC.L\(^{-1}\)

Campbell et al., 2001

Maps et al., next generation zooplankton model

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> 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

C. finmarchicus

Ingestion Rate (μg C. cop⁻¹.d⁻¹)

Phytoplankton concentration (μg C.L⁻¹)

150 μg C
75 μg C

Koski and Wexels Riser, 2006
Mechanistic model

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Mechanistic model

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Mechanistic model

Egg Production Rate (egg.fem⁻¹.d⁻¹) vs Female mass (µg C) for C. glacialis

Hirche, 1989

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> Develop models integrating various scales
&
> Develop models coupled to NPZD-GCM:

Physical methods, PDEs in a 2-D stage & mass space
$Pseudocalanus \ & \ Calanus$

Day = 0

Mass, \ \log_{10} (\mu gC)$

E  \ NII  \ NIV  \ NVI  \ CII  \ CIV  \ A

Stage

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> 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
> 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

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> Selection by genetic algorithm

Maps et al., next generation zooplankton model

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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.