How different are *Calanus finmarchicus* and *Calanus helgolandicus* really?

Robert Wilson,
University of Strathclyde
Why care about the differences between *C. finmarchicus* and *C. helgolandicus*?

- *Calanus* copepod species play a vital role transferring biomass from phytoplankton to higher trophic levels
- *C. finmarchicus* dominates the mesoplankton biomass in large parts of the North Atlantic
- However, recent biogeographic shifts are seeing it being replaced by *C. helgolandicus* in certain regions, in particular the North Sea.
- This may have significant ecosystem impacts
- AIM: synthesize differences between each species and produce new models relating development and egg production rate with temperature

Top/bottom: *C. finmarchicus* and *C. helgolandicus* females.
Picture reference: http://www.zooplankton.no/
Biogeographic shifts: climate change implicated. What inter-species differences drive this?

*Calanus finmarchicus*

*Calanus helgolandicus*

(Bonnet *et al.* 2005, surface CVs from CPR)
The North Sea: Changing *Calanus* composition revealed by the Continuous Plankton Recorder
C. finmarchicus and C. helgolandicus: more similar than thought

• Conventional wisdom: C. helgolandicus is smaller and has lower lipid content, a poor replacement for C. finmarchicus

• We performed a quantitative review of the published literature finding fewer inter-species differences than expected

• Evidence is consistent with no interspecies differences in body size and lipid content

• Review of published literature suggests the relationship between development time, ingestion rate and temperature is the only concrete difference between each species
Body Size: no inter-species differences in female prosome length where the species co-exist

Data sources: Jónasdóttir et al. 2005; Jónasdóttir and Koski 2011
Body Size: geographic continuity

Annual average sea surface temperature explains much of the geographic variation in both species’ body size.

Prosome length data compiled from the literature
Published development times: some ambiguities

- Below 10°C, *C. finmarchicus* appears to develop more slowly
- Development time for *C. helgolandicus* are not consistent above 12°C.

Identical dietary regimes in these studies

Are there inter-species difference above 12°C?
A key difference: the response of ingestion rate to temperature

- Moller et al. (2012) estimated the response of ingestion rate to temperature
- Both species exhibit distinct dome-shaped ingestion rate-temperature curves

- Moller et al. used this relationship to model development time, assuming inter-species differences in temperature etc.
- Our review indicates that only differences in ingestion rate should be assumed a priori.
- What is the result?
How much of differences in published development times can be explained by ingestion rates?

- We modelled *C. finmarchicus* and *C. helgolandicus* development time assuming that the only inter-species difference is the response of ingestion rate to temperature.
- Growth was modelled as follows

\[
\frac{dw}{dt} = i(T)AE\mu w^{0.75} - Q10^{T/10}\lambda w^{0.75}
\]

- where
- \(w\) - carbon weight
- \(i(T)\) the response of ingestion rate to temperature, scaled to 1
- \(AE\) – assimilation efficiency
- \(\mu\) - maximum ingestion rate for a given body size
- \(Q10\) – increase in respiration rate for 10 C increase in temperature
- \(\lambda\) – respiration rate at 0 C.
- Development terminates when an individual reaches a terminal body size, determined from the literature.

Model was parameterised using *C. finmarchicus* development times from Campbell et al. 2001
Both species show U-shaped development time-temperature relationships.
Inter-species differences are reasonably consistent with species’ ranges.
Model results indicate that Bonnet et al. (2009) is an anomalous result for C. helgolandicus.
A new egg production rate model

- Assumption: production of egg carbon assumed to be equivalent to carbon growth
- Both species show dome-shaped responses
- Model very successfully reproduces the egg production rate from only existing experimental study of *C. finmarchicus*
- Dome-shaped responses are common in zooplankton. Evidence required for *C. finmarchicus* and *C. helgolandicus*
Conclusions

- Development time and egg production rate probably do not decrease and increase monotonically respectively with temperature, as is commonly assumed.

- The only known difference between *C. finmarchicus* and *C. helgolandicus* is the response of ingestion rate with temperature.

- This response may play a key role in influencing their geographic distributions.

- Further experimental work is required to confirm the precise form of the relationship between development, egg production and temperature. We could be proved wrong!
Thank you!

Acknowledgements to the Marine Alliance for Science and Technology Scotland and the University of Strathclyde for funding this work. Thanks to my supervisors Dr. Douglas Speirs and Prof. Mike Heath