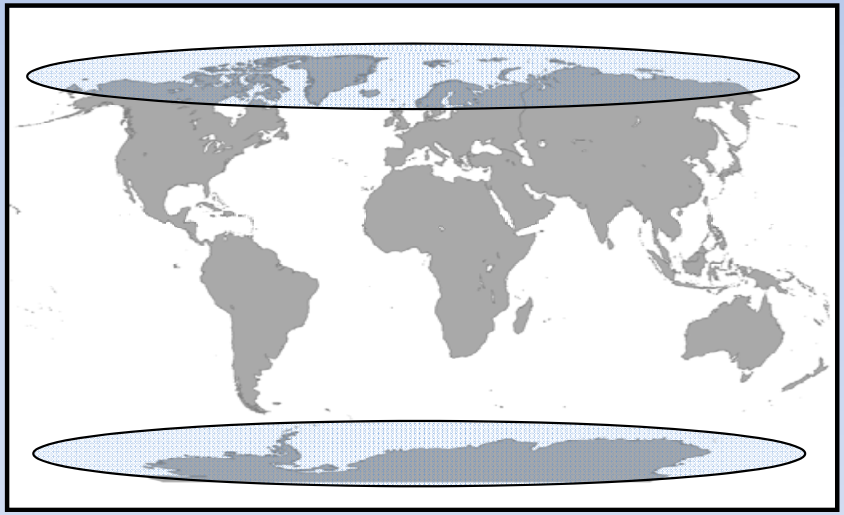
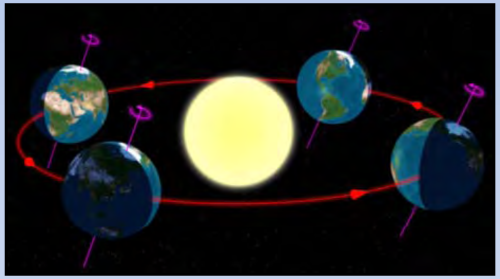
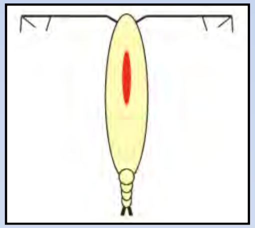
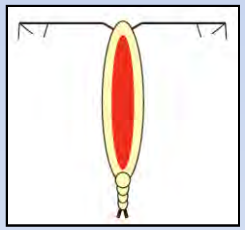
Adaptations to seasonality and the annual routine perspective for zooplankton

Øystein Varpe
Norwegian Polar Institute







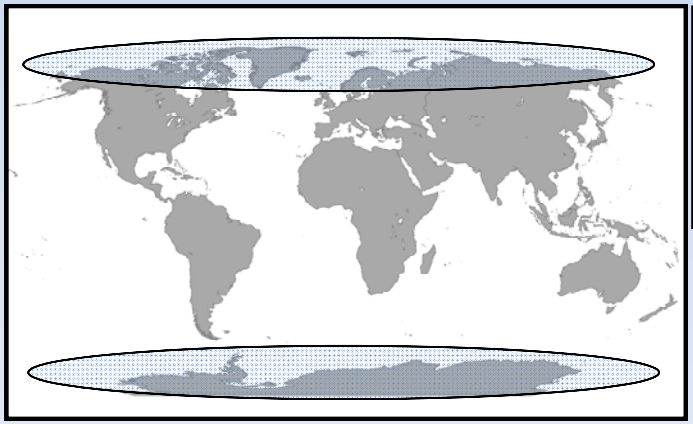


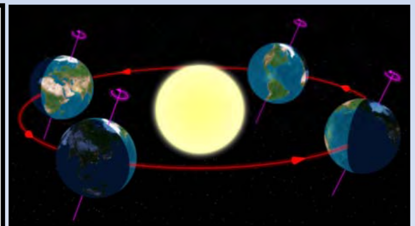
CENTRE FOR ICE, CLIMATE AND ECOSYSTEMS

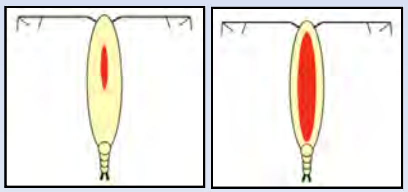
14 March 2011, Pucon
5th International Zooplankton Production Symposium

CONTENT

- Polar environments
- Zooplankton adaptations
- Annual routines
  - Temporal trade-offs
  - Models of *optimal* annual routines
  - State-dependence
  - Environmental change and predicitve power
- Examples from field studies





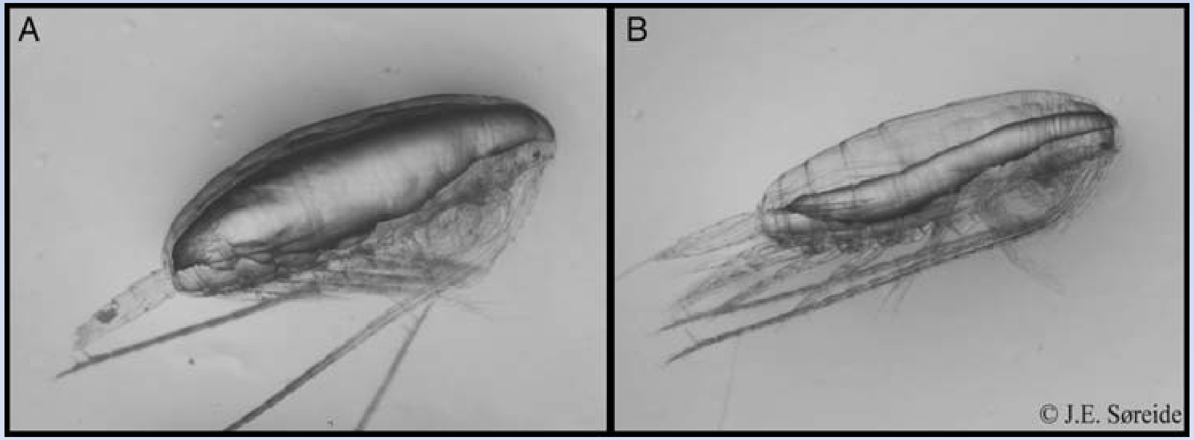



Great to be among
zooplankton enthusiasts

Copepodology for ornithologists

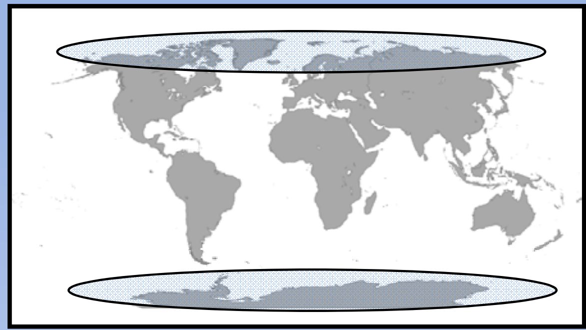
Hutchinson, G. E. 1951. Copepodology for the ornithologist. Ecology 32: 571-577.

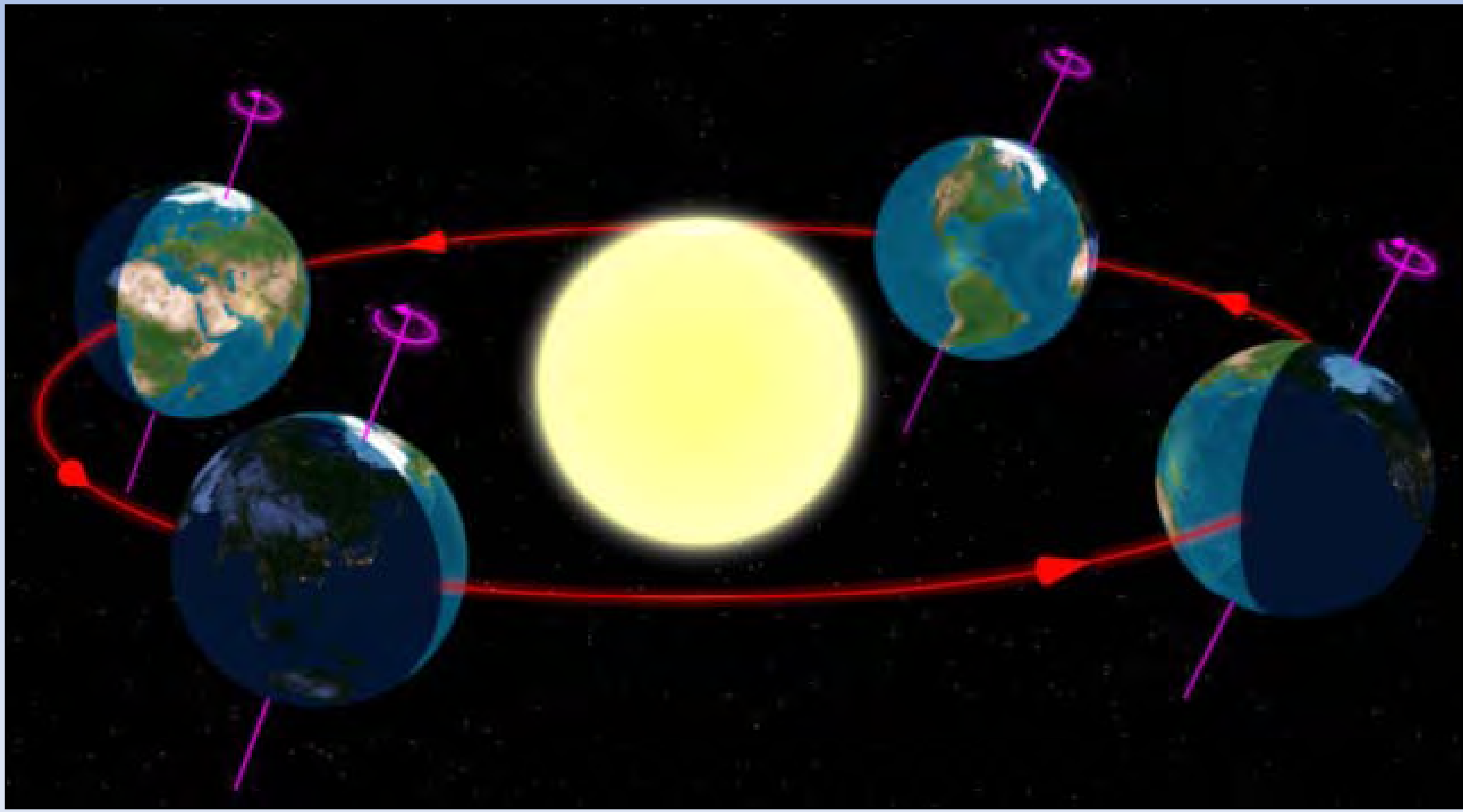
Our zooplankton work may have considerable value also for ecology and evolutionary theory in general.



Photos from Vogedes et al. 2010

Polar environments and seasonal cycling

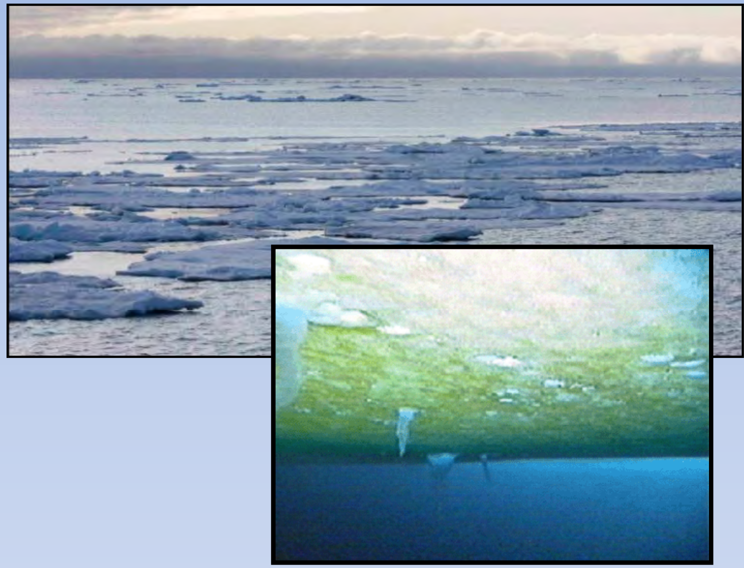




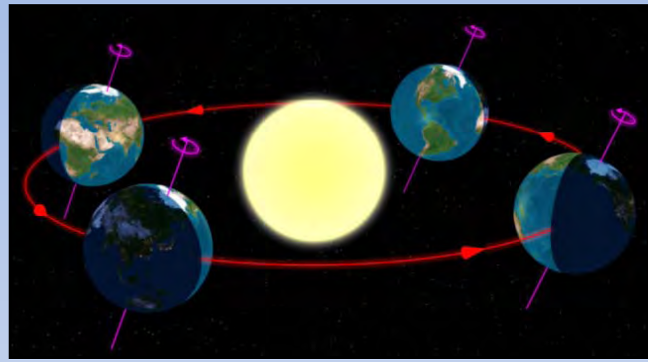
Polar biomes and the zooplankton environment

Low temperatures

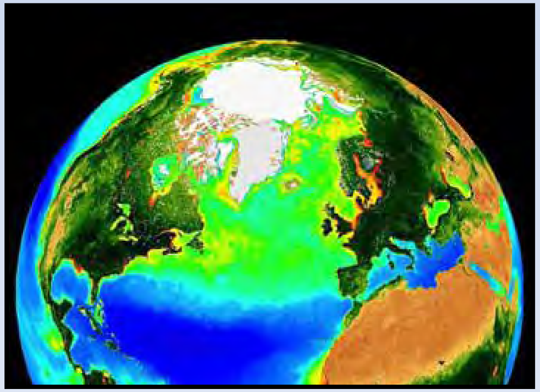
Sea Ice



Extreme cycling in light



Short blooms



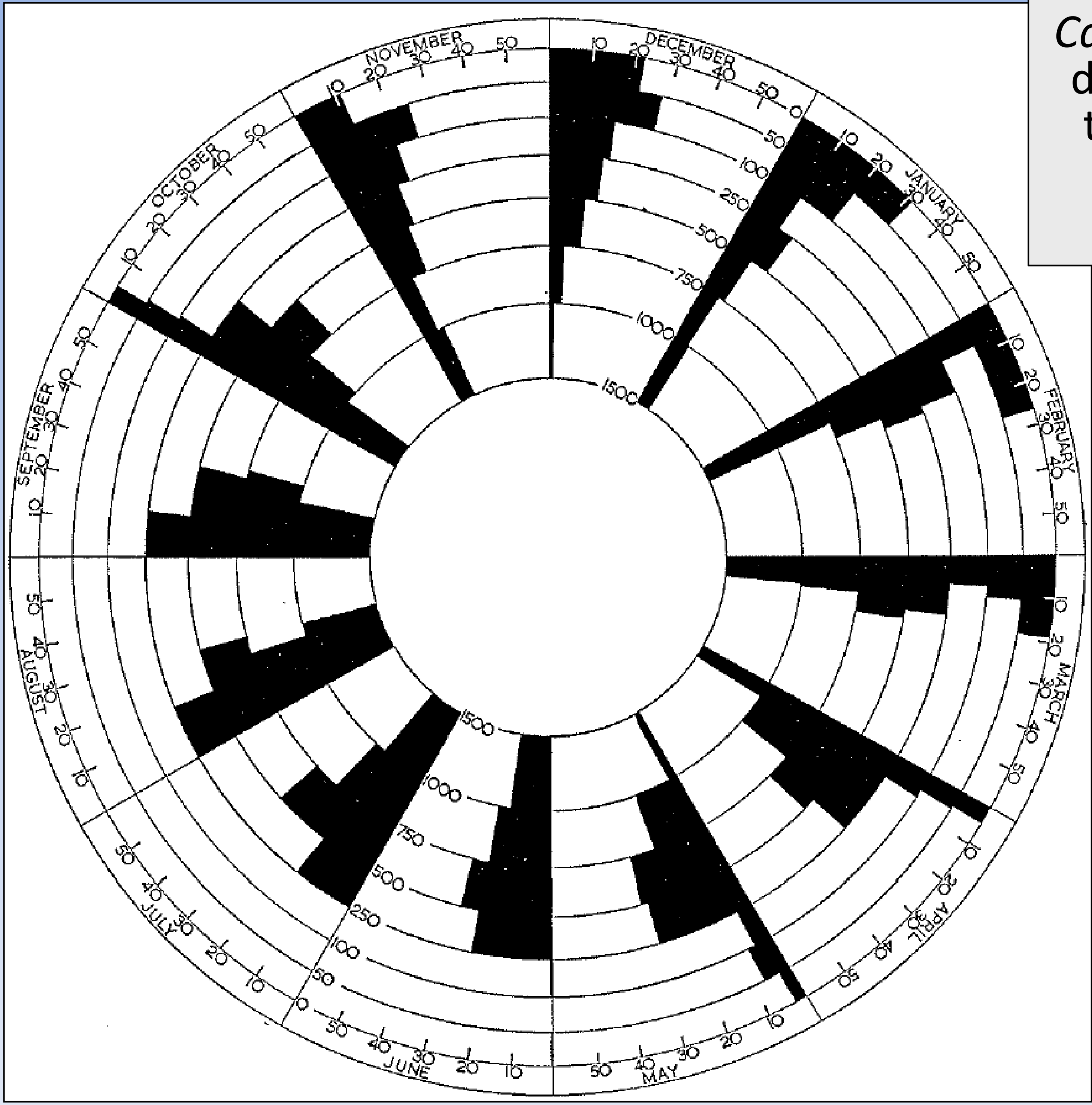
Predators – seasonal presence

Zooplankton adaptations to polar conditions

- Seasonal migrations

Calanoides acutus – depth distribution through the year

Andrews 1966

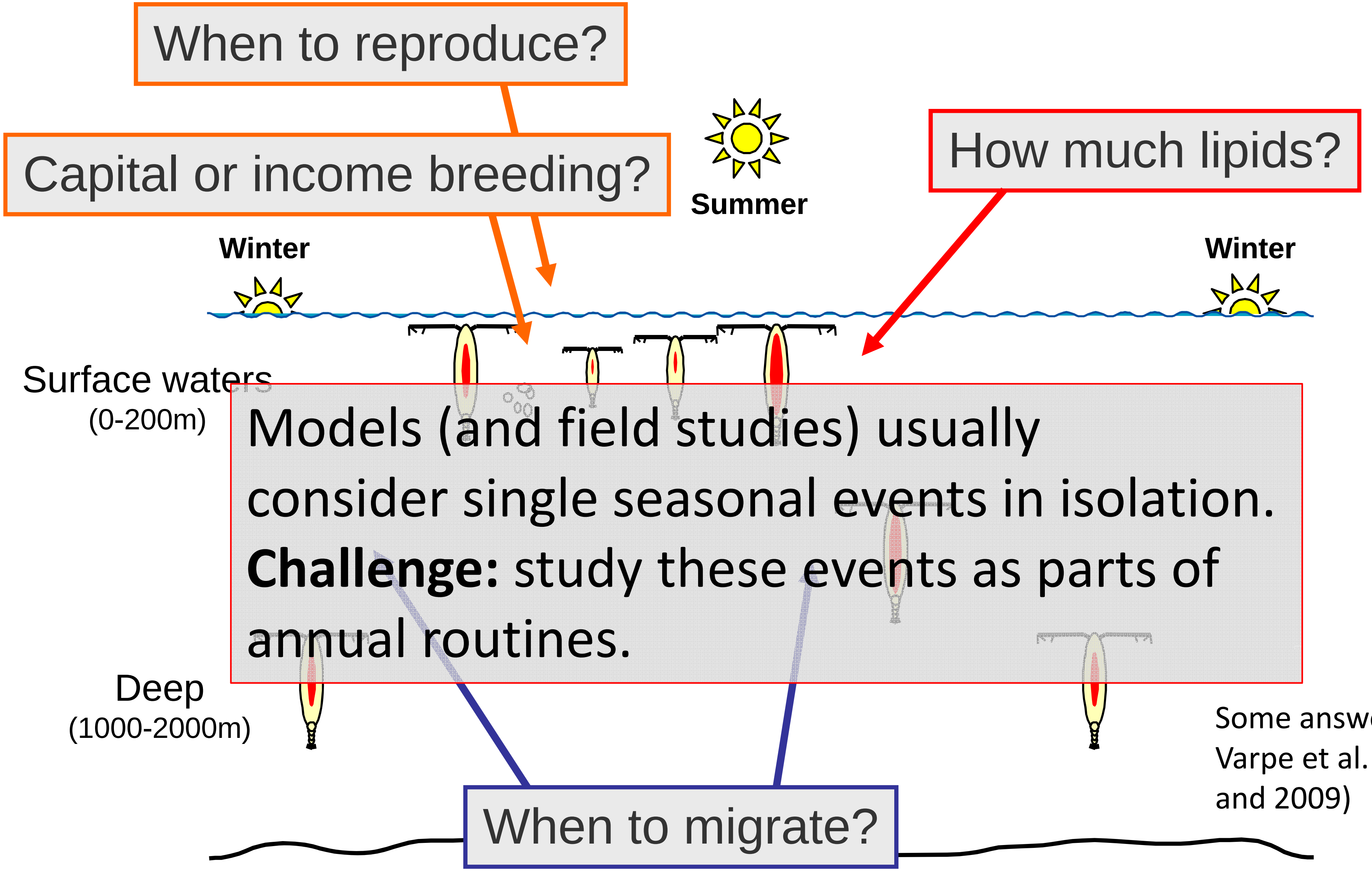


Zooplankton adaptations to polar conditions

- Seasonal migrations
- Dormancy
- Energy reserves
- Large size, slow growth, low metabolism (McLaren 1966)
- Use of sea ice and ice algae

From
Saito and Tsuda
2000

Annual routine:
schedule of activities over the year

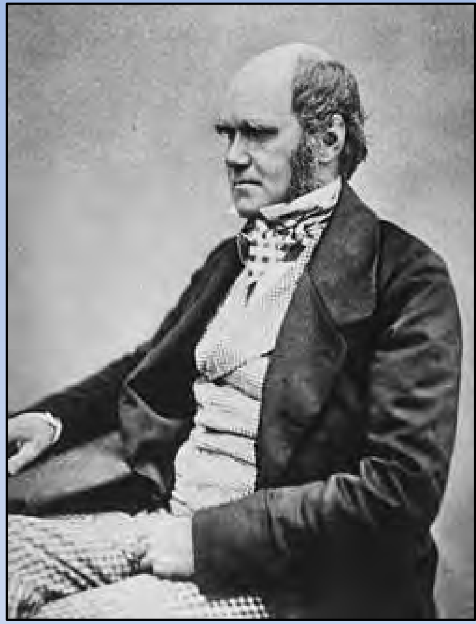


Models (and field studies) usually consider single seasonal events in isolation. **Challenge:** study these events as parts of annual routines.

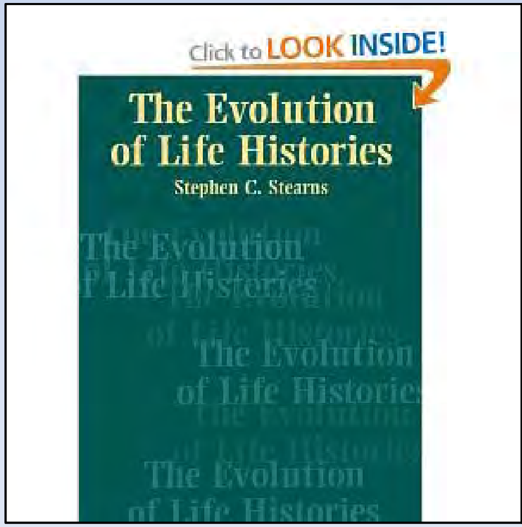
Some answers by Varpe et al. (2007 and 2009)

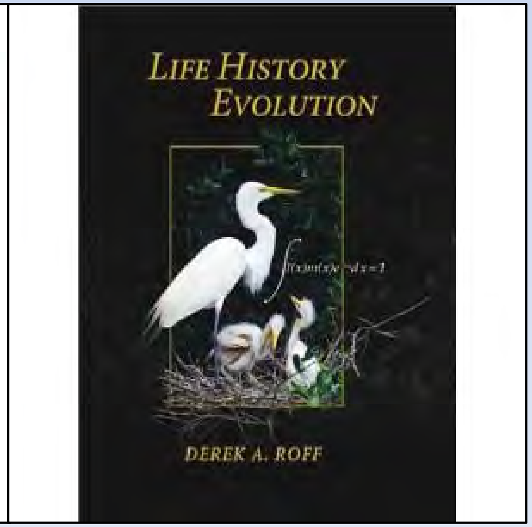
Annual routine:
schedule of activities or events over the year

Product of **evolution by natural selection**



Life history theory is our basis for explaining the routines





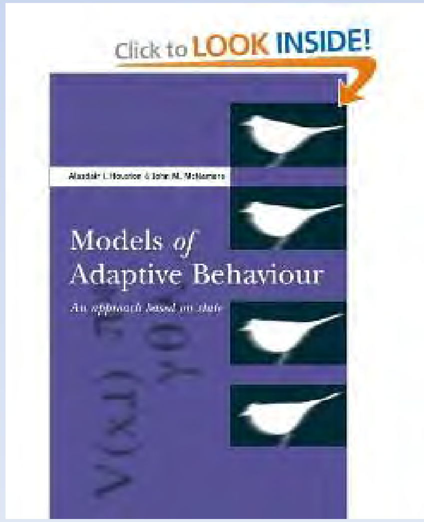
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Phil. Trans. R. Soc. B (2008) **363**, 301–319
doi:10.1098/rstb.2007.2141
Published online 2 August 2007

Optimal annual routines: behaviour in the context of physiology and ecology

Models:

- Include **temporal trade-offs** between fintess components.
- Trade-offs mediated by physiological **states** (e.g. lipid reserves).
- Predictions based on **long term fitenss considerations**.
- Example: Migration, reprodcution and moulting in birds

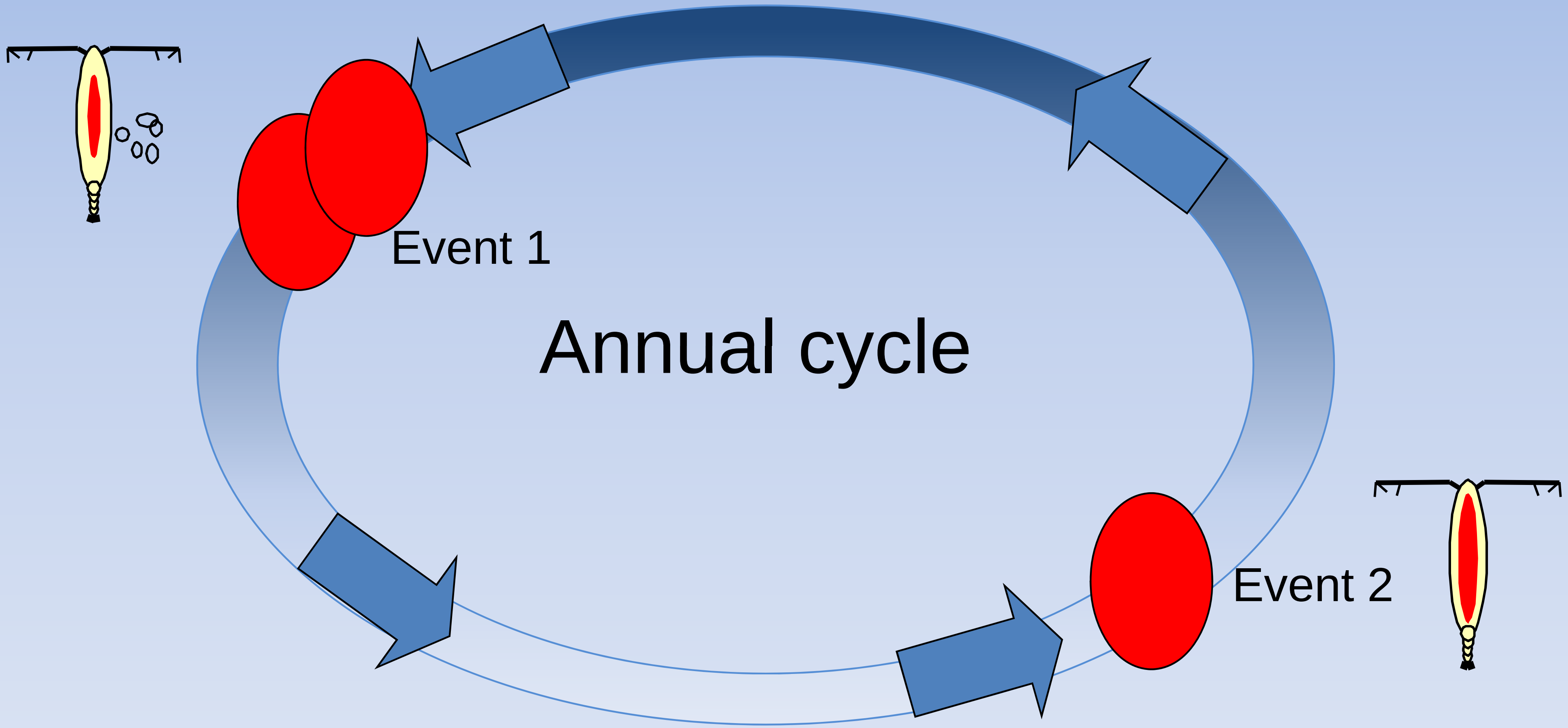


Reading

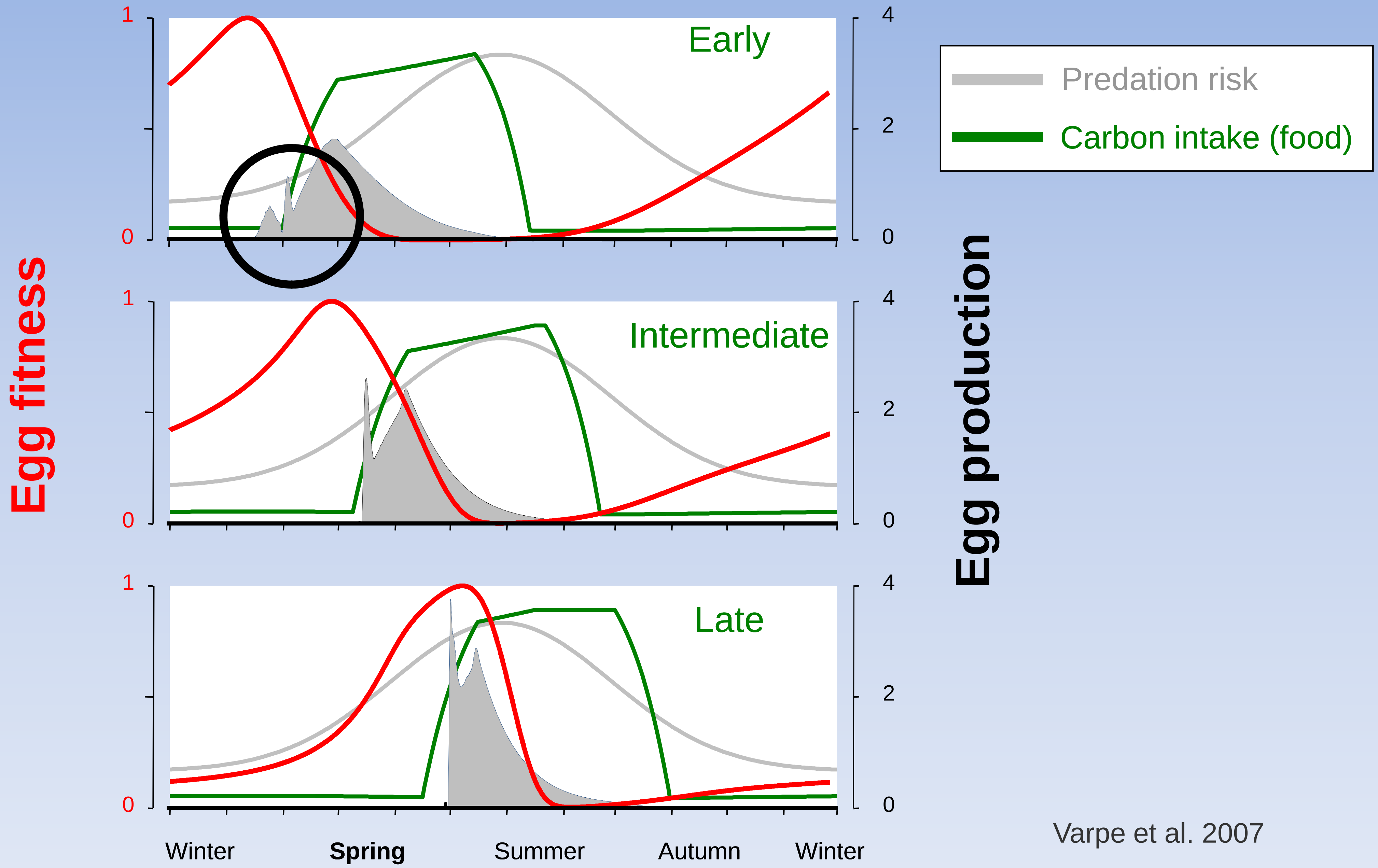
McNamara & Houston (2008)

Fero et al. (2008)

Environmental change, phenology and temporal trade-offs

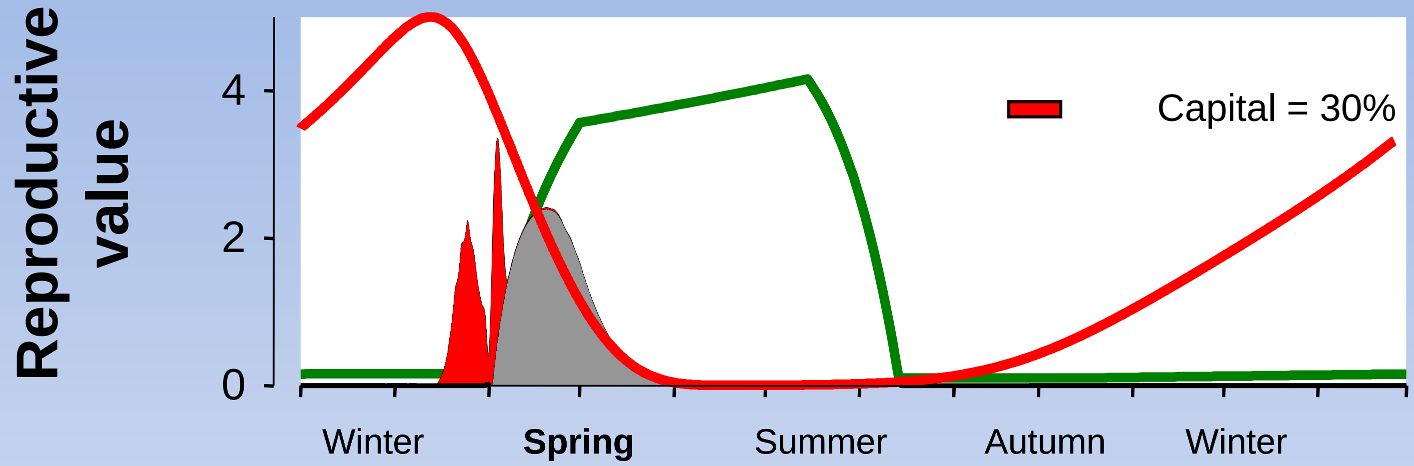


When to reproduce?



Varpe et al. 2007

Capital and income breeding



Varpe et al. 2009

Earlier feeding season:

- More capital breeding

Accompanying life history change:

- More energy storage before descent.

- For late eggs: first reproduction as 2-year-olds.

A MODEL OF OPTIMAL LIFE HISTORY AND DIEL VERTICAL MIGRATION IN *CALANUS FINMARCHICUS*

ØYVIND FIKSEN & FRANÇOIS CARLOTTI

SARSIA

FIKSEN, ØYVIND & FRANÇOIS CARLOTTI 1998 06 02. A model of optimal life history and diel vertical migration in *Calanus finmarchicus*. – *Sarsia* 83:129-147. Bergen. ISSN 0036-4827.

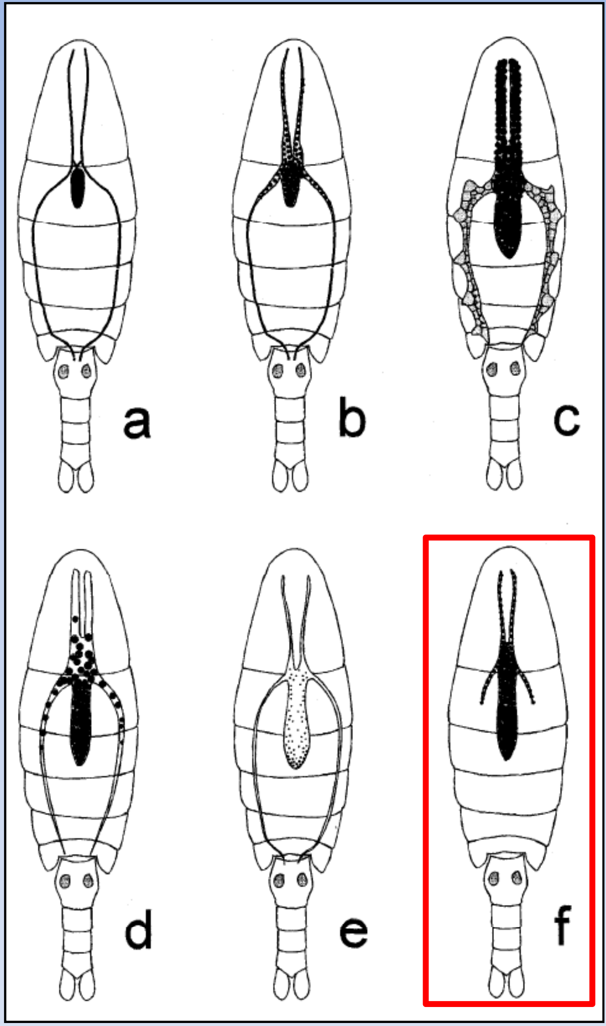
ICES Journal of Marine Science, 57: 1825–1833. 2000
doi:10.1006/jmsc.2000.0976, available online at http://www.idealibrary.com on IDEAL®

The adaptive timing of diapause – a search for evolutionarily robust strategies in *Calanus finmarchicus*

Ø. Fiksen

- Strategies **emerge**. Not predefined by modeller.
- Strategies depend on **state** (the conditon of the individual).

Case 1: Measuring state, for instance **gonad maturation**



f) rematuring

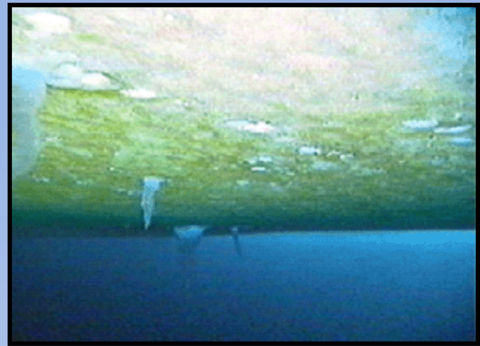
- Kosobokova 1991. *Calanus glacialis* in the White Sea.

Iteroparity:

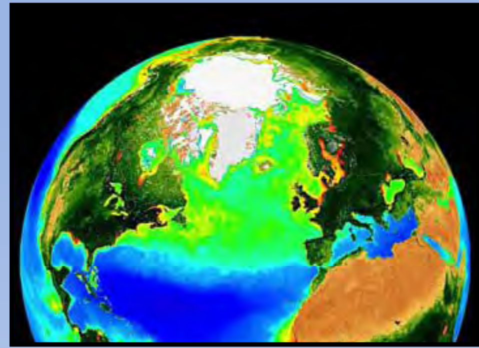
- Several breeding seasons for the same individual.
- Consequences for the optimal annual routine.
- Contrast with species know to be semelparous, e. g *Neocalanus spp.* (Miller et al. 1984)

Case 2: Zooplankton and **sea ice**

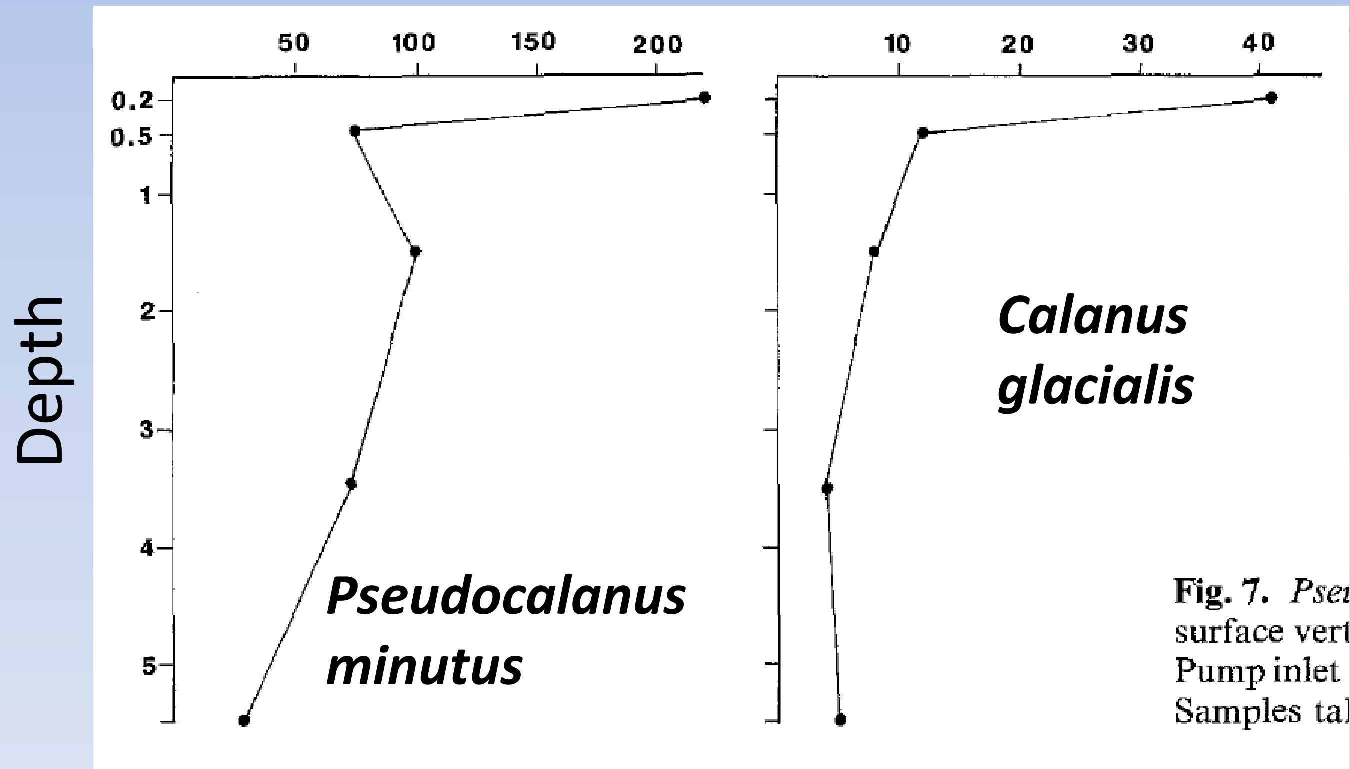
Zooplankton



Ice algae



Phytoplankton



Runge and Ingram 1991

<u>Also:</u>
- Antarctic krill

Ice algae: *regular and principal source of nutrition*

Global Change Biology

Global Change Biology (2011) 17, 1733–1739, doi: 10.1111/j.1365-2486.2010.02312.x

Are phytoplankton blooms occurring earlier in the Arctic?

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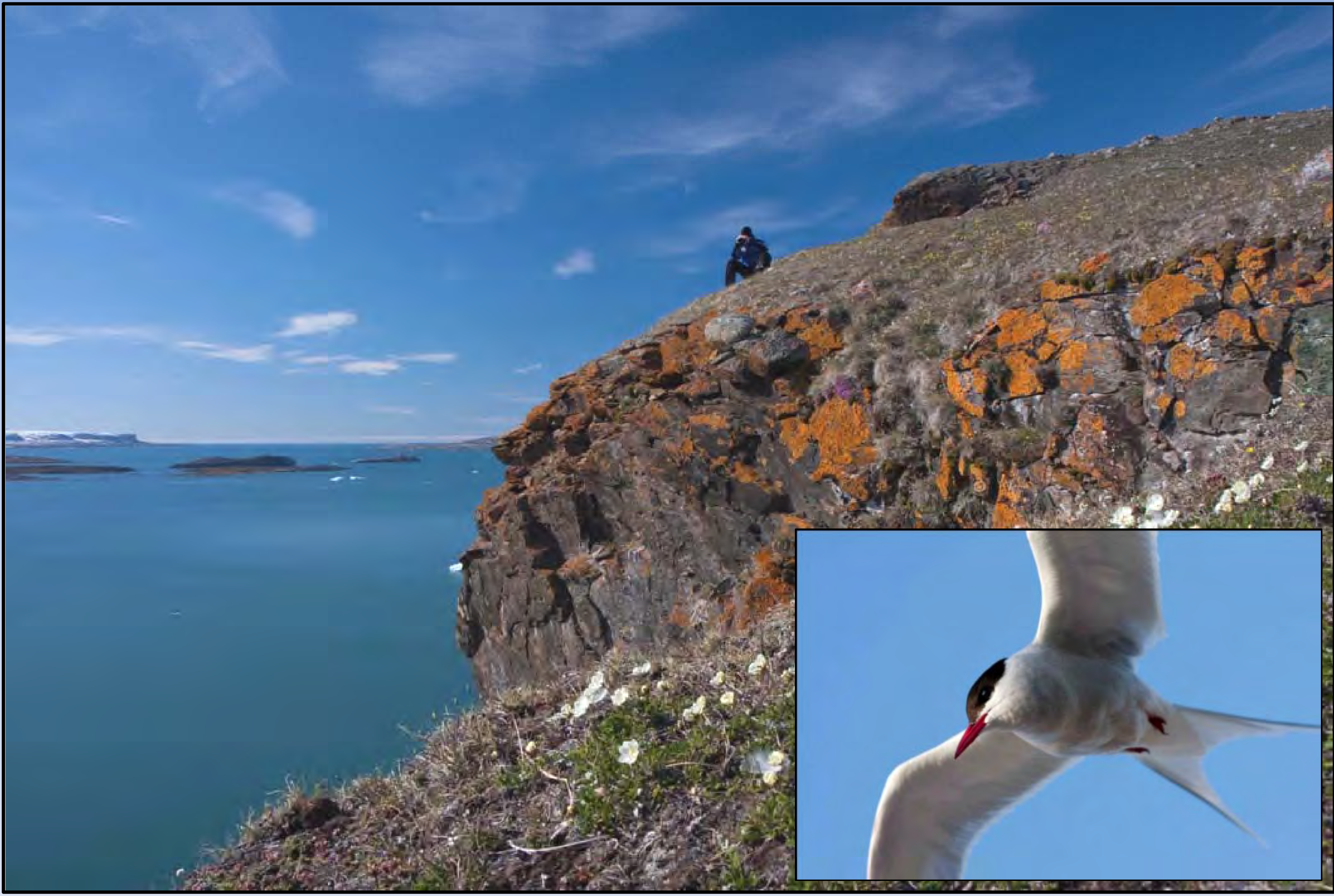
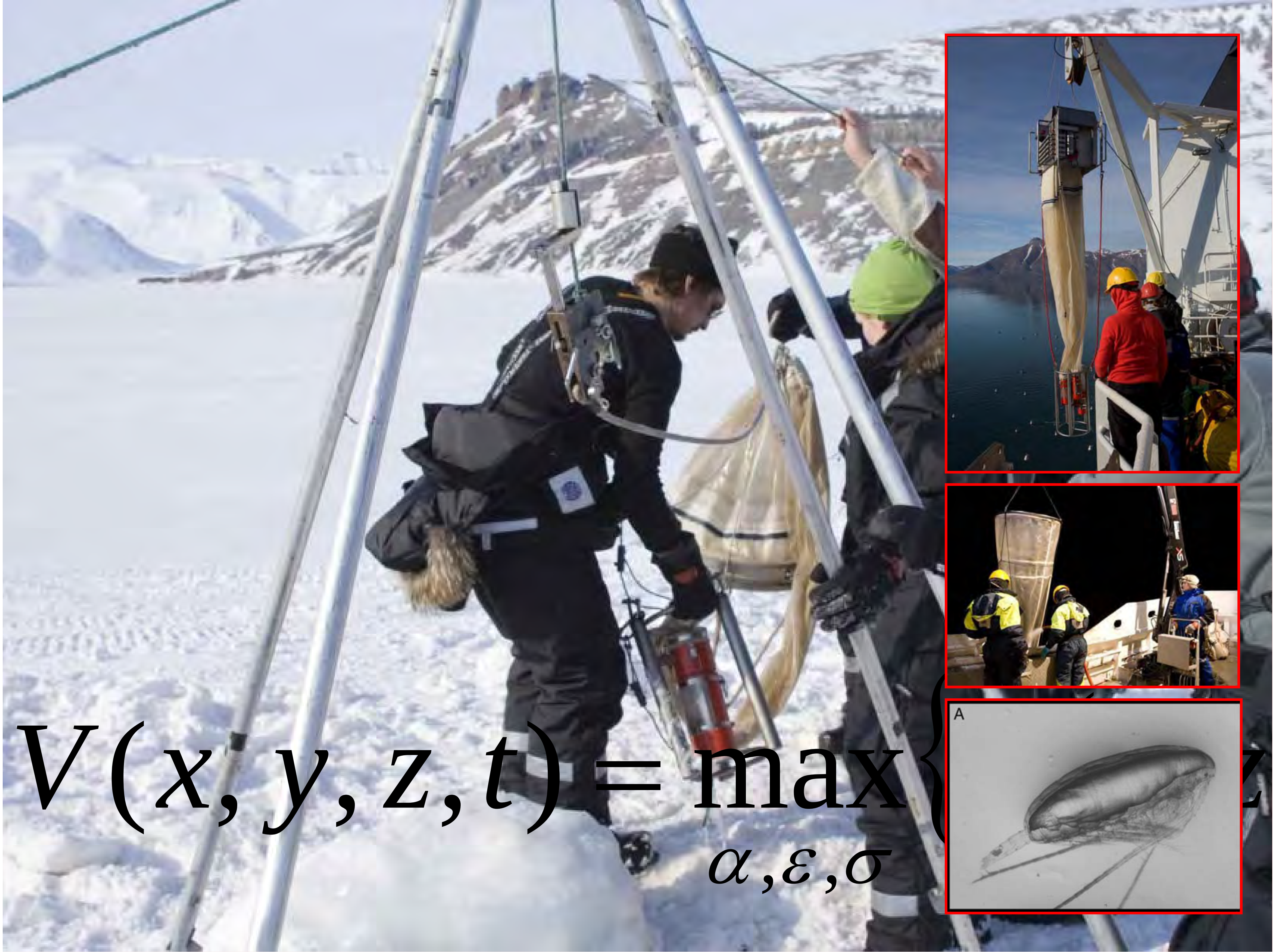
*Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA, †Centre of Oceanography, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal, ‡Facultad de Ciencias del Mar, Universidad Autónoma de Sinaloa, Mazatlán, Sinaloa, México

Yes – in regions where sea ice concentrations has declined in early summer.

What are the zooplankton responses?
(see for instance Søreide et al. 2010)

Requires an annual routine perspective.





$$V(x, y, z, t) = \max_{\alpha,\varepsilon,\sigma} \Bigg\{$$