The unique life cycle of Antarctic krill: Adaptations to a high latitude environment

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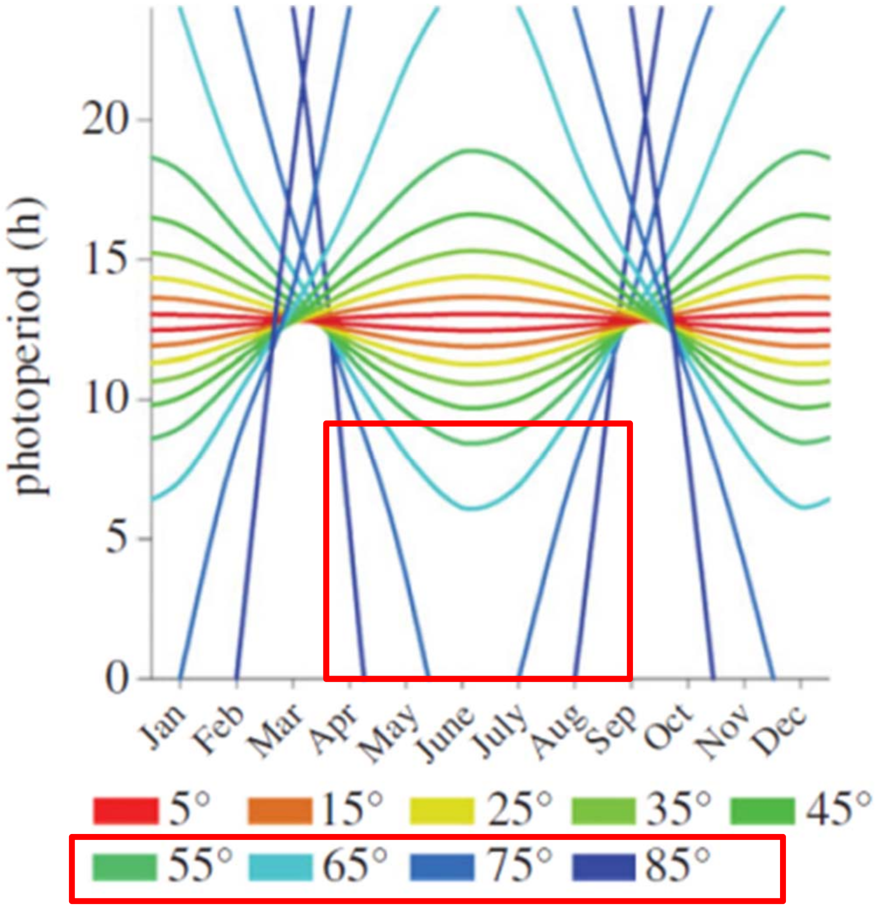
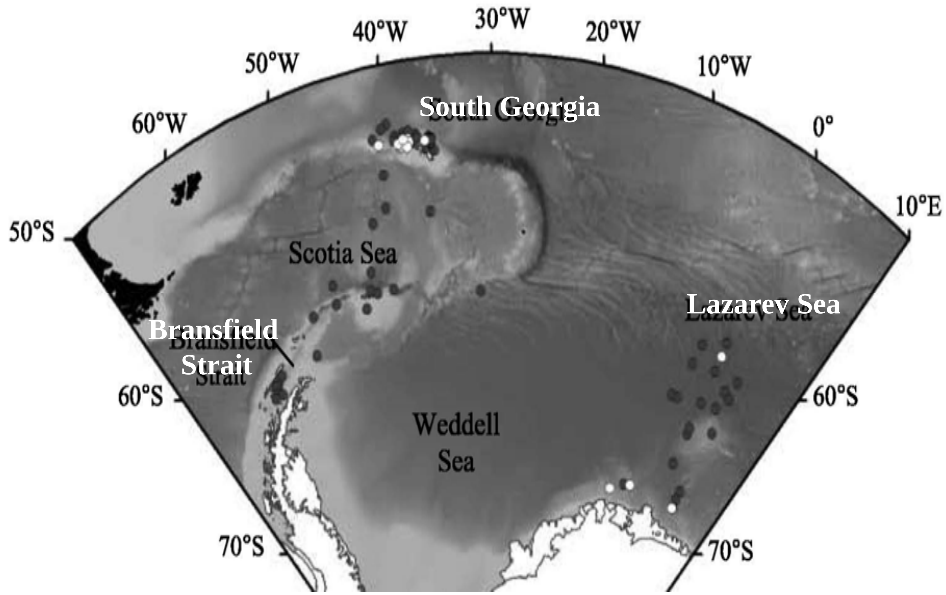
Content

- Synchronisation of krill to the seasonal environment
- Environmental Zeitgeber and molecular clocks
- A molecular clock in Antarctic krill
- Summary and outlook

Photoperiod at different latitudes

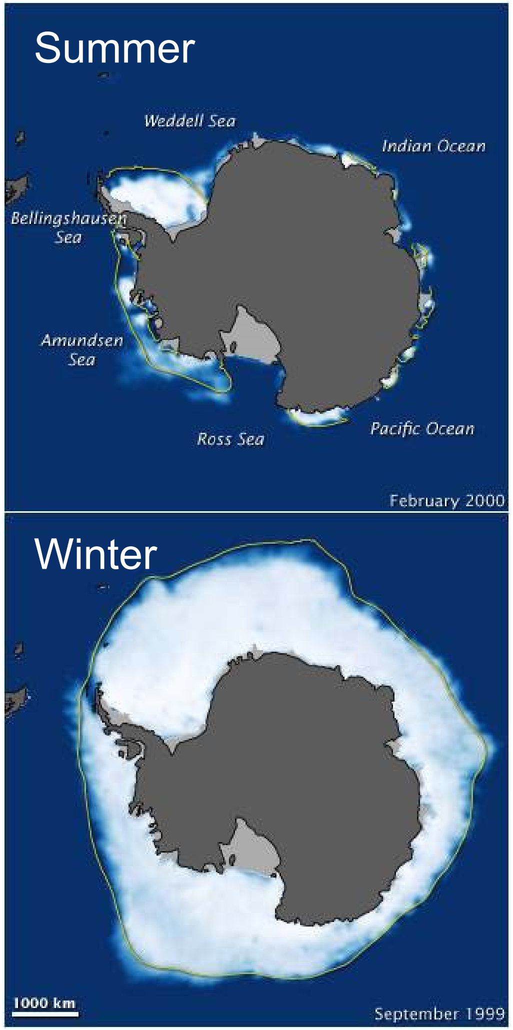


Hut et al. 2013

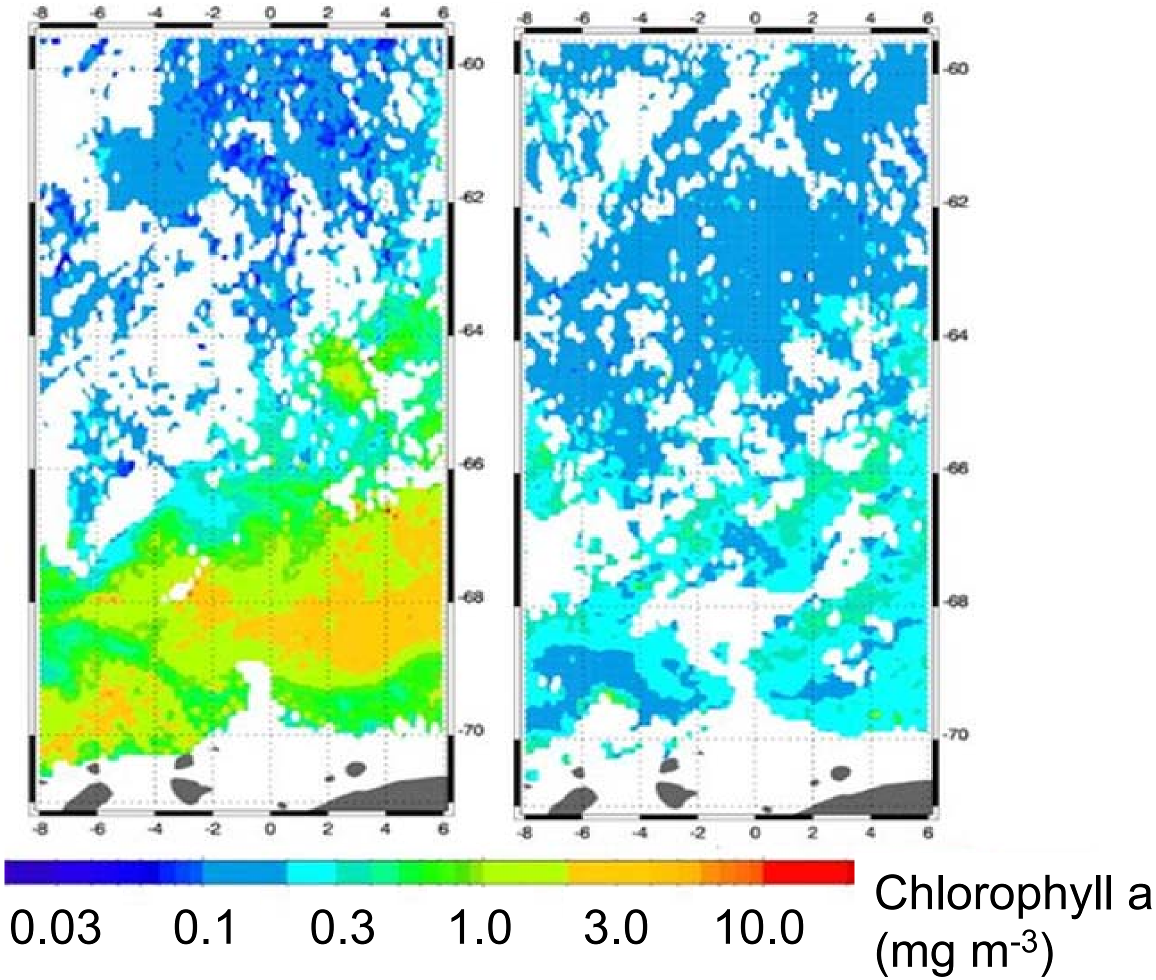


Schmidt et al. 2014

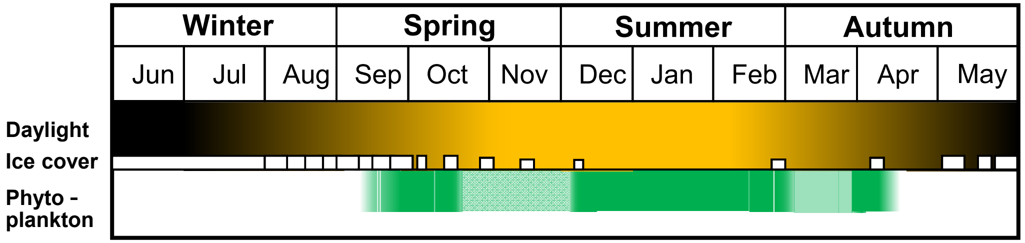
Sea ice extent



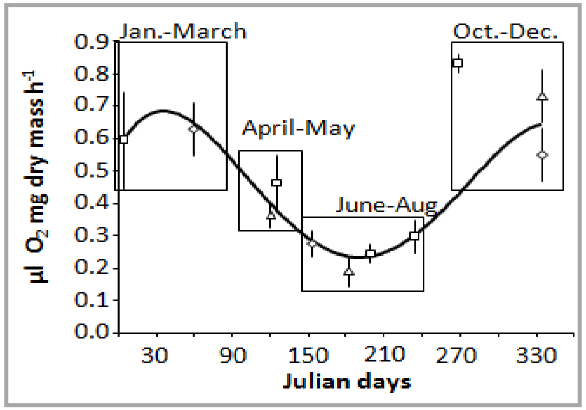
Food supply



Seasonal physiological functions in krill

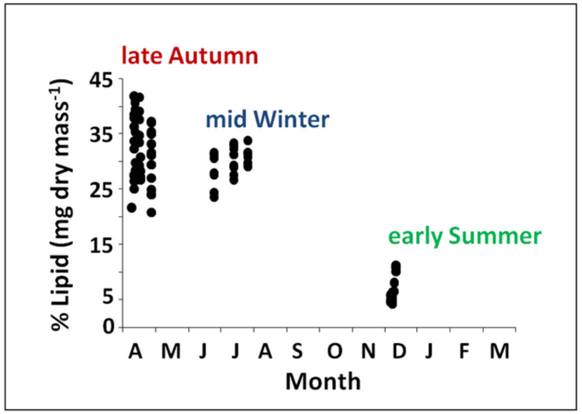


Metabolic activity



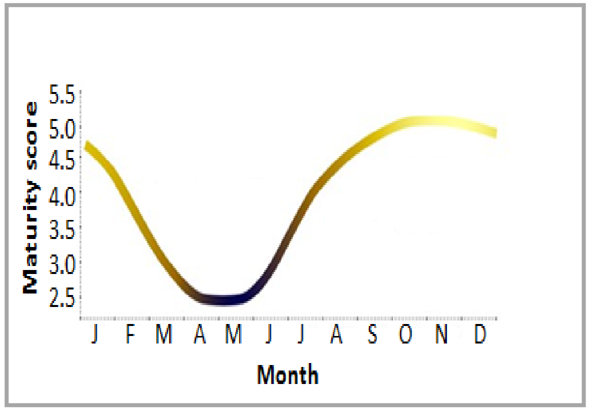
Meyer et al. 2012

Lipid dynamic



Meyer et al. 2010

Maturity

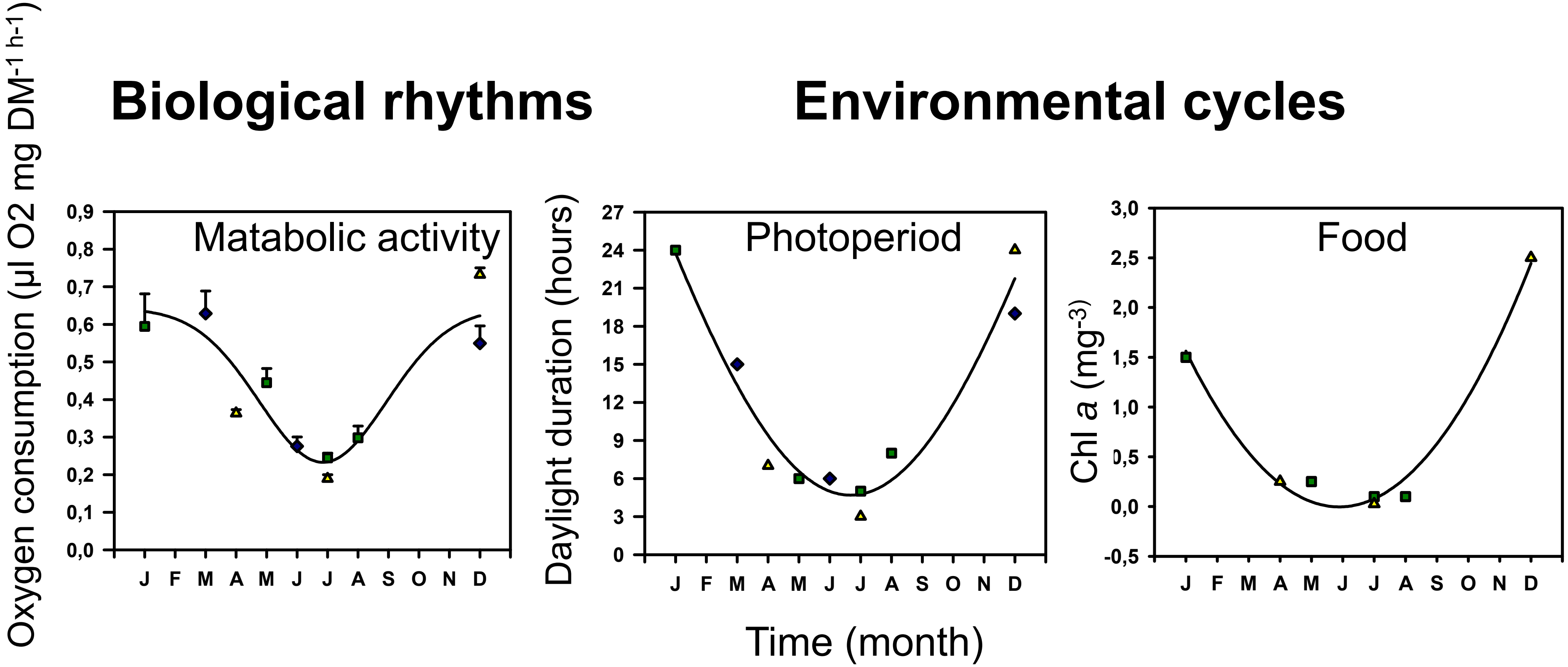


Brown et al. 2010

Which environmental factor is the main driver – FOOD or LIGHT or both?

Biological rhythms

Environmental cycles



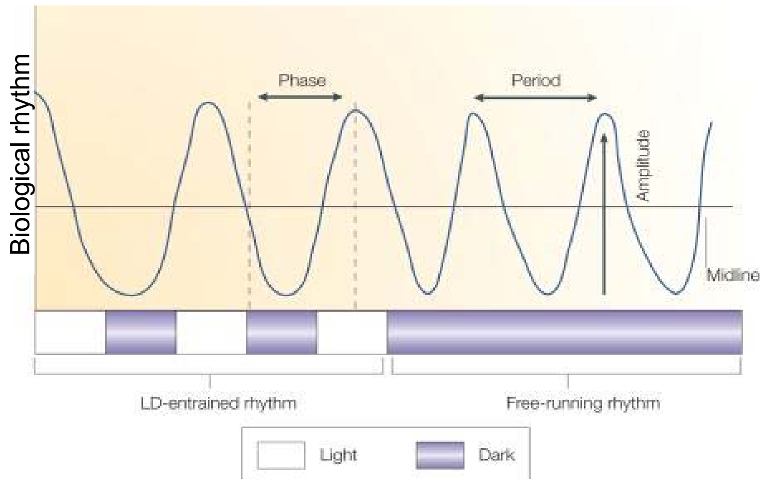
Teschke et al. unpubl.

△ Lazarev Sea (Atkinson et al. 2002, Meyer et al. 2010)

■ Lütz-Holm Bay (Kawaguchi et al. 1996)

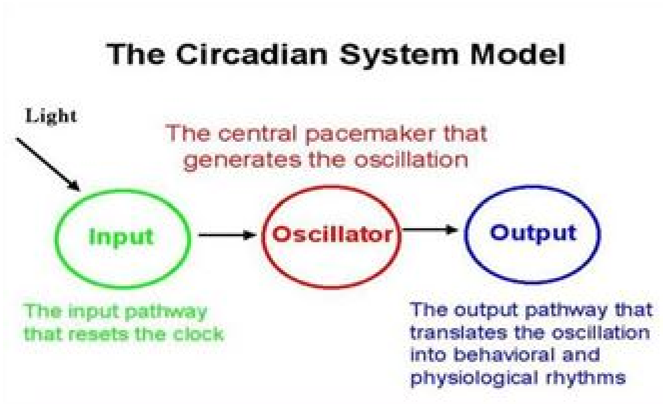
◆ Southern Scotia.Northern weddell Sea (Torres et al. 1994)

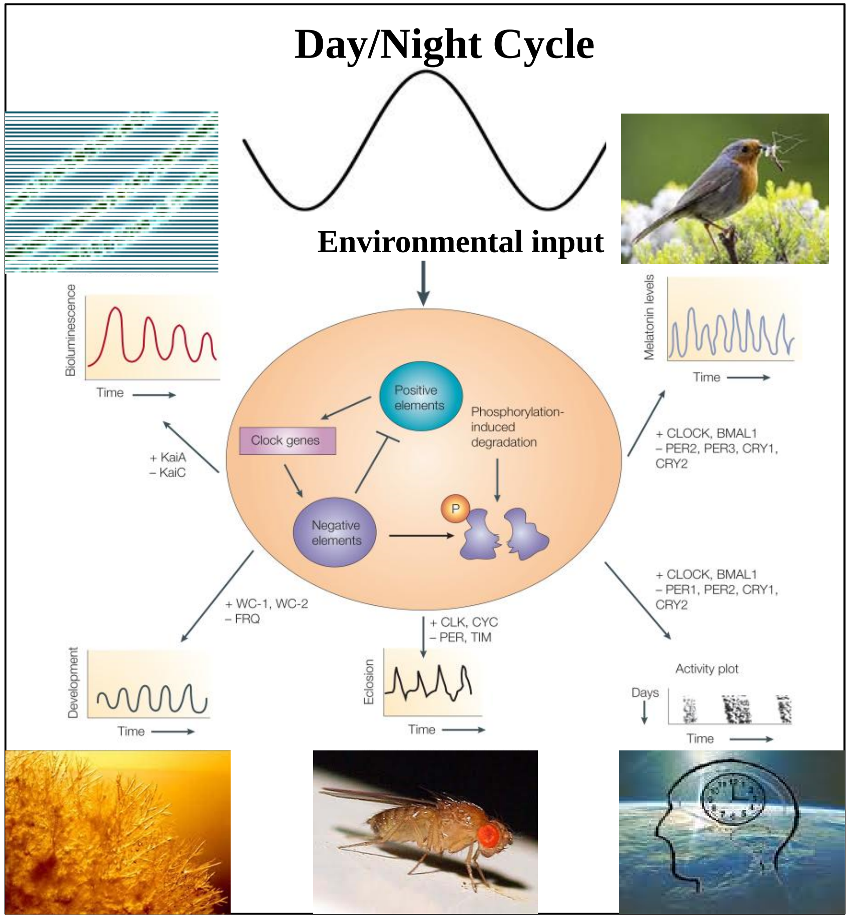
Molecular clock: Molecular system that is able to maintain a given biological rhythm even under free-running conditions, i.e. in the absence of a **Zeitgeber**: Environmental stimulus that serves as a synchronization cue: → **Entrainment**



- Rhythms are temperature-compensated
- Unaffected by metabolic poisons or inhibitors
- Occur with approximately the same frequency such as some environmental features
- Self-sustaining – maintain cyclicity in absence of cues
- Can be entrained by environmental cues

Principle of endogenous rhythm generation: „The circadian clock“





- ➢ A unifying principle of eukaryotic circadian clocks is the existence of transcriptional/translational autoregulatory feedback loops.

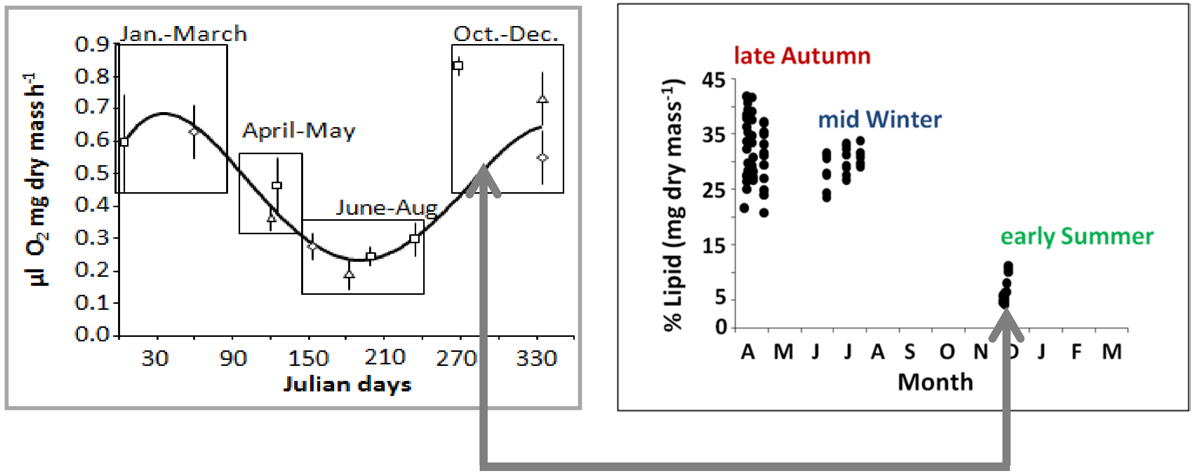
Principle of endogenous rhythm generation: „The circadian clock“

- the earth’s rotation, generating predictable daily fluctuations of light and temperature as well as food availability that most organisms are exposed to.

- a wide range of organisms have adapted to this 24 h rhythm by developing an endogenous timing system → **Circadian clock** (Latin: “*circa dies*”: about a day)
  - An endogenous near-24 h periodicity
  - Are protected from changes in temperature, nutrition and pH
  - Can be tuned to oscillate with exactly 24 h period → **Entrainment**
  - It is believed that also seasonal rythmicity is driven by these clock

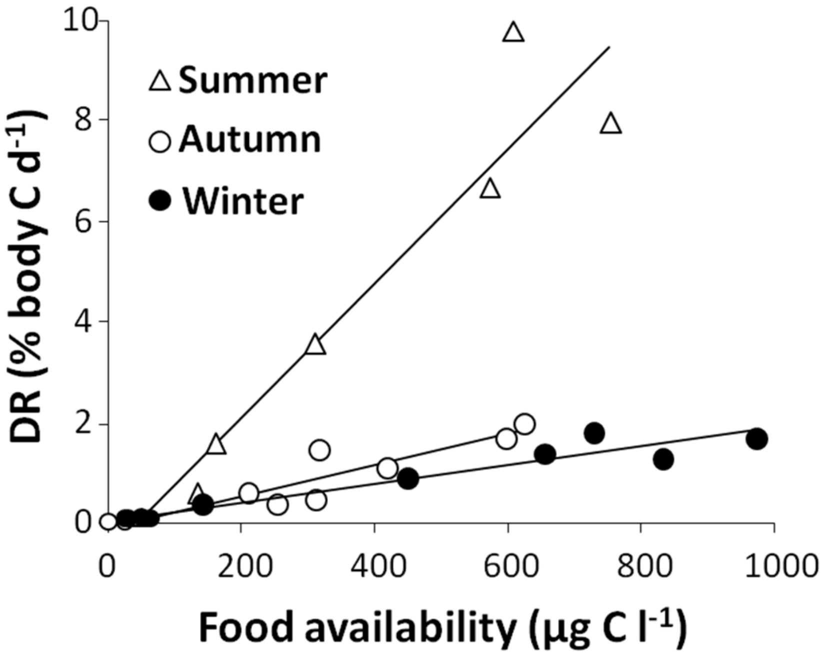
Act photoperiod and/or food as Zeitgeber for an molecular clock in krill?

Metabolic activity | Lipid dynamic



A chronobiological miss-match might occur in times of climate change

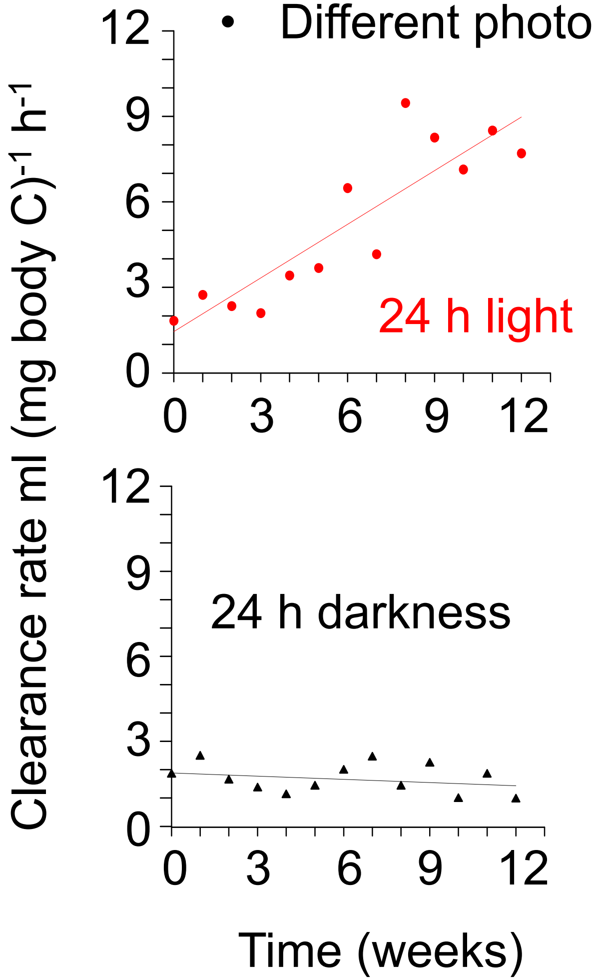
Seasonal feeding activity on board experiments



Meyer et al. 2010

Feeding activity in lab experiments

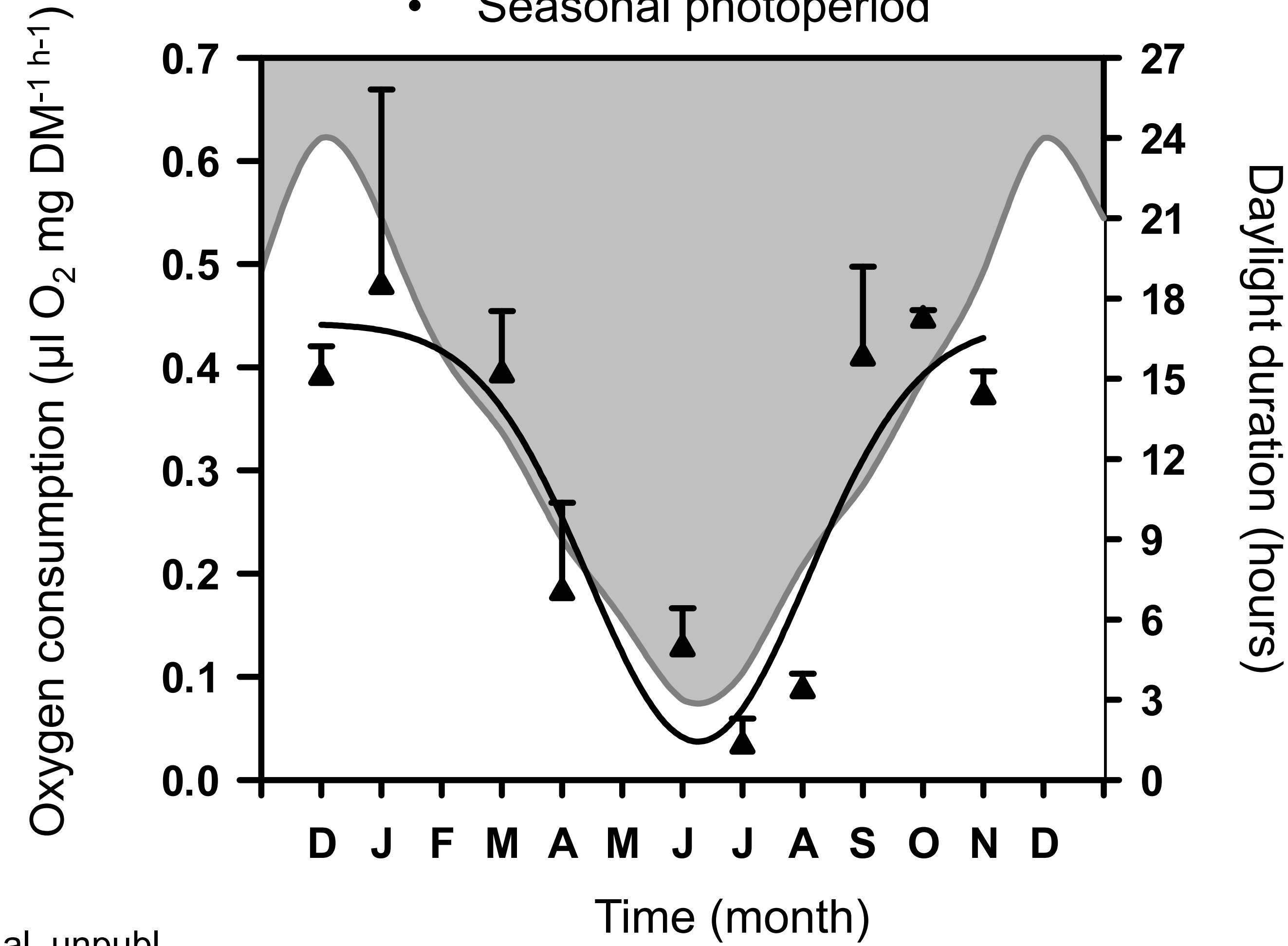
- Constant high food
- Different photoperiod



Teschke et al. 2007

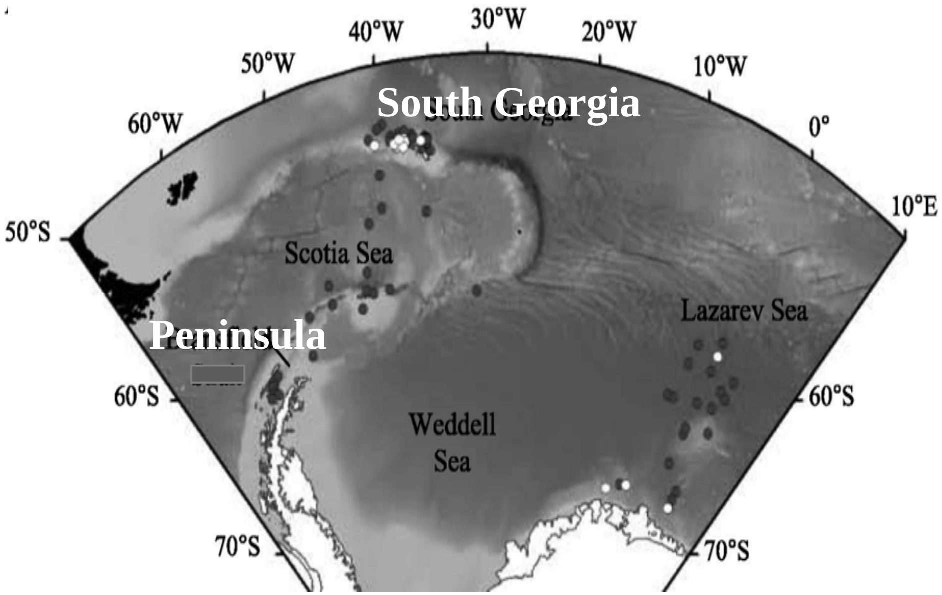
Metabolic activity in lab experiments

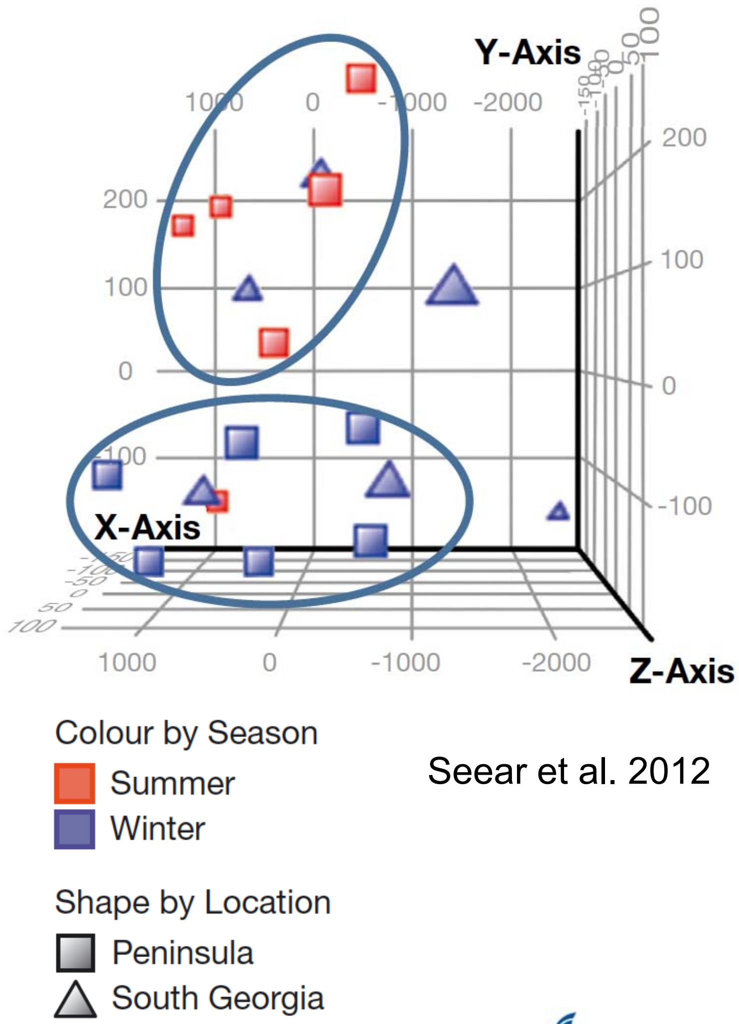
- Constant high food
- Seasonal photoperiod



Teschke et al. unpubl.

Seasonal gene expression at different latitudes



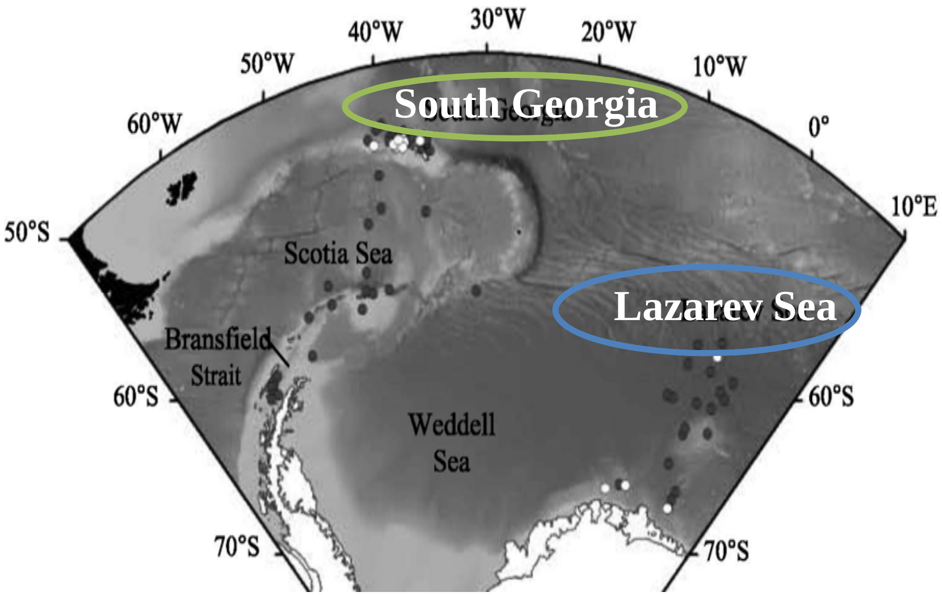


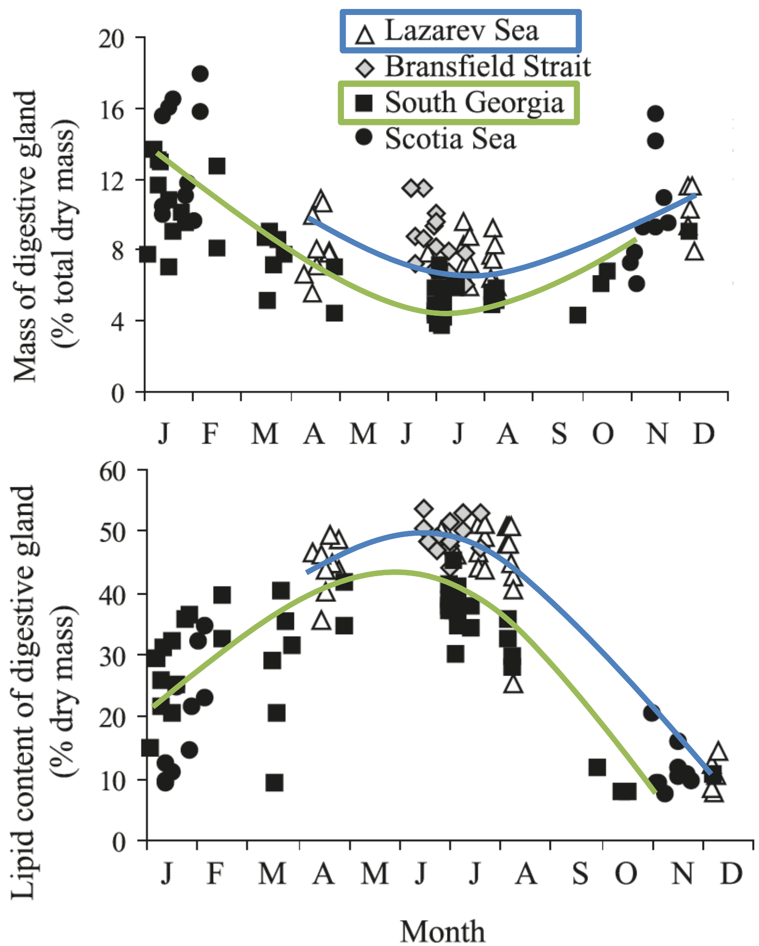
Seear et al. 2012

Summer Chl *a*: 0.2-5 mg m^{-3} at both locations

Winter Chl *a*: 0.3-0.6 mg m^{-3} at both locations

Seasonal feeding activity and lipid dynamic at different latitudes





Schmidt et al. 2014

Summer Chl *a*: (0.2-5 mg m^{-3}) at both locations

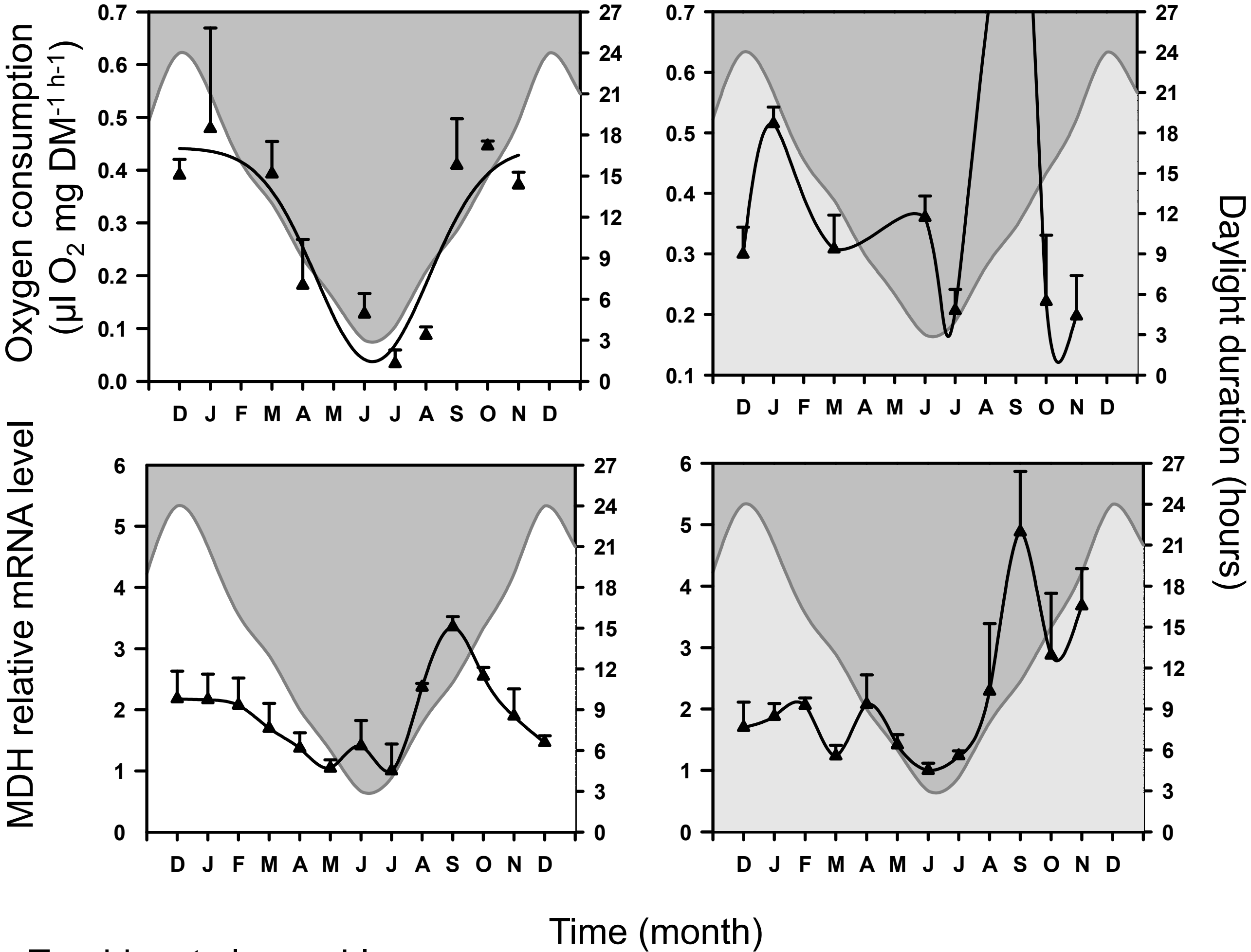
Winter Chl *a*: Lazareav Sea, 0.01-0.04
South Georgia, 0.3-0.6
(mg m^{-3})

Photoperiod seem to act as important Zeitgeber for physiological functions such as:

- Metabolic activity
- Appetite

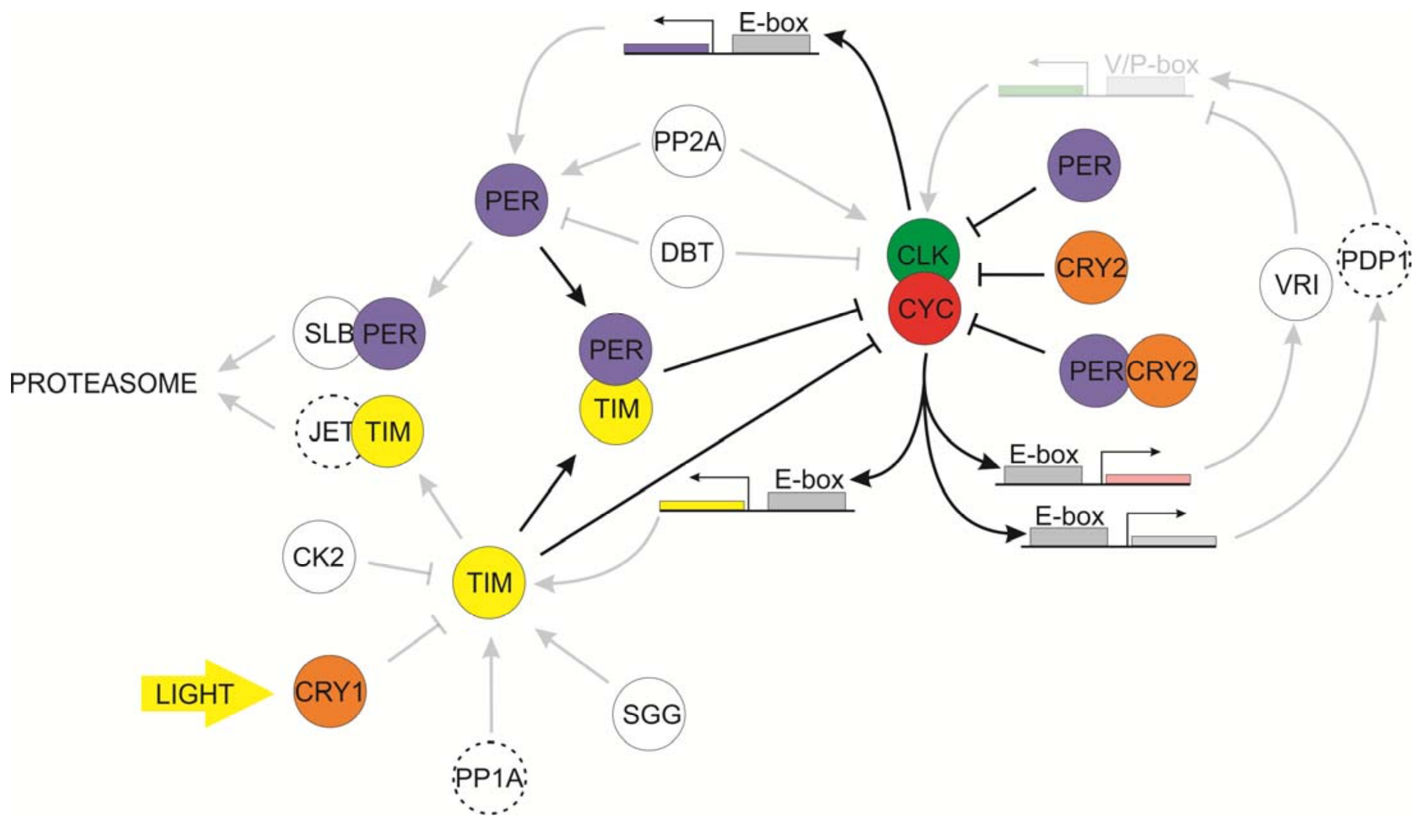
Indication that physiological function in krill are mediated by an molecular clock?

Seasonal rhythms during light and constant darkness at constant high food concentration



Teschke et al. unpubl.

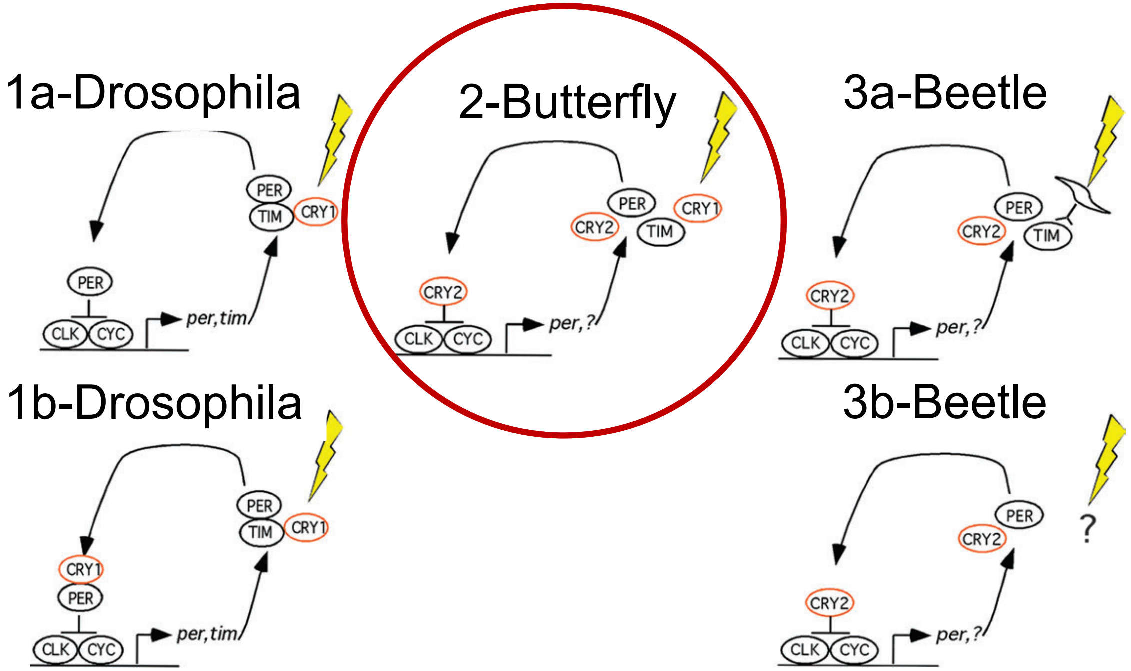
The clock machinery in krill



Components for which a functional characterization has been performed are indicated in color (◌ = not found yet ➔ = activation ⊣ = inhibition).

Biskontin et al. unpubl.

Clockwork machinery reference models



Krill circadian oscillator seems to be a 2 cryptocromes-based system (butterfly model); where CRY1 is involved in the synchronization of the clock through the light-mediated degradation of TIM, while CRY2 inhibits CLOCK:CYCLE-mediated transcription.

- Photoperiod is an important Zeitgeber for Antarctic krill
- A molecular clock in krill is identified
- The clock machinery of krill is similar to the monarch butterfly model
- The work is part of the international PolarTime project

PolarTime-Project:

Biological timing in a changing marine Environment:

Clocks and rhythms in polar pelagic organisms

Funded by the Helmholtz Association

www.polartime.org

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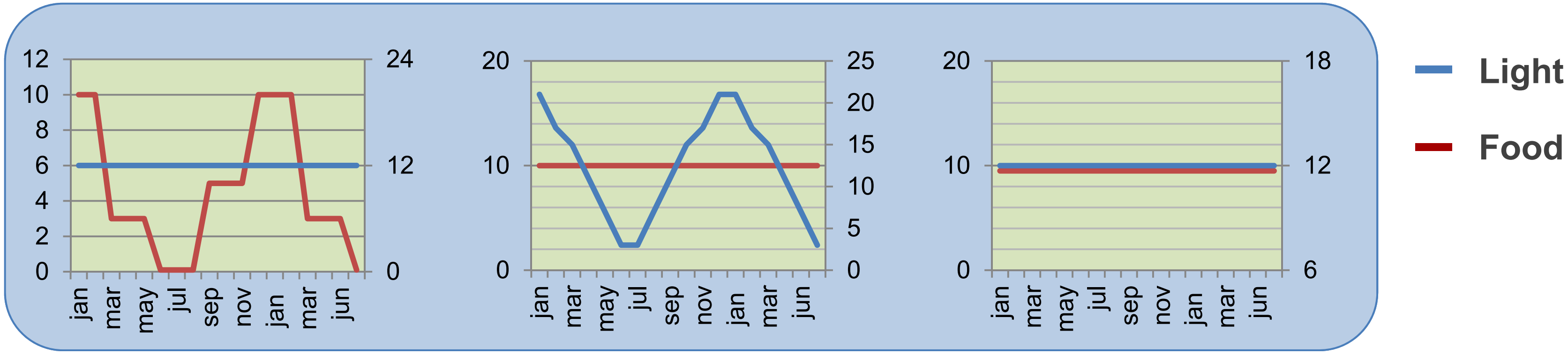
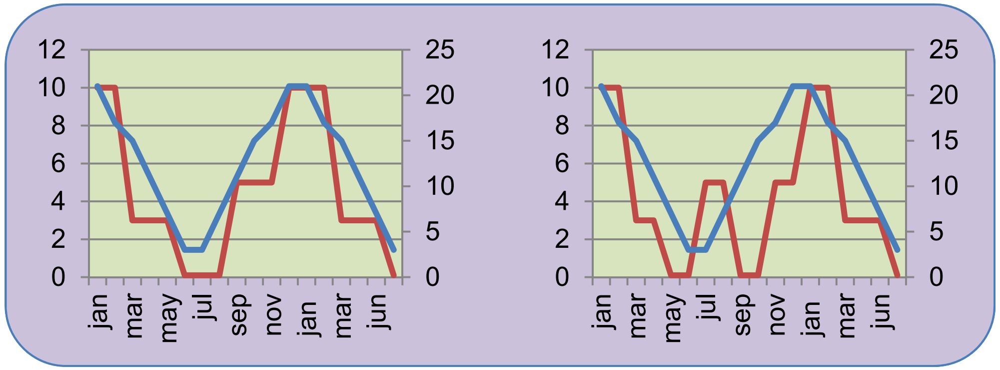
What next?

Long-term simulations (1.5 years) with changing light and food conditions study the importance of photoperiod and food as seasonal Zeitgeber (**end of experiments June 2016**)





- Single effect
- Interaction
- Out-of-phase interaction

Summary and outlook

- Marine chronobiology in times of climate change gets more and more attention.

Current Biology

Moonlight Drives Ocean-Scale Mass Vertical Migration of Zooplankton during the Arctic Winter

Last et al. 2016

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Cell Rep. 2013 Oct 17; 5(1): 99–113. PMCID: PMC3913041
doi: 10.1016/j.celrep.2013.08.031

Circadian and Circalunar Clock Interactions in a Marine Annelid

Juliane Zantke,[1,2] Tomoko Ishikawa-Fujiwara,[3] Enrique Arboleda,[1,5] Claudia Lohs,[1,6] Katharina Schipany,[1,7] Natalia Hallay,[1,2] Andrew D. Straw,[4] Takeshi Todo,[3] and Kristin Tessmar-Raible[1,2,*]

- Marine chronobiology research will be an essential part to understand and predict population shifts of pelagic key invertebrates and ecosystem response