

# 3rd. International Krill Symposium

*University of St. Andrews, 12 to 16 of June 2017*

Ecosystems: why are krill so successful?

## Seasonal modulation of the circadian clock of the Antarctic krill

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**Australian Government**  
**Department of the Environment**  
Australian Antarctic Division



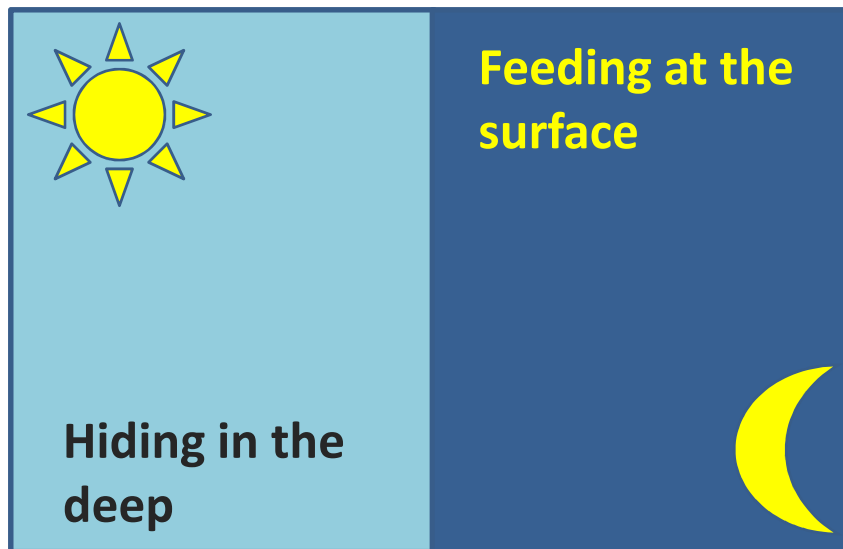
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**PolarTime**  
Helmholtz Virtual Institute  
Clocks & Rhythms in Polar Pelagic Organisms

# Organization of daily rhythms

## ➤ When are krill more active?



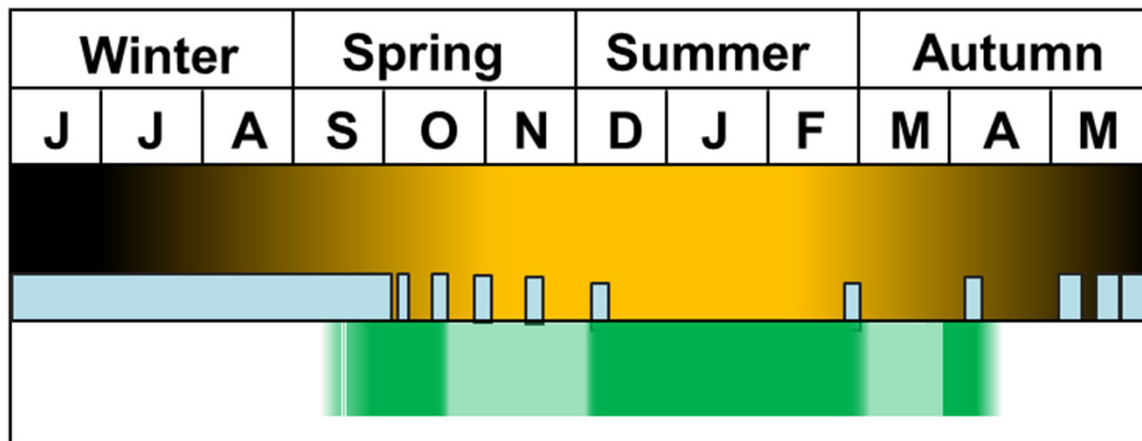
Diel Vertical Migration paradigm

- Irregular patterns have been observed
  - time of the year
  - geographical region
  - food availability
  - predators

## ➤ Organization of daily rhythms is flexible

# Organization of daily rhythms

## ➤ EXTREME SEASONALITY (66° south)



→ photoperiod  
( day length)

→ primary production

→ sea-ice cover

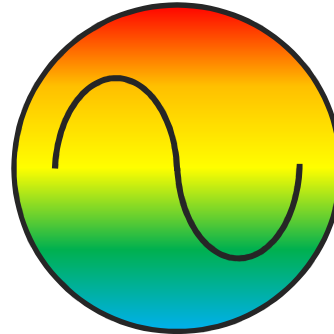
## ➤ How do krill regulate their daily rhythms throughout the seasons?

# Circadian clock

PHOTOPERIOD  
day/night cycle



CIRCADIAN CLOCK  
≈24h (circa-dies)



OUTPUT



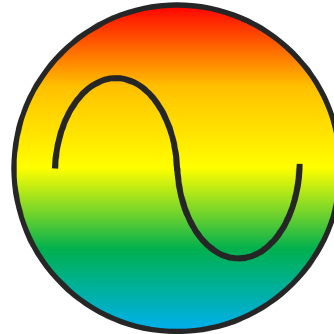
- Rhythmic expression of **CLOCK GENES**
- Synchronized to day/night cycle by the interaction with **LIGHT SENSITIVE** molecules
- Clock genes act as transcription factors and promote daily rhythms

# Circadian clock

PHOTOPERIOD  
day/night cycle



CIRCADIAN CLOCK  
≈24h (circa-dies)



OUTPUT

24h Rhythms:

- Behavior
- Metabolism
- Physiology

- Clock gene activity has been detected in krill (Mazzotta et al 2010, Teschke et al 2011, Biscontin et al in preparation)

How is the activity of the clock affected by the extreme seasonal photoperiodic variability of the SO?

# Aim of the study

➤ Investigate effect of seasonal photoperiodic variability on:

1) Daily patterns of clock gene activity

→ is the clock ticking throughout the year?

→ does it stop in extreme photoperiodic conditions ?

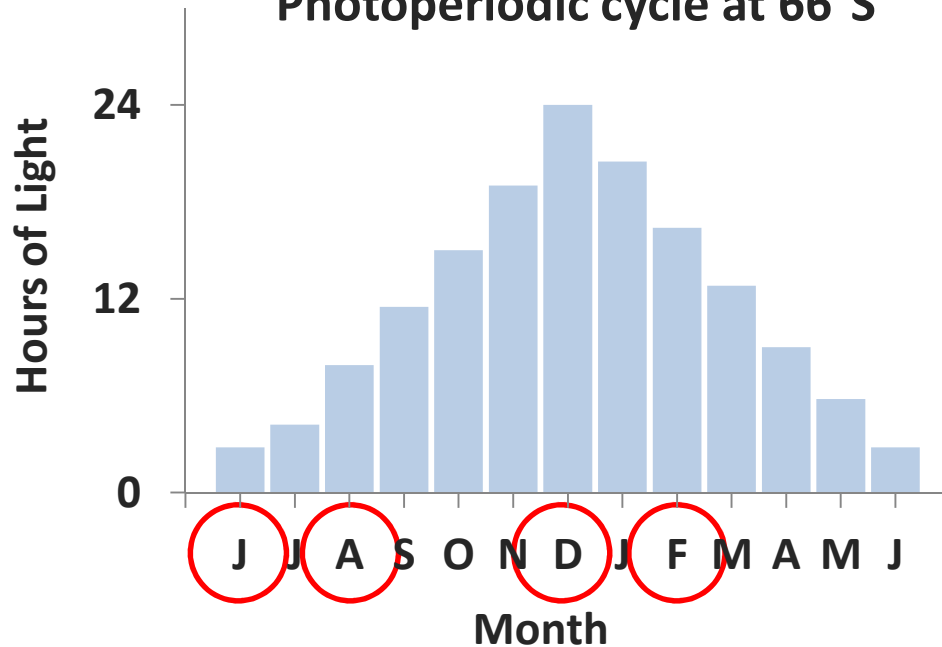
2) Daily regulation of metabolic output rhythms

→ Are they changing throughout the year?

→ If the clock stops ticking, what happens to them?

# Experimental design

Photoperiodic cycle at 66°S



**(J) MIDWINTER**  
→ polar night

**(D) MIDSUMMER**  
→ midnight sun

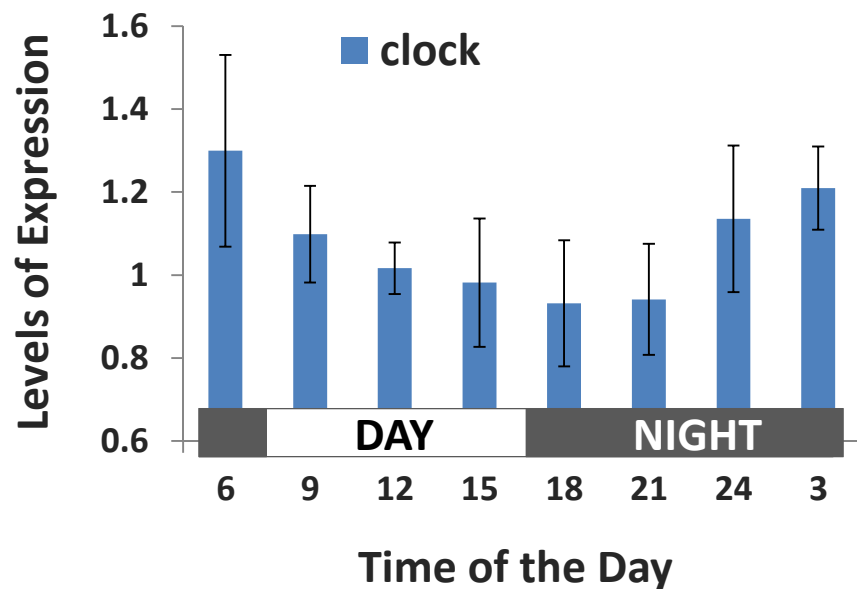
**(A) LATE WINTER**  
→ short days

**(F) EARLY AUTUMN**  
→ long days

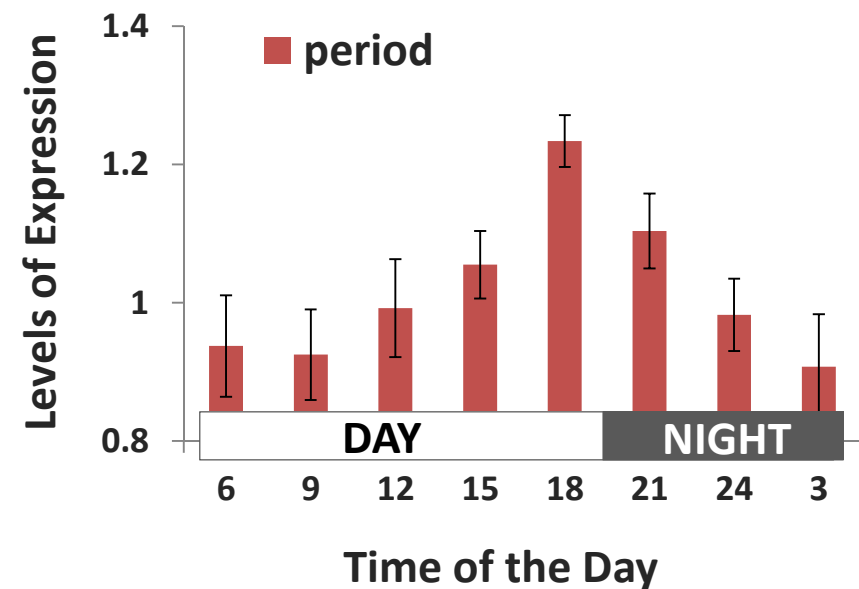
- Long-term laboratory simulation (AAD)
- 24h samples
- Daily patterns of gene expression
  - clock genes
  - key metabolic genes (citric acid cycle, glycolysis...)

# Results: clock gene expression

## ➤ LATE WINTER



## ➤ EARLY AUTUMN

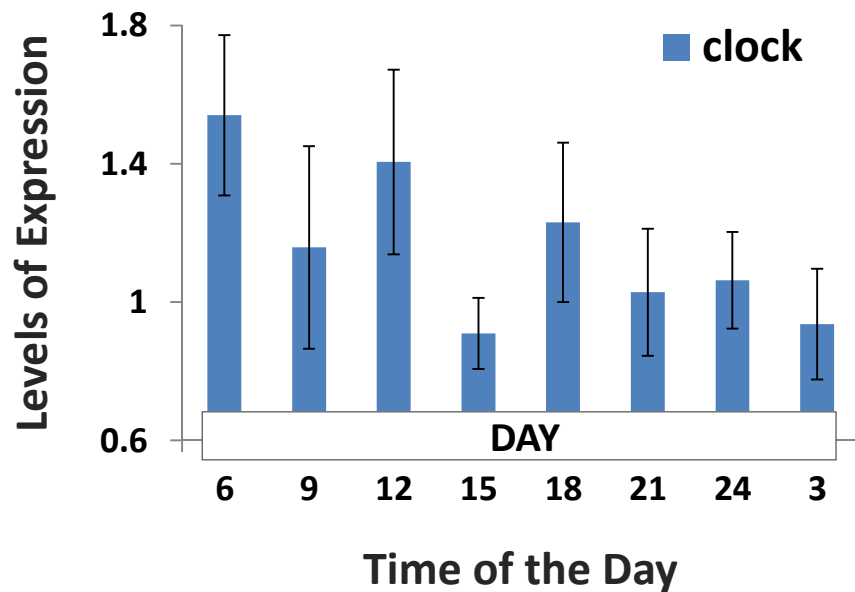


- 24h rhythm of clock gene expression → **clock is active**
- Daily patterns are **synchronized** to the day/night cycle

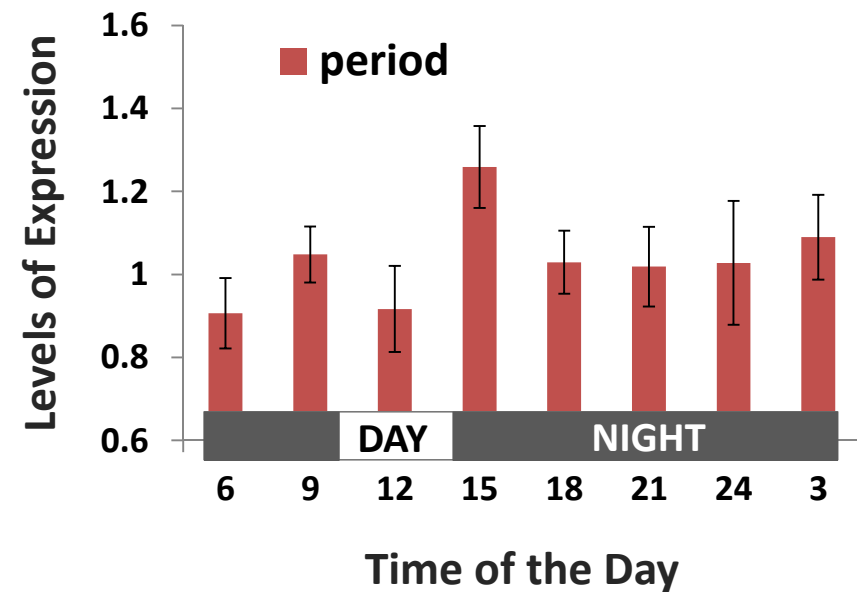


# Results: clock gene expression

## ➤ MIDSUMMER



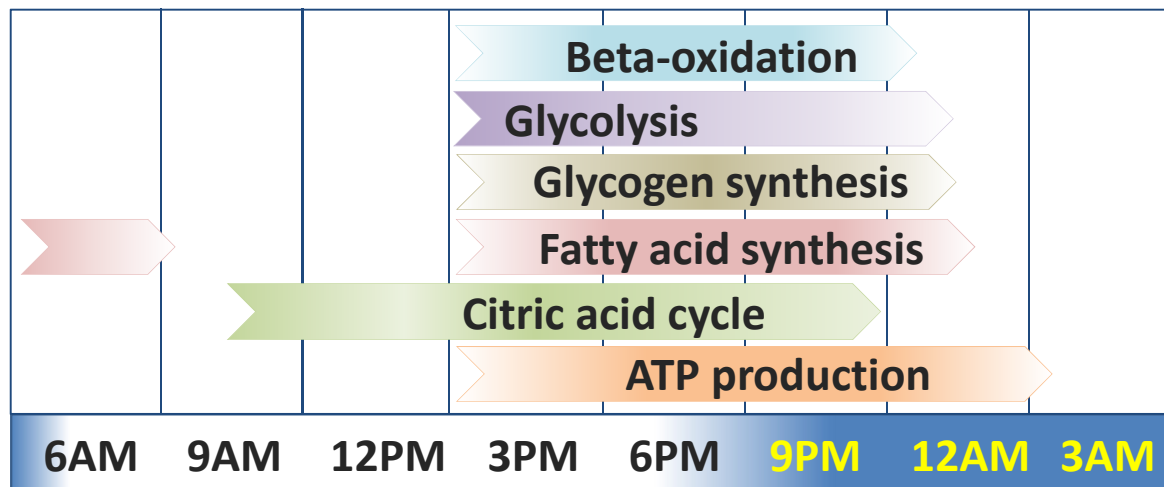
## ➤ MIDWINTER



- Irregular clock gene expression → **clock not active**

# Results: metabolic gene expression

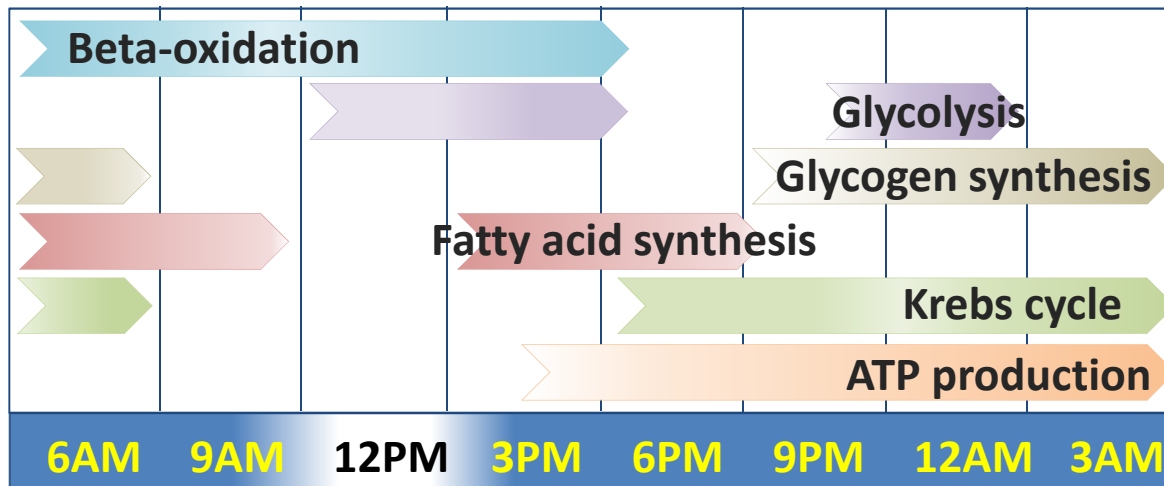
## ➤ EARLY AUTUMN



- Up-regulation of key metabolic pathways is **coordinated around dusk**
- Similar picture in LATE WINTER

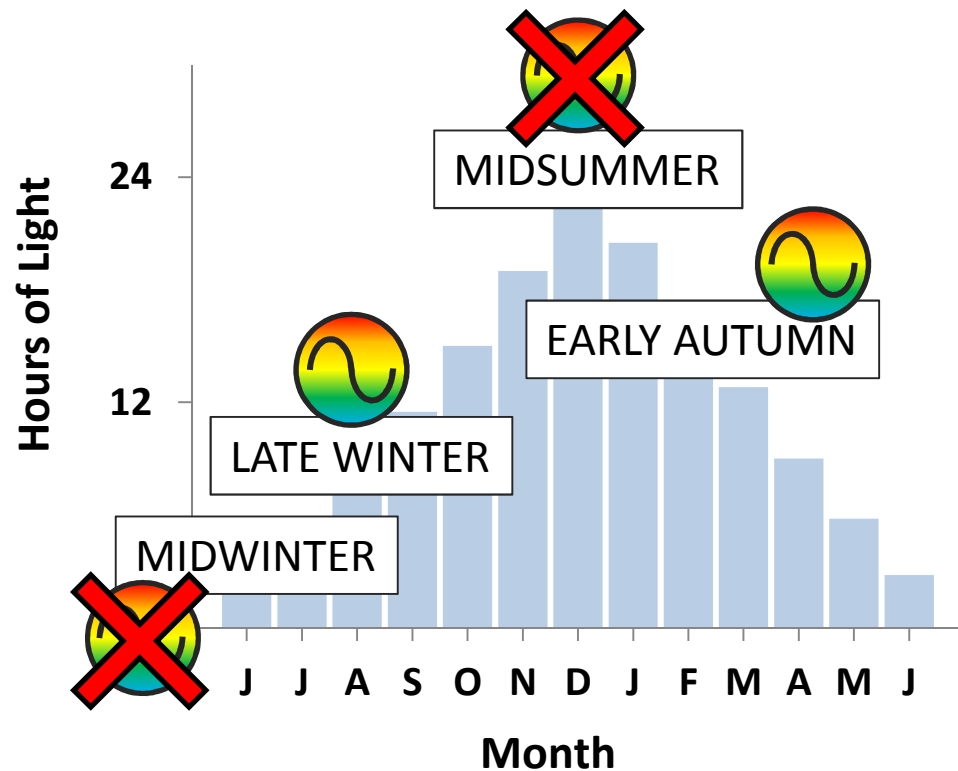
# Results: metabolic gene expression

## ➤ MIDWINTER



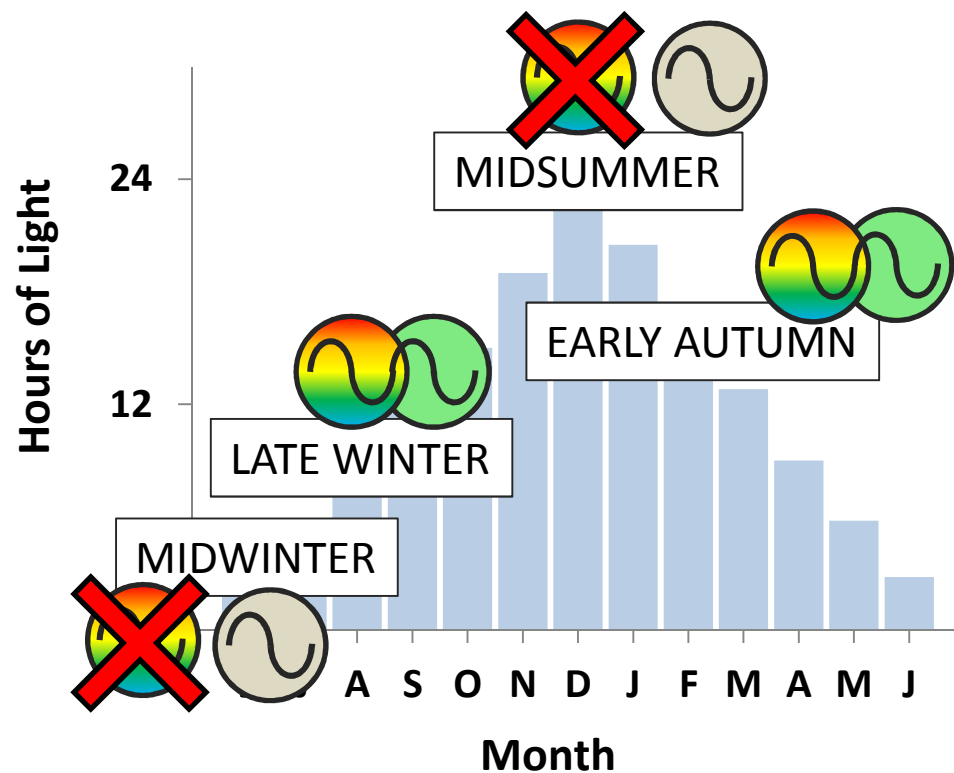
- Regulation of key metabolic pathways is **spread throughout the day**
- Similar picture in MIDSUMMER

# Discussion: seasonal modulation



- Day/night cycle  
→ clock active
- Extreme conditions  
→ clock not active

# Discussion: seasonal modulation



- Day/night cycle  
→ clock active  
→ **metabolism synchronized**
- Extreme conditions  
→ clock not active  
→ **metabolism not synchronized**

➤ Adaptive value?

# Discussion: seasonal modulation



Diel Vertical Migration paradigm

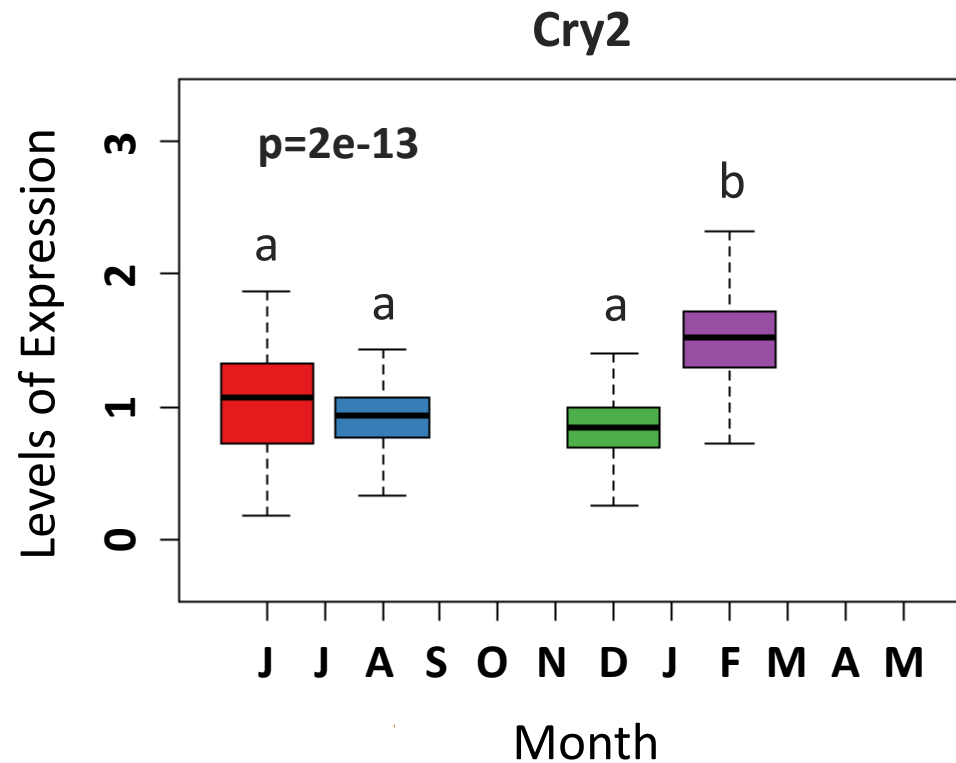
- day/night cycle
- rhythmic predation
- **rhythmic 24h life-style**
- **clock gene activity**
- **coordination of metabolism**

- no day/night cycle
- constant predation
- **opportunistic 24h life-style**
- **no clock gene activity**
- **metabolism spread**

# Conclusions

- **The clock of krill shows photoperiodic modulation**
  - active when day/night cycle is present
  - not active when day/night cycle is extreme
- **Rhythmic regulation of metabolism is coupled to the clock**
  - synchronized when day/night cycle is present
  - spread when day/night cycle is extreme
- **There is a switch between two 24h life-strategies**
  - 1) regular day/night cycles → regular daily rhythms → activity at night
  - 2) extreme day/night cycles → irregular daily rhythms
    - „around the clock“ activity

# Perspectives



- Clock gene expression shows a seasonal pattern

**Higher in EARLY AUTUMN**

- towards overwintering
  - reduction of activity
  - lipid accumulation
  - sexual regression

- **A role of the clock in seasonal timekeeping?**



# Acknowledgements



**UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA**

# Thank you!

Rob King  
Tasha Waller  
Blair Smith

Cristiano De Pittá  
Alberto Biscontin