Increased sea water pCO2 on Northern krill *Thysanoessa inermis: Effect on survival, moulting, growth, grazing and respiration*

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Background

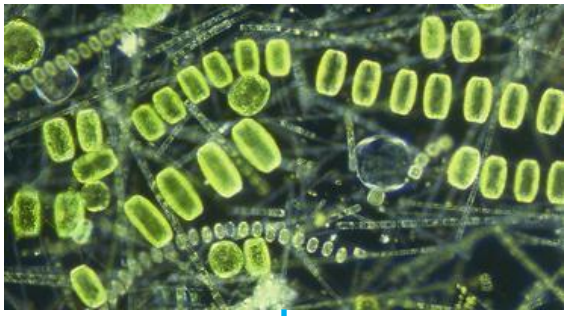
- Atmospheric pCO_2 has increased over the last 200 years and some of this carbon dioxide is absorbed by the world´s oceans (Le Quere et al.,2009).

- The solubility of CO_2 is highest in cold water and polar oceans might be among the first marine environments to exhibit the effect (Steinacher et al., 2008; Bellerby et al., 2008).

- There is a concern of the effects the increasing ocean acidification might have on important species.

- The most abundant euphausiid species in the northern waters e.g. Barents Sea, *Thysanoessa inermis.*

Thysanoessa inermis is a key prey



Hypothesis

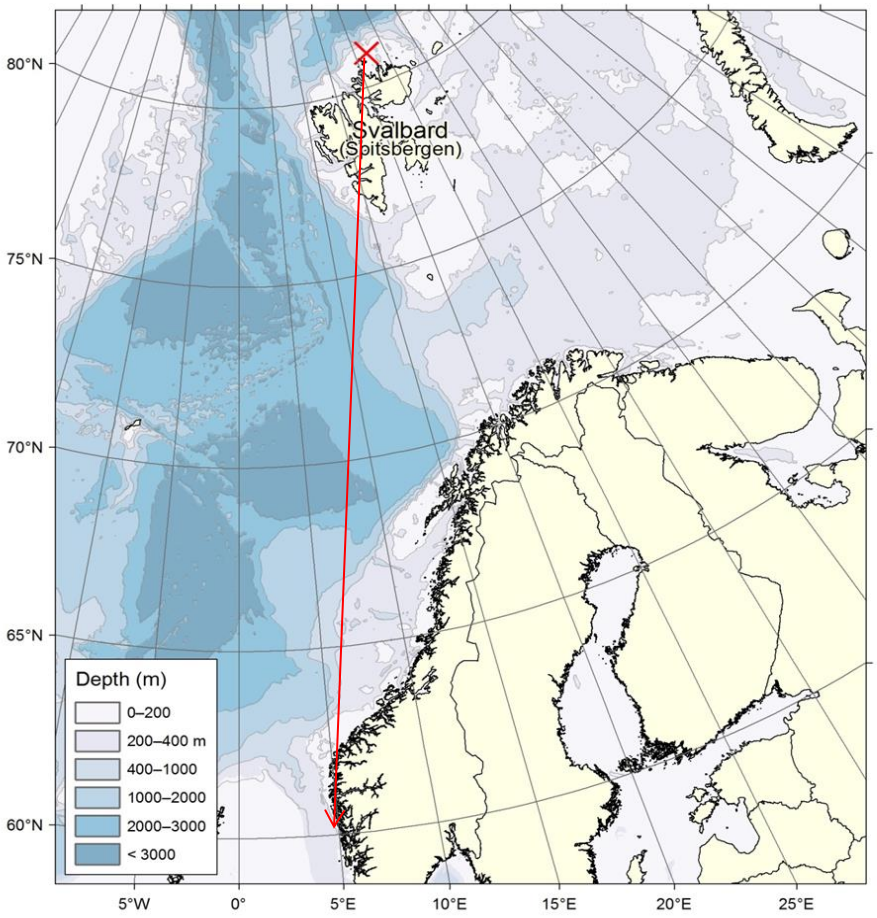
Increased pCO_2 would impose an energetic cost on *T.inermis* resulting in reduced growth, increased respiration and increased ingestion rate.

Approach

We have used an experimental approach to study the effects of rising CO_2 levels on *T. inermis*. Individuals were exposed to two levels of pCO_2

- **ambient pCO_2 of 450 µatm and**
- **elevated pCO_2 of 1200 µatm for 75 days.**

Sampling location



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The process room: CO_2 gas bottle, stock solution tank (S), pH transmitter (T), dosage pumps (P), mixing tank (M) circulation pump (C).

Experimental set up

We followed single krill for 75 days in tanks fed live algae and comercial feed at pH 8.0 and 7.6

Response variables

- **During the experiment (75 days)**
- Water chemistry
- Mortality
- Day of moult (for inter-moult period)
- Uropod length of moult (for growth)
- Sex identification
- Total length of dead individuals

- **At the end of the experiment**
- Total length
- Uropod length
- Wet mass
- RNA concentration
- Ingestion rate
- Oxygen consumption

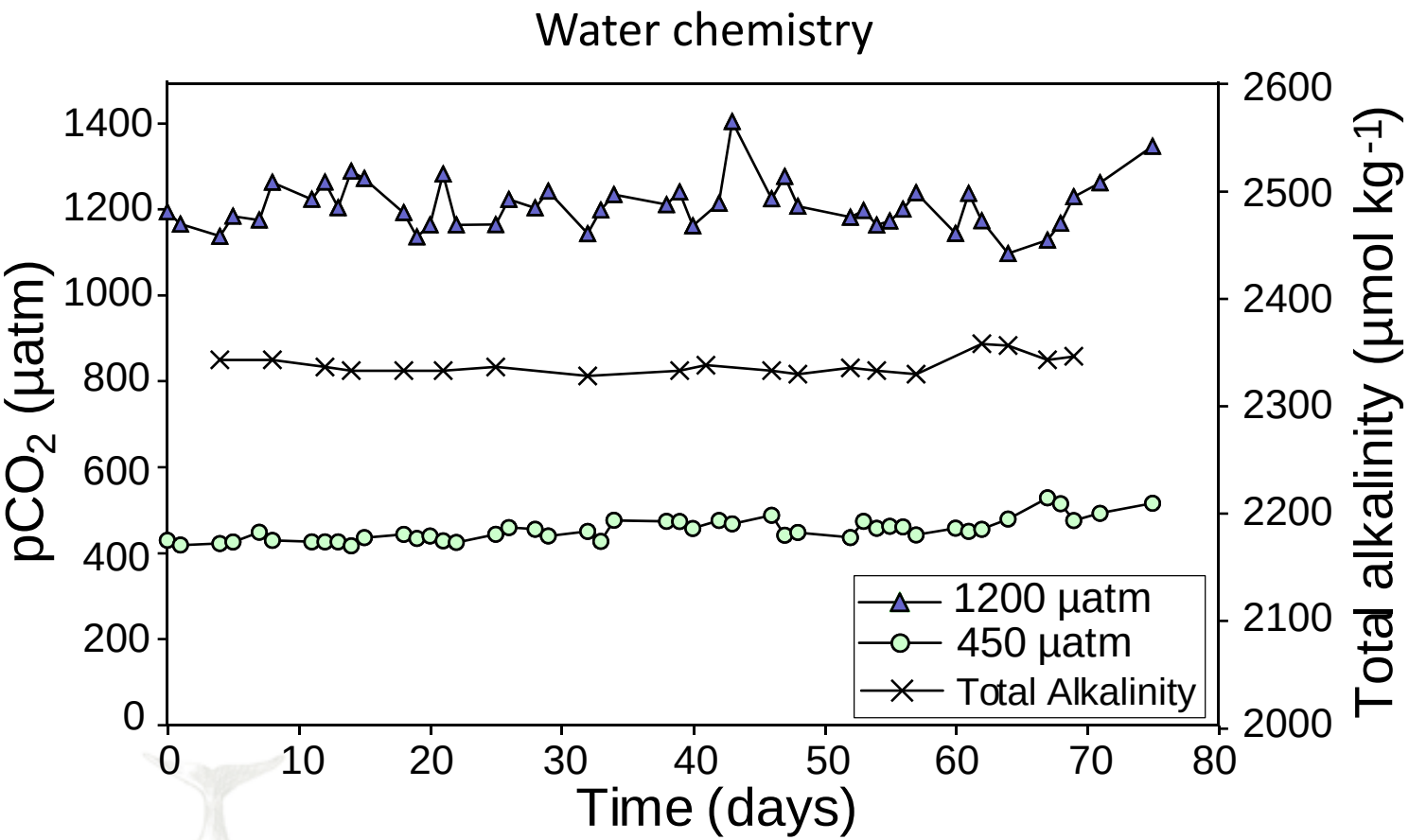
Statistical analyses

Two-tailed t-tests assuming equal variances were used to test for differences in means of inter-moult period, growth, and mass-specific ingestion rates between the two pCO_2 levels.

Differences in total length, wet mass, RNA concentration, and oxygen consumption of krill between the two applied pCO_2 levels were analysed using an analysis of covariance (ANCOVA) with uropod length, total length, or wet mass as covariates to account for size differences in individuals.

Response variables showing an exponential relationship with the covariate were log transformed before ANCOVA to linearize the relationship and meet statistical assumption. We did not find an effect of sex on any of the response variables and therefore, pooled the data of females and males in all data analyses.

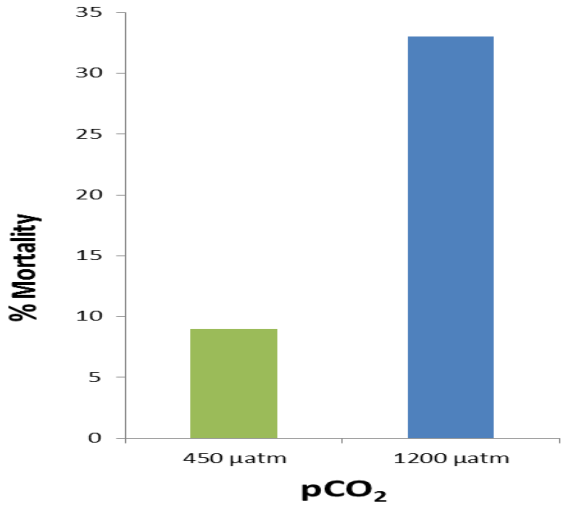
RESULTS


Water chemistry
pCO2 (µatm)
Total alkalinity (µmol kg-1)
Time (days)
1200 µatm
450 µatm
Total Alkalinity
0
200
400
600
800
1000
1200
1400
2000
2100
2200
2300
2400
2500
2600
0
10
20
30
40
50
60
70
80

Carbonate chemistry

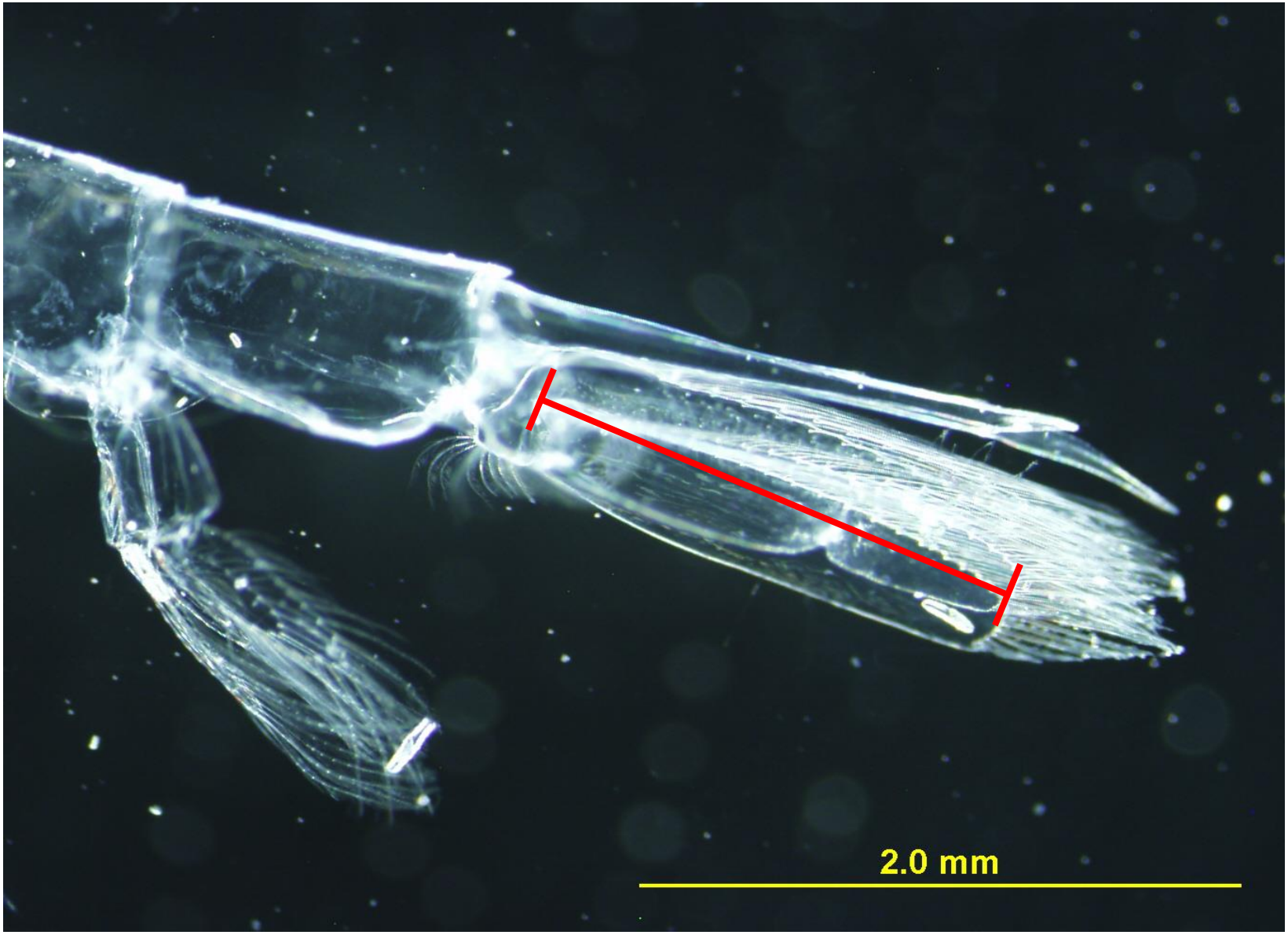
pH transmitter setting	8.0	7.6
Temperature (°C)	7.3 ± 0.4	7.4 ± 0.5
pH (total scale)	8.00 ± 0.02	7.61 ± 0.02
*p*CO2 (*µ*atm)	**453.7** ± 26.5	**1208.9** ± 57.7
DIC (*µ*mol kg^{-1})	2187.5 ± 9.9	2318.2 ± 8.2
HCO_3^- (*µ*mol kg^{-1})	2053.3 ± 11.9	2211.3 ± 7.6
CO_3^{2-} (*µ*mol kg^{-1})	112.5 ± 3.7	49.1 ± 2.4
CO_2 (*µ*mol kg^{-1})	21.7 ± 1.1	57.8 ± 2.9
ΩCa	2.69 ± 0.09	1.17 ± 0.06
ΩAr	1.70 ± 0.06	0.74 ± 0.04

% Mortality (75 days)



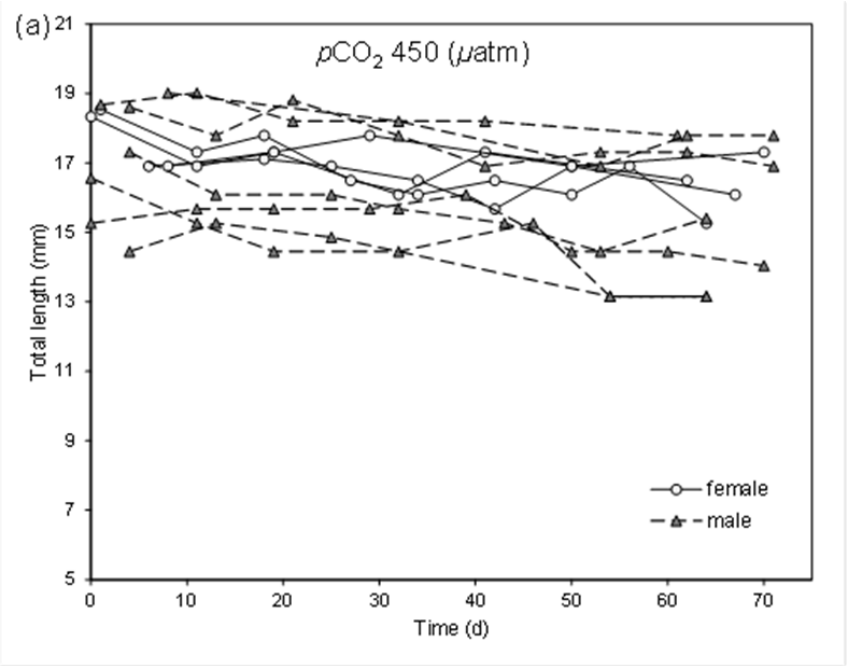
Statistical analyses

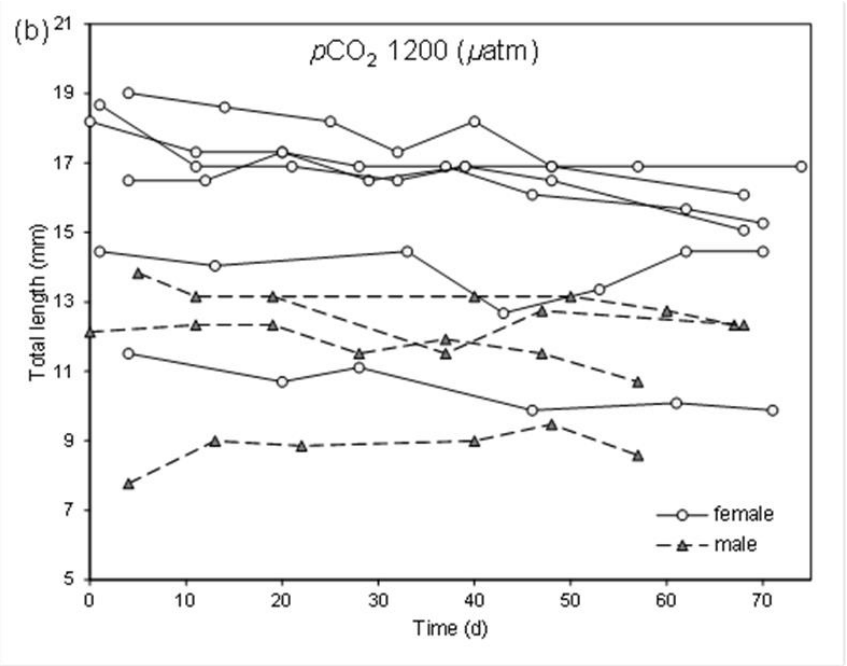
A Log rank test was applied to test for significant differences between survival in the two different pCO_2 levels (Bewick et al. 2004) using the 'survival' package (Therneau 2012) of the statistical software R version 2.15.2 (R Core Team 2012).


2.0 mm

Indvidual growth

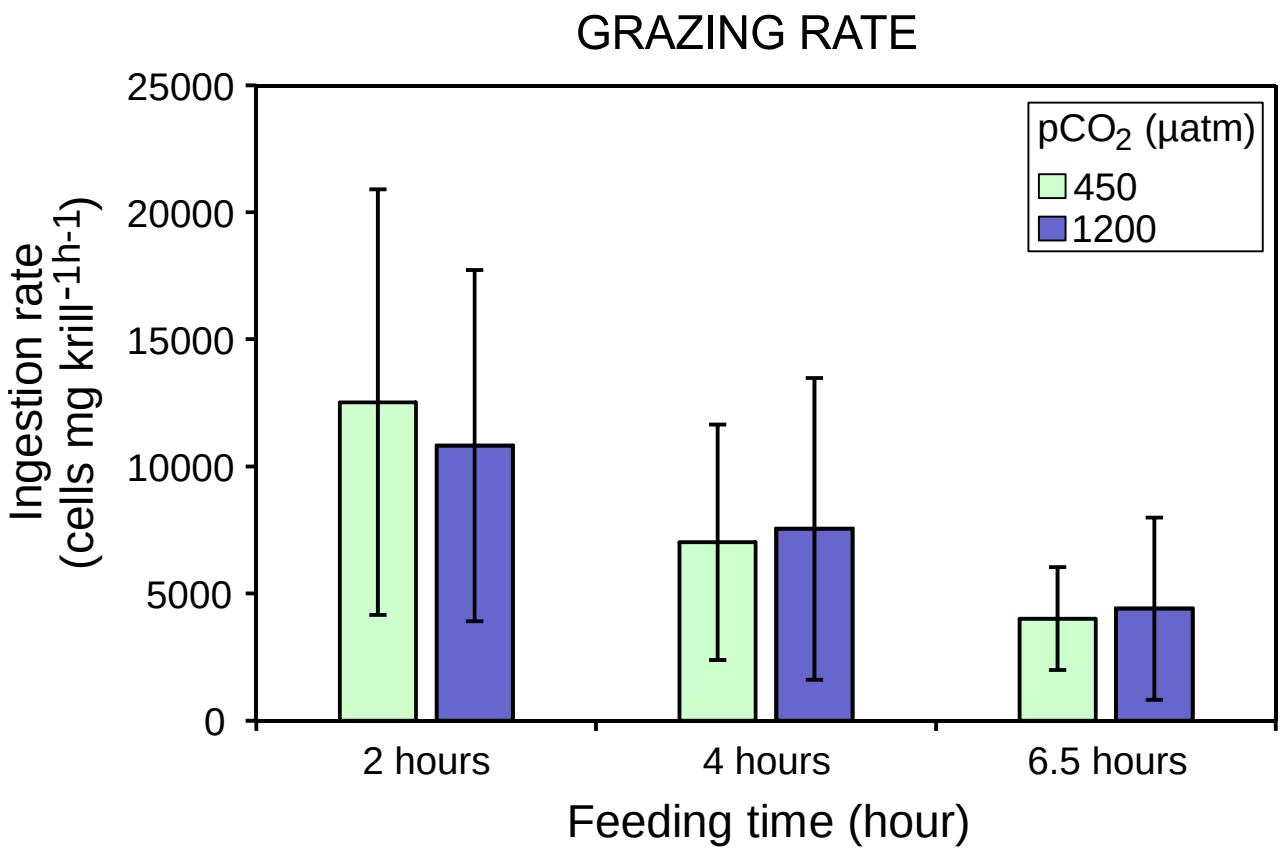
Total length (mm) = (6.817 x uropod length) – 0.957

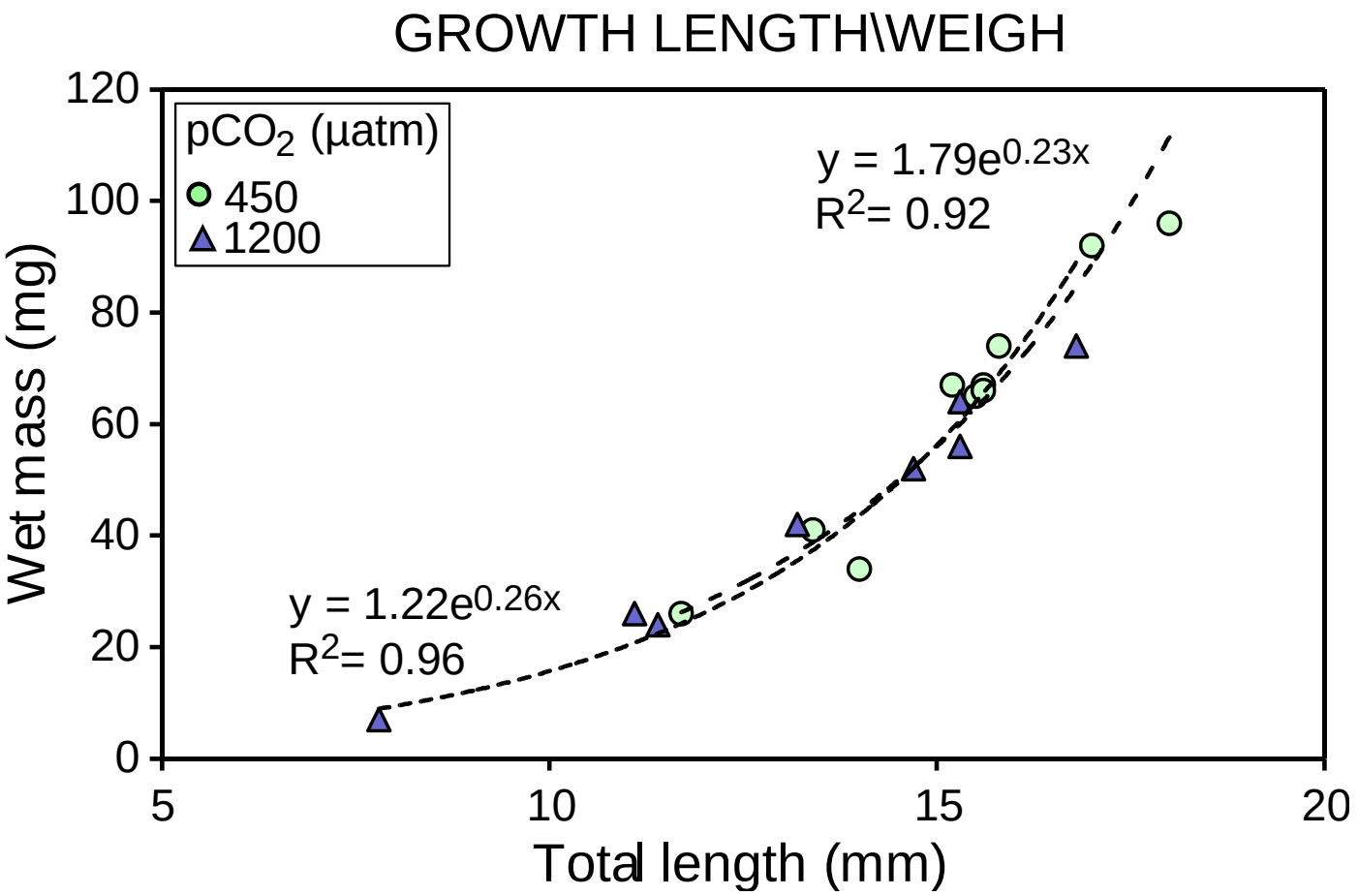




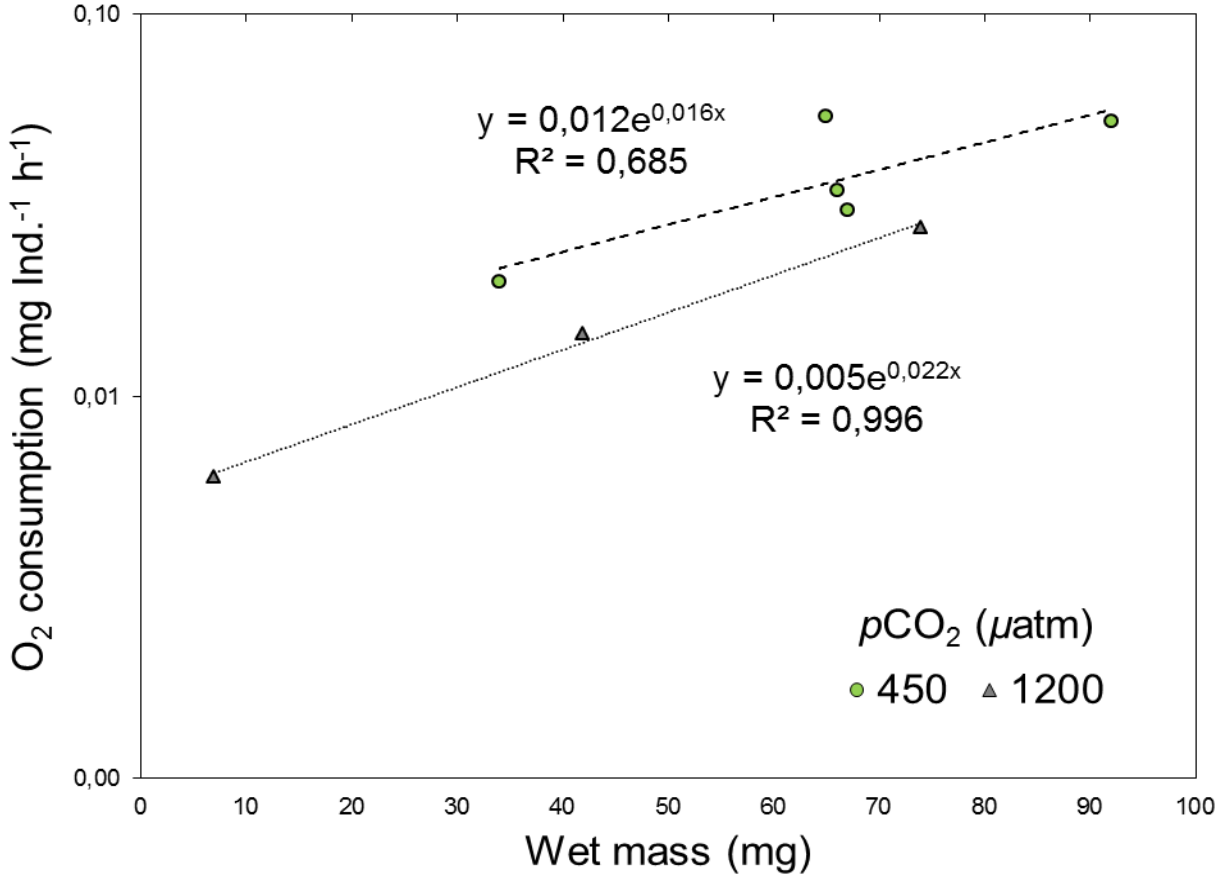
Inter-moult period (d)

pCO2 (µatm)	Inter-moult period (d)	Growth of total length (mm d-1)
450	9.9 ± 0.8	–0.025 ± 0.015
1200	9.1 ± 0.6	–0.021 ± 0.019

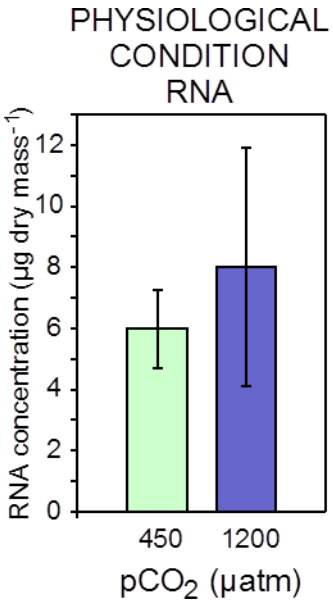

GRAZING RATE
25000
20000
15000
10000
5000
0
Ingestion rate
(cells mg krill-1h-1)
pCO2 (µatm)
450
1200
2 hours
4 hours
6.5 hours
Feeding time (hour)


GROWTH LENGTH\WEIGH
pCO2 (µatm)
450
1200
y = 1.79e0.23x
R2= 0.92
y = 1.22e0.26x
R2= 0.96
Wet mass (mg)
Total length (mm)
0
20
40
60
80
100
120
5
10
15
20

Oxygen consumption



RNA content used as a index to determine physiological condition (Spicer and Saborowski 2010 and growth (Båmstedt and Skjoldal 1980)



Conclusion

From this experimental set up and investigated factors (mortality, intermolt period, uropod length, wet weight, RNA-content, ingestion rate and oxygen consumption)

we only see minor effects on

on *Thysanoessa inermis* from predicted near future, pCO_2.

Thank you

- The crew on R/V Lance and for collecting and shipping krill
- Technical staff at Austevoll
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