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S2.P6. Effects of Ocean Acidification and Warming on the mitochondrial physiology of Atlantic cod

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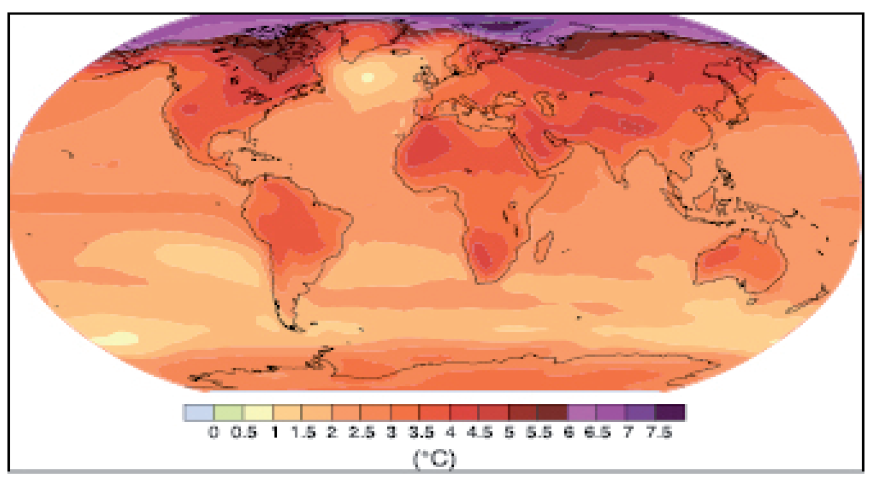
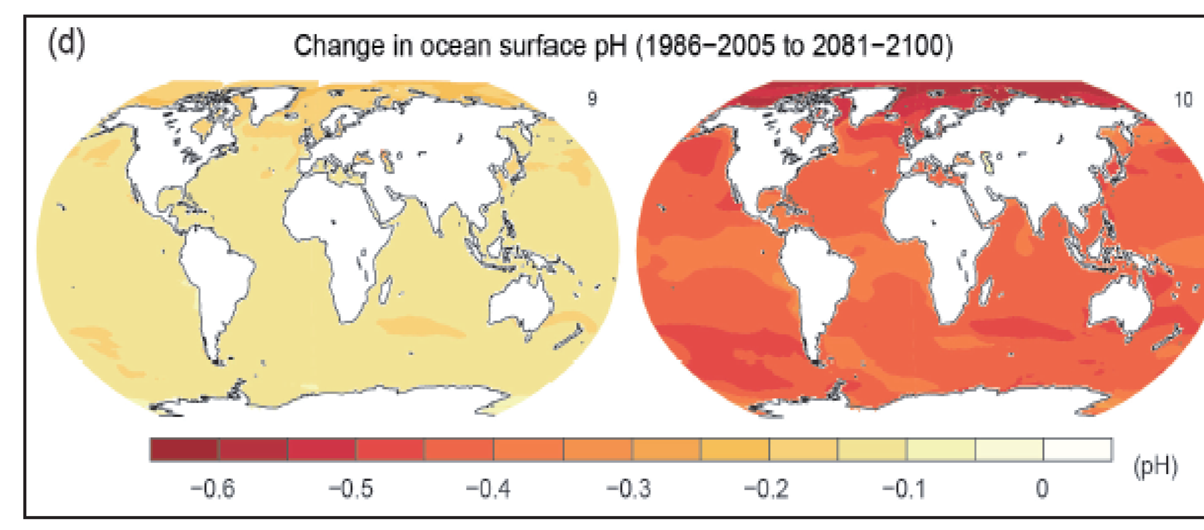
Introduction:

Over the past 250 years atmospheric carbon dioxide (CO_2) levels increased by nearly 40%, from pre-industrial levels of approximately 280µatm to nearly 390µatm in 2011[1]. This rise is expected to continue, leading to significant global temperature increase by the end of this century. This leads to substantial warming of the ocean mean surface temperature and is predicted to rise further by 2- 4.5 °C until the year 2100[1]



Projected surface temperature changes for the late 21st century (2090-2099)[1]

The dissolution of atmospheric CO_2 in the oceans leads to a decrease of the seawater pH commonly stated as Ocean Acidification. During 20th century, pH was lowered by 0.1 units in the global oceans and a further drop of 0.5 units by 2100 is predicted in parallel with the increasing water temperature[1]. An organism's thermal tolerance is influenced by environmental stressors like ocean acidification, e.g. high CO_2 levels can provoke a narrowing of the thermal tolerance window of marine ectotherms[2,3], increasing their thermal sensitivity. These climate changes happen faster in the high latitude oceans with higher increase of temperature and a steeper decrease in water pH.



Comparison between the Observed and Projected surface pH changes for the late 21st century (2051-2100)[1]

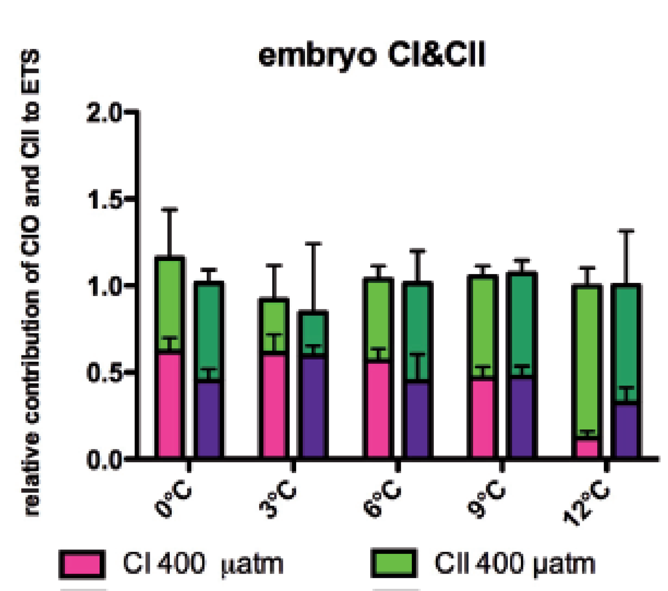
Objectives:

The Atlantic cod (*Gadus morhua*) is an economically important marine fish exploited by both fishery and aquaculture, especially in the North Atlantic and Arctic Oceans.
In this study we investigated the possible difference in sensitivity to climate change in two life stages of Atlantic cod from Skagerrak and Kattegatt and we looked at the effect of CO_2 at the upper side of their thermal window.

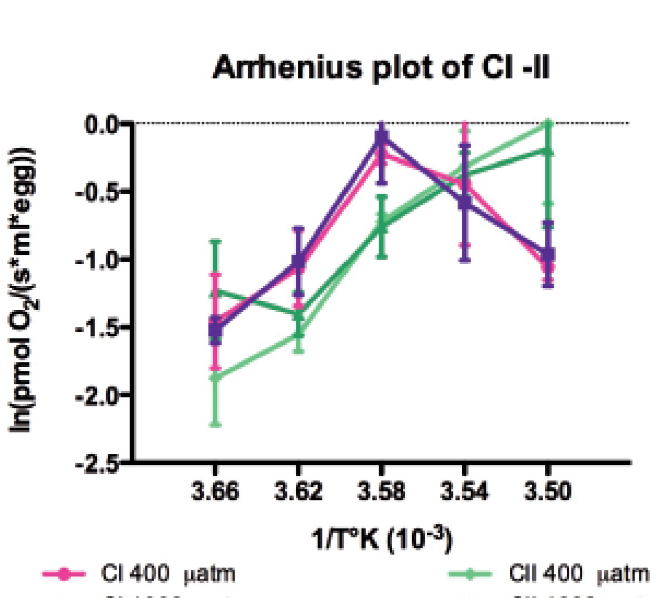
Results:

Embryos

Embryos represent the very early stage of life and they have undifferentiated mitochondrial distribution.
Eggs from Øresund spawners (DK) were fertilized in vitro and incubated until hatching at 0°C, 3°C, 6°C, 9°C and 12°C with CO_2 levels of 400 µatm and 1000µatm, respectively. At the “first heart beat” stage, whole embryo mitochondrial respiration was analysed.



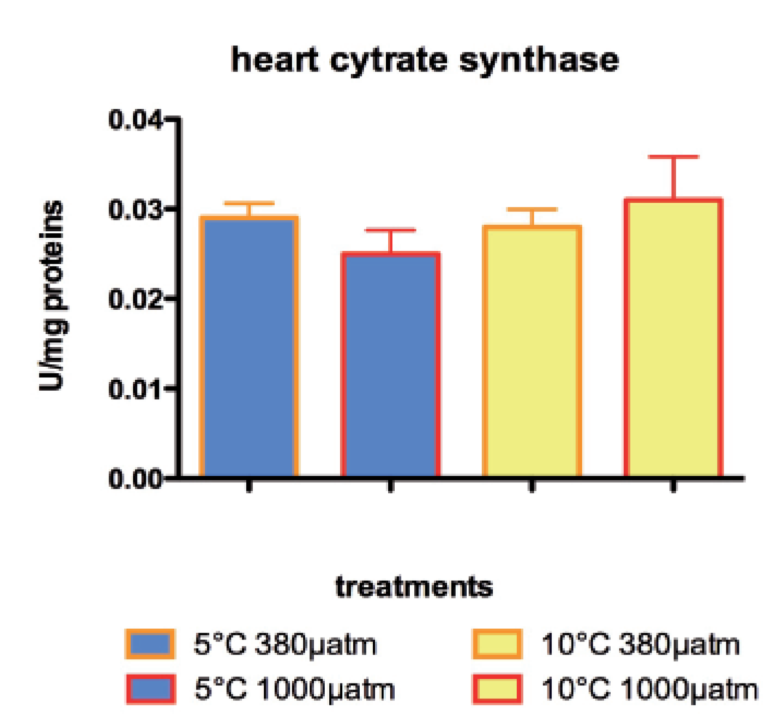
The graph displays the relative contribution of Complex I and Complex II to ETS: the oxygen consumption of both complexes increases with temperature, but at 12°C the contribution of Complex I to the total respiration drops.



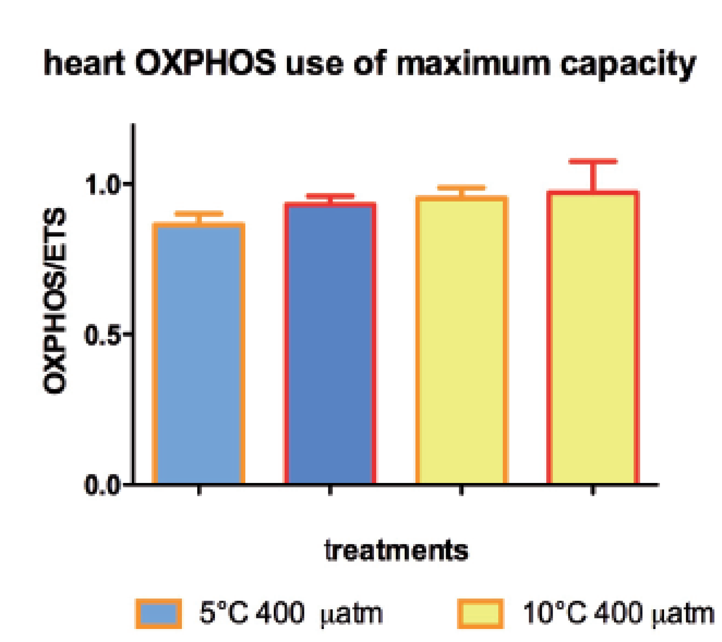
The graph shows the thermal sensitivity of Complex I and Complex II. While the activity of Complex II rises with temperature, Complex I activity drops after 6°C.

Adults

Specimens from Gullmar Fjord (SE) were acclimated for 2 months from control condition of 5°C and 400µatm CO_2 to 10°C and 1000µatm CO_2. After acclimation the mitochondrial respiration of the heart was analysed. The highly aerobic fish heart is most sensitive to temperature and fails before any other organ at the thermal limits, providing a very suitable model to investigate aerobic capacity.



In the heart, mitochondrial respiration remains stable troughout all acclimation scenarios, indicating full metabolic compensation of thermal influence.



However, the proportion of the maximum capacity of the ETS used by oxidative phosphorylation (OXPHOS) increases with temperature and CO_2 level until the capacity limit is reached in the 10°C +1000µatm CO_2 acclimated group.

Conclusions:

Data from embryos and adults allow for a wider view of the effects of climate change on the North Atlantic cod population. At the mitochondrial level, the embryos (with not completely developed compensatory systems) are not affected by high CO_2 levels but by rising temperature. Whereas adult cod coped with the current trend of climate change.

Data from embryos and adults allow for a wider view of the effects of climate change. The drop in activity of Complex I at 12°C indicates that this temperature is already beyond the embryonic thermal limit. The result, combined with the use of the maximum of the respiratory capacity in the heart of the adult fish at 10°C+1000µatm CO_2 suggests that a further increase in temperature and CO_2 will influence the population at different life stages, affecting the embryonic development and imparing mitochondrial respiration in heart of adults resulting in reduced cardiac output.

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2. **Metzger et al. 2007.** J. Thermal Biology
3. **Dissanayake & Ishimatsu 2011.** ICES J. Marine Science