Polar cod: physiological sensitivity of an Arctic key species to climate change

In the past, increased emissions of anthropogenic greenhouse gases have already caused extreme climatic changes in ecosystems around the world. One of those dramatically affected ecosystems is the Arctic, where higher atmospheric temperatures have already caused a loss of almost 50 % sea ice coverage, within the last two decades of the 20th century [1][2][3]. This dramatic sea ice loss can also be observed in the fjord systems of the Svalbard archipelago [4] [5]. To close gaps in knowledge and predict future climate change scenarios in these already severely affected polar ecosystems, we have addressed all kinds of questions about the evolution, phenology, physiological and epigenetic adaptation of Arctic (and Antarctic) key species. Thus during the last decade, our working group (Integrative ecophysiology, AWI) focused on the physiological sensitivity and adaptive potential of an Arctic key species Polar cod, *Boreogadus saida* to various climate change scenarios. Polar cod is one of the most abundant fish species inhabiting the deep fjord basins of Svalbard. Feeding on small invertebrates such as copepods, amphipods, gastropods and krill and being themselves a main food source for large fish, marine birds, and mammals, Polar cod build the link between the lower trophic levels and top predators, and are therefore of great importance for the whole Arctic ecosystem [6].

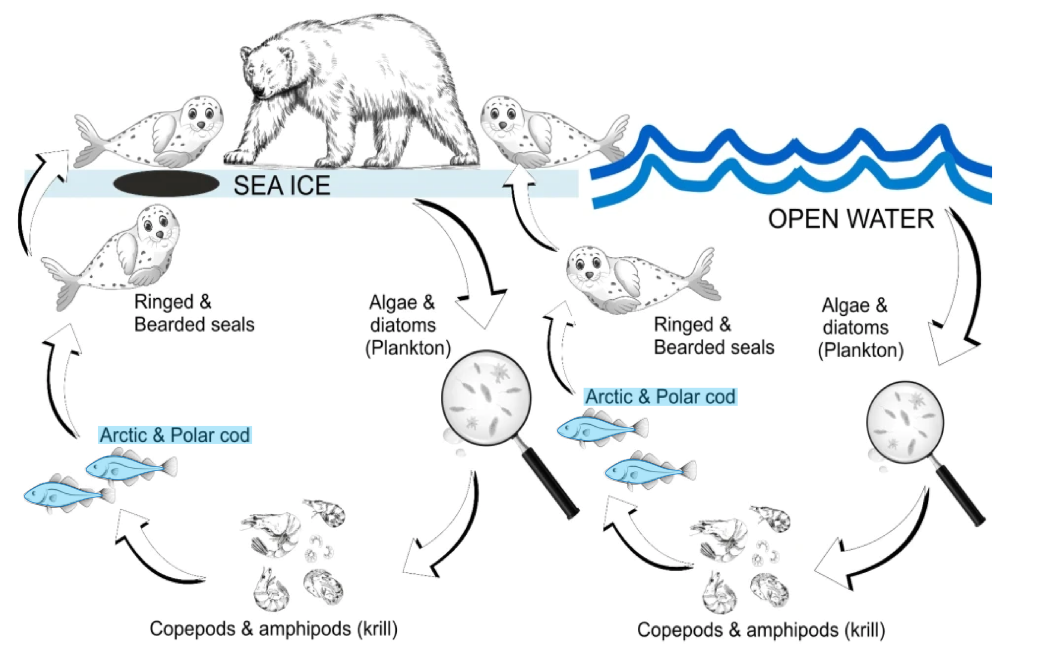

Fig. 1: Arctic food web

In the light of the Topic 6.2 program, our working group looked at different organizational levels, from the whole organisms performance to epigenetic adaptations using following approaches:

Metabolic, swimming, and cardiac performance

- warming and hypoxia -

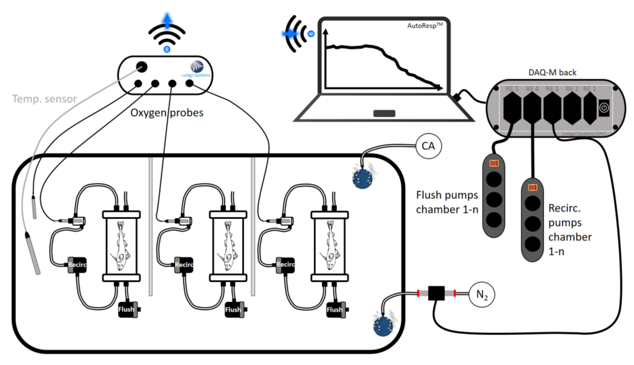

Fig. 2: Schematic respiration chamber system

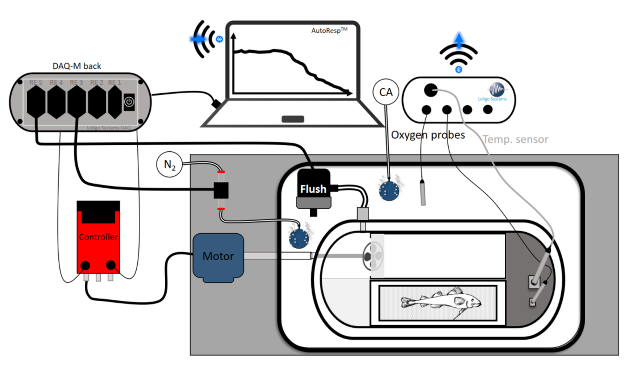

Fig. 3: Schematic swim tunnel system

Fig. 4: Implantable heartrate bio-logger (Star-Oddi, Iceland)

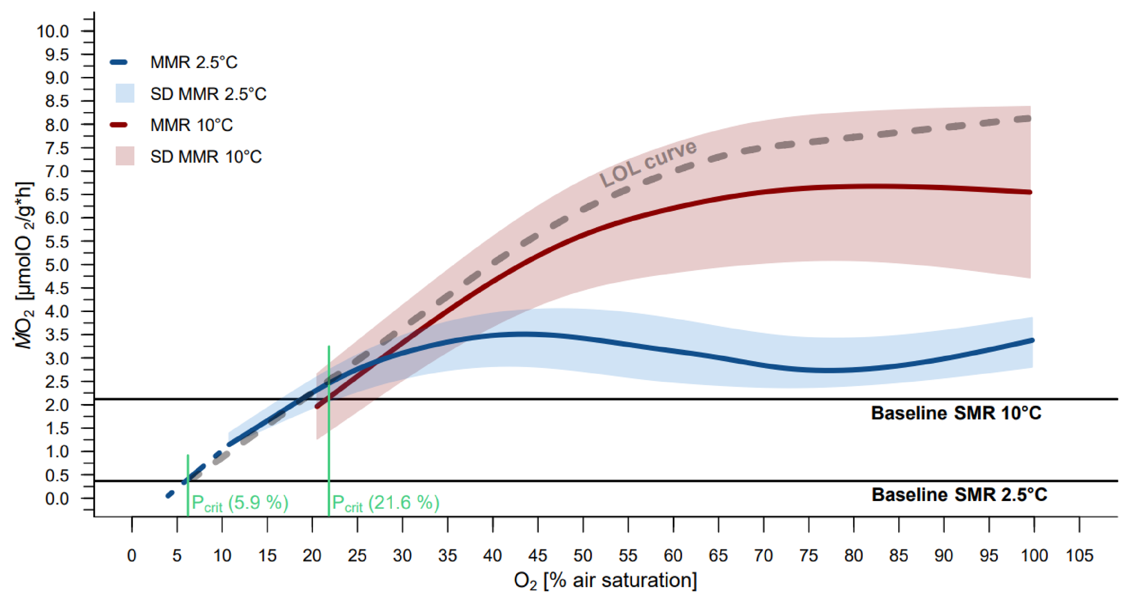

Fig. 6: Temperature-specific limiting oxygen level (LOL) curve after Claireaux and Chabot (2016) (Kempf et al. in prep)

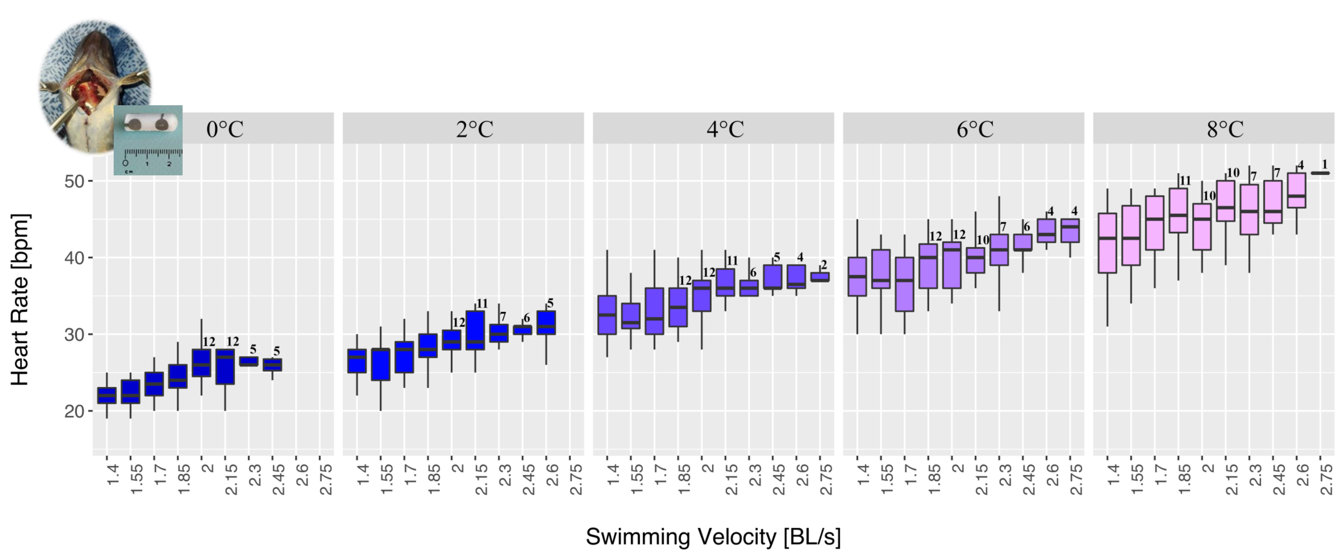

Fig. 5: Bio-logged, temperature-specific heart rate measurements (Kuchenmüller et al. in prep)

Phenology

- gonad development over a seasonal cycle -

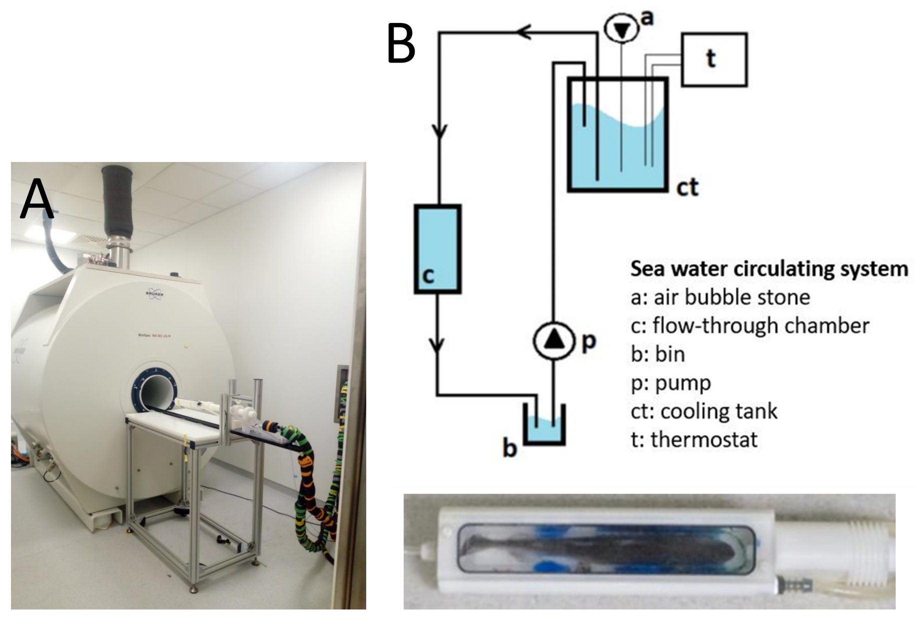

Fig. 7: **(A)** Nuclear magnetic resonance (NMR) scanner, **(B)** scheme of sea water circulation system

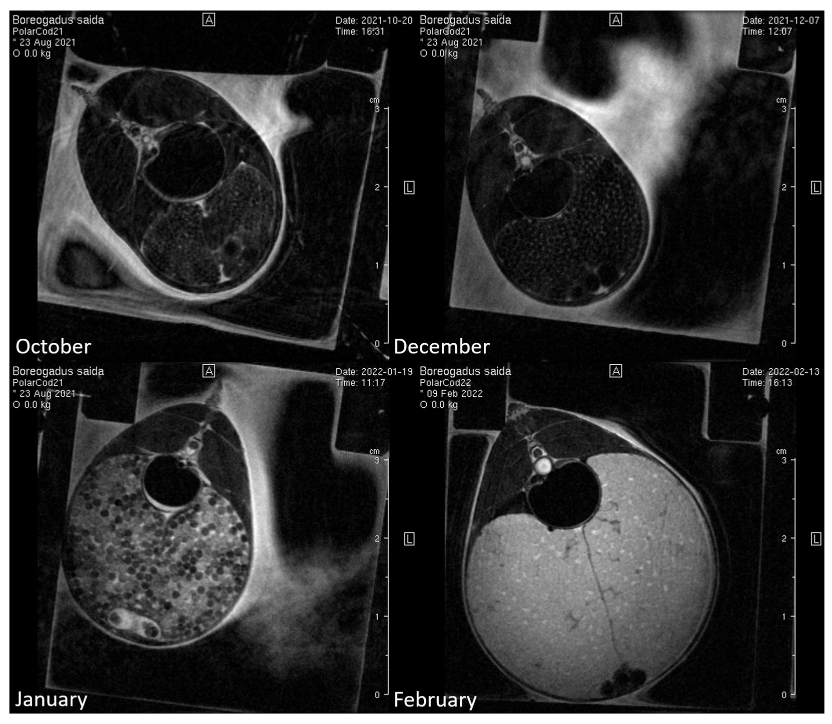

Fig. 8: axial *In vivo* RARE images of seasonal development of female gonads at 9.4 T (Vogt et al. in prep)

Metabolomics and epigenetics

- warming and acidification -

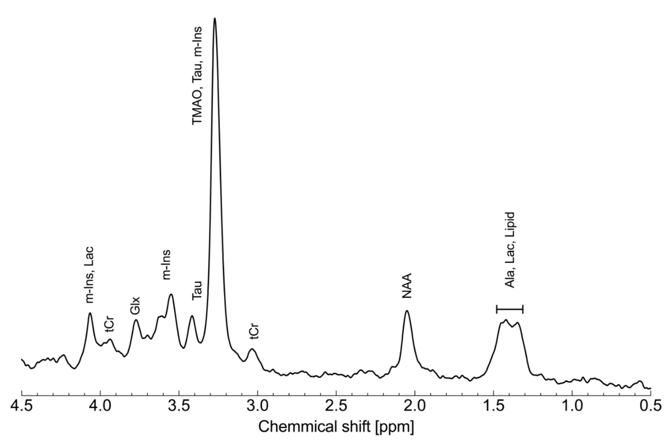

Fig. 9: *In vivo* localized ^{1}H MR spectrum at 9.4 T in brain (Wermter et al. 2018)

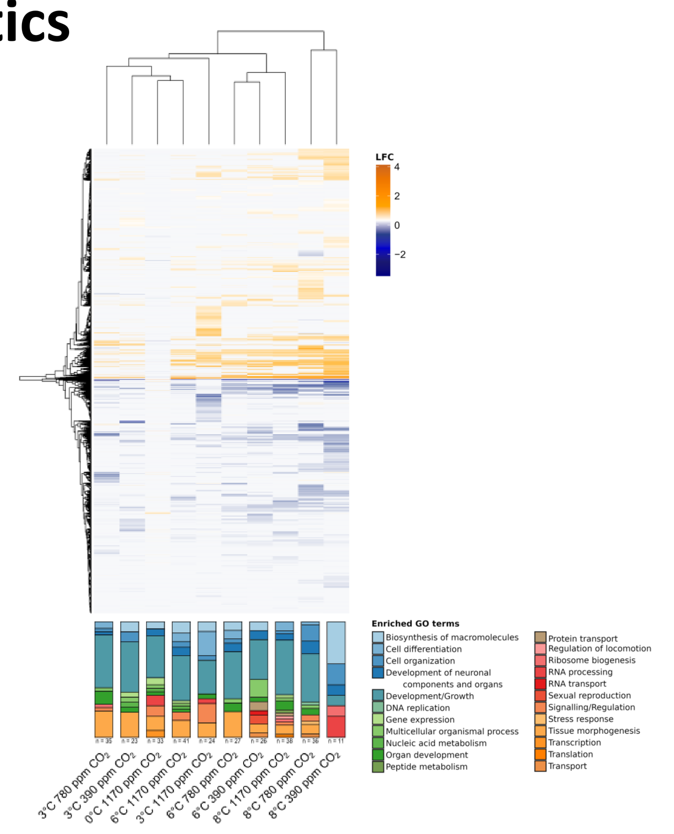

Fig. 10: Differentially expressed genes (DEG) and enriched GO terms (Kempf et al. in prep)

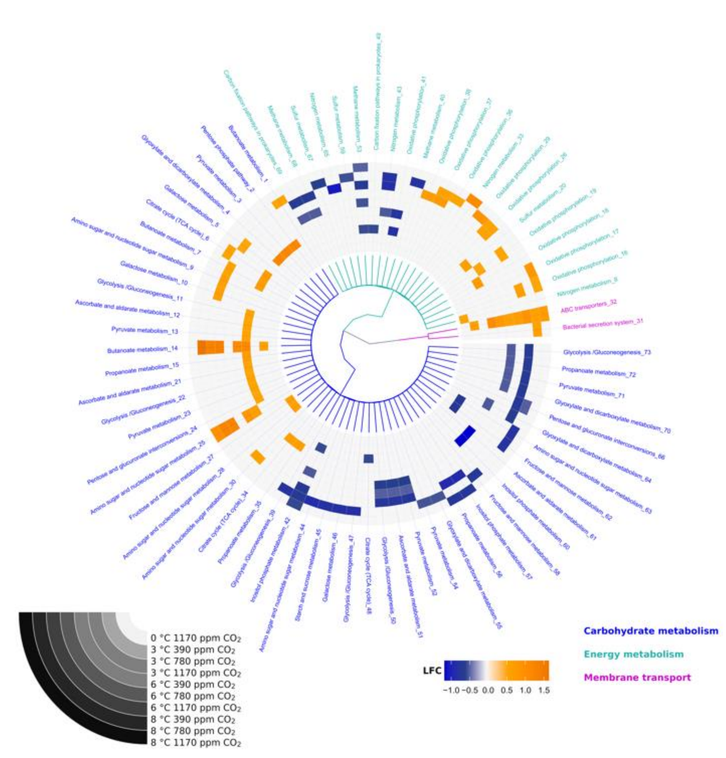

Fig. 11: KEGG pathway analysis of DEGs (Kempf et al. in prep)

Conclusion

warming and hypoxia: Polar cod is an extremely hypoxia tolerant/compensating fish species, has an extraordinary oxyregulating capacity, little anaerobic capacities and low baseline metabolism, wirh a P_{crit} of 5.9 % a.s. at optimum temperature and 21.6 % a.s. at 10 °C, generally displays a very low heart rate (ƒH) of 8bpm, primary dependency of ƒH and $\dot{M}O_2$ during acute warming, suggesting a species-specific potential of ƒH as a proxy for energy expenditure

gonad development over a seasonal cycle: parameter adaption for gonad visualization

warming and acidification: in general only moderate changes in NMR spectrum as well as genetic patterns, more distinct thermal reaction than reaction to elevated PCO_2, optimum temperature for aerobic scope for exercise at 6 °C mirrored by high gene activities at 6°C throughout the CO_2 range

References
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