Thermal sensitivity of energy budgets in Antarctic fish hepatocytes

Felix Mark, Timo Hirse, Hans-O. Pörtner

Alfred Wegener Institute for Polar and Marine Research

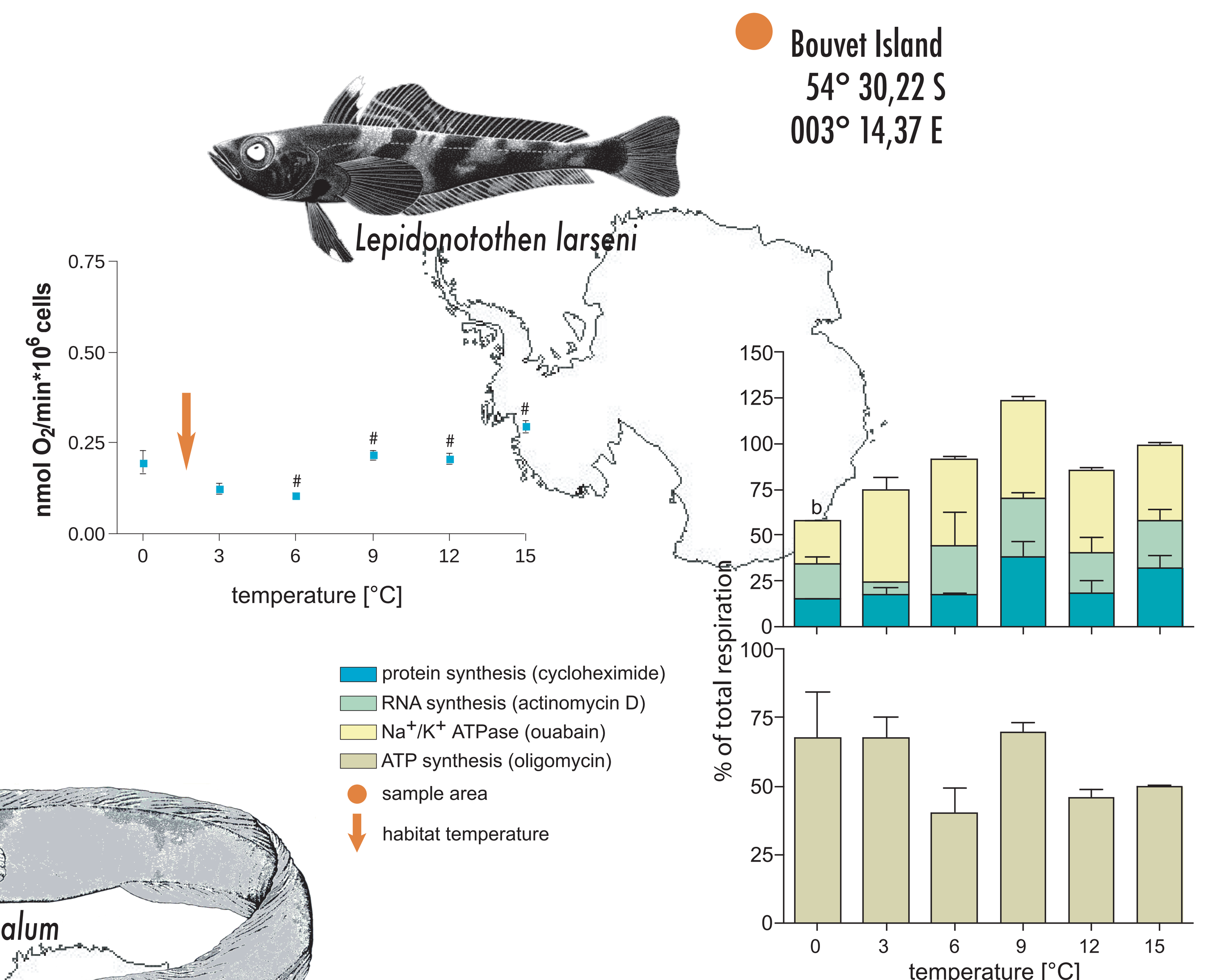
introduction

Specialisation to the cold has rendered many Antarctic fish species much more susceptible to stress induced by warming than their temperate relatives. This leads to very low systemic heat tolerance and upper lethal temperatures of as low as 5-6°C for some high Antarctic notothenioids. For analysis of the effects of temperature on metabolic energy allocation at the cellular level, we focused on both energy requiring and energy providing processes.

Which processes are influenced by temperature and may become limiting at which functional level?

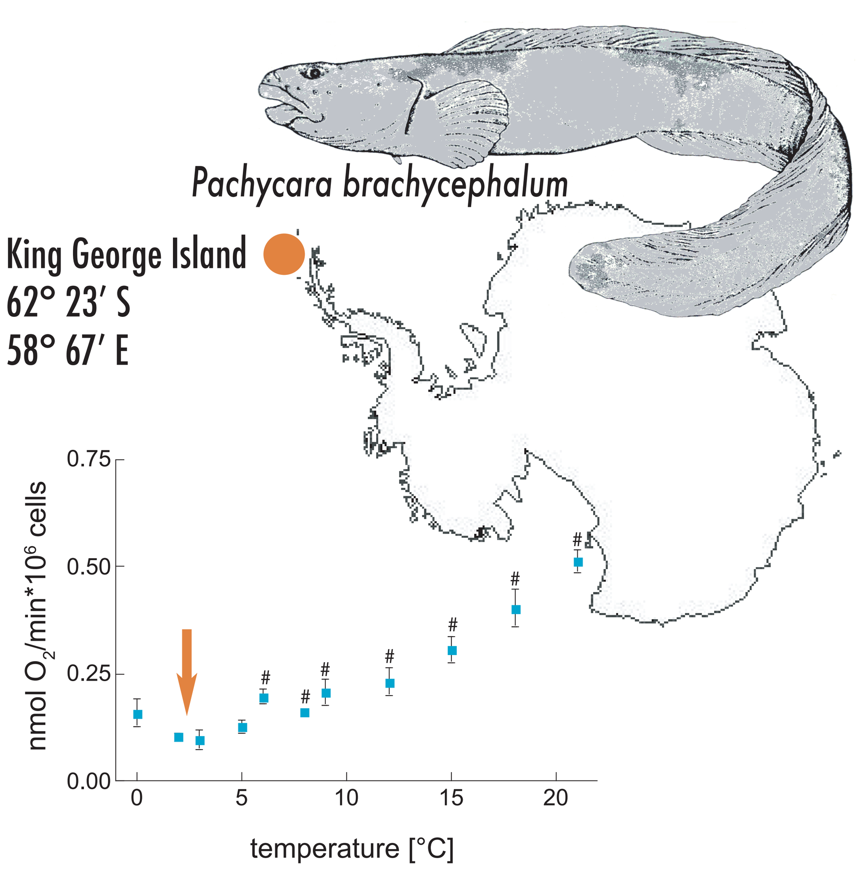
Comparing three high Antarctic notothenioids and two low Antarctic fish species of similar ecotypes, we investigated whether the proportions of energy allocated to specific processes in the cell underlie thermally induced changes. Cellular respiration and the fractional contributions of RNA and protein synthesis, ion regulation (Na^+/K^+ ATPase) and ATP synthesis to energy turnover were measured at temperatures ranging from 0 to 15°C [1].

low antarctic species

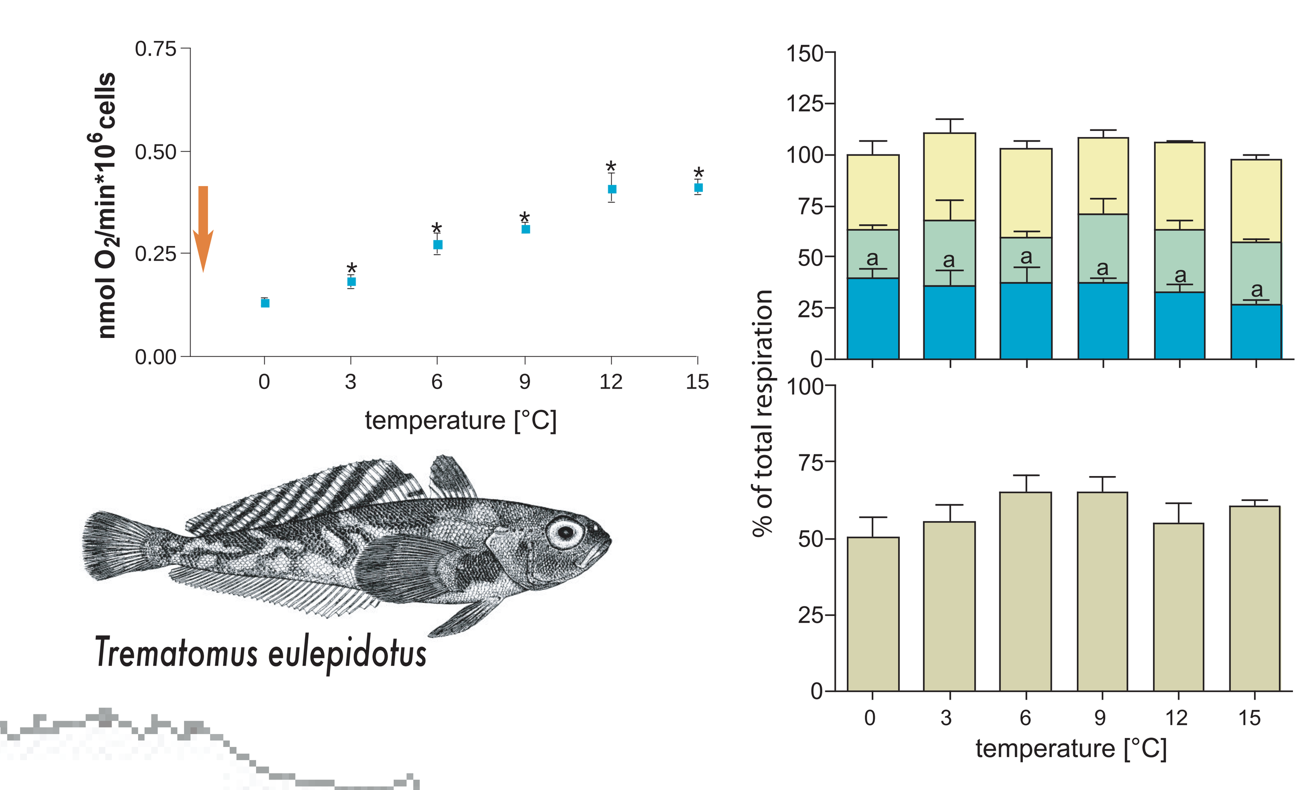


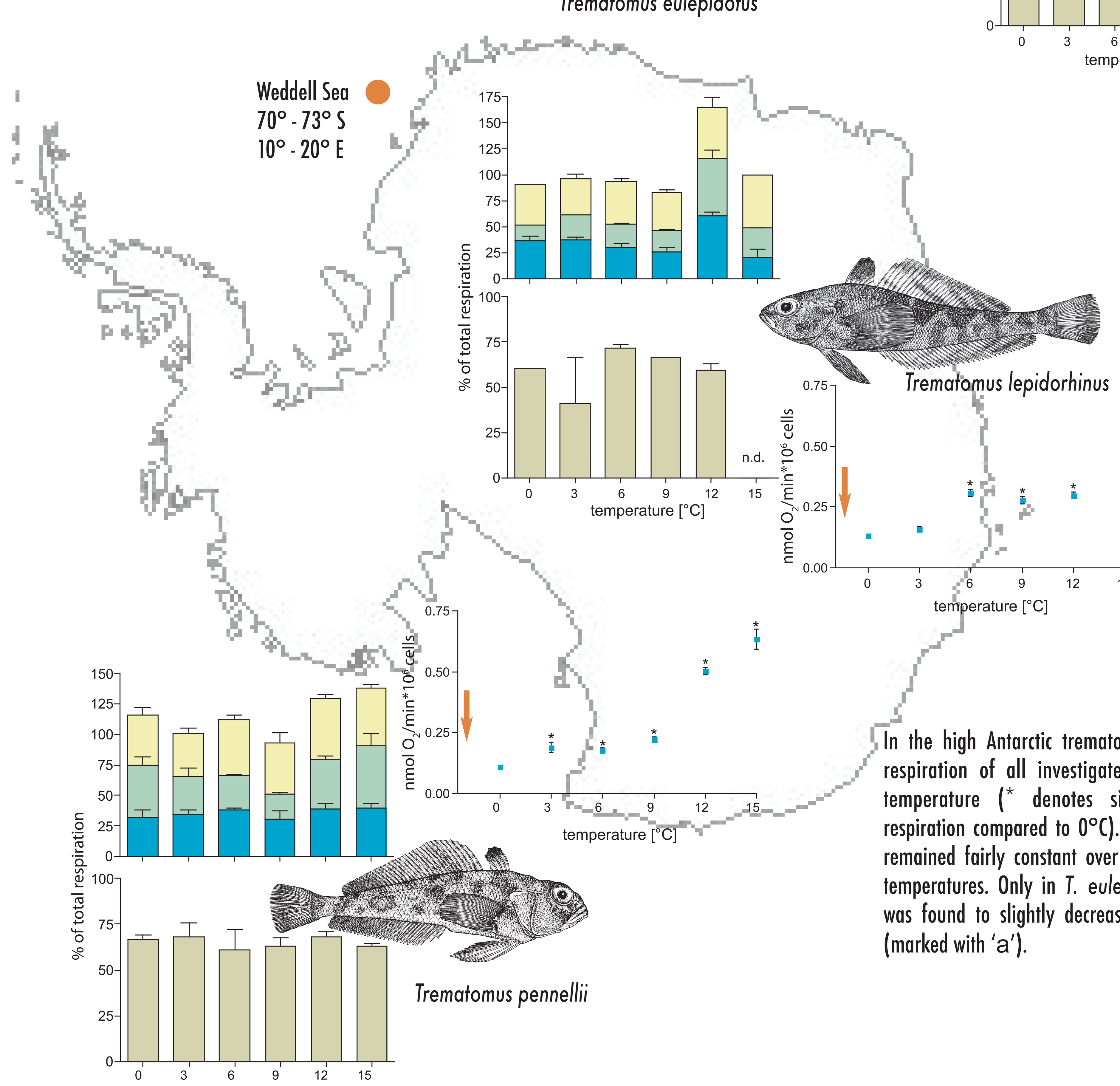
Right & below: Respiration rates of hepatocytes of the notothenioid *L. larseni* and the zoarcid *P. brachycephalum*, representing low Antarctic species, measured between 0 and 15°C.
#: significant differences in respiration compared to cells at 3°C.
Note that cellular respiration also increased below habitat temperatures.

Top: Cellular energy provision by ATP synthesis and allocation to protein and RNA synthesis and ion regulation (Na^+/K^+ ATPase) in hepatocytes of *L. larseni*, measured between 0 and 15°C. Energy allocation did not change significantly with increasing temperatures.



high antarctic species





In the high Antarctic trematomid notothenioids, cellular respiration of all investigated species increased with temperature (* denotes significant differences in respiration compared to 0°C). Cellular energy allocation remained fairly constant over the investigated range of temperatures. Only in *T. eulepidotus*, protein synthesis was found to slightly decrease with rising temperature (marked with 'a').

conclusions

Although low Antarctic species appear to have wider ranges of thermal tolerance than high Antarctic species, almost no shifts in energy allocation could be found at the cellular level.

Average habitat temperatures are reflected in lowest rates of cellular oxygen consumption, where energy metabolism is most efficient. As long as isolated cells are sufficiently supplied with oxygen and glucose, restrictions in energy turnover and shifts in allocation do not become evident at the cellular level.

Further investigations at the whole animal level will have to show whether whole animal thermal tolerance is restricted by increased energy consumption of the cardiovascular system, which is designed to perform optimally only within the thermal tolerance window [2].

Bottlenecks hence appear to be located at higher systemic levels. In accordance with a previous hypothesis, constraints in O_2 supply may thus build the basis for biogeographical distribution [3].

Correspondence:
Dr Felix Mark
Marine Animal Ecophysiology
Alfred-Wegener-Institut für
Polar- und Meeresforschung
27570 Bremerhaven, Germany
email: fmark@awi-bremerhaven.de

References: 1) Mark et al. (2005) Polar Biol DOI: 10.1007/s00300-005-0018-0
2) Mark et al. (2002) Am. J. Physiol. 283: R1254-1262 3) Pörtner (2002) Comp. Biochem. Physiol. 132(4): 739-761