Energy budgets in antarctic & boreal fish

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introduction

Slower growth and lower relative fecundity of Antarctic fish as compared to their temperate relatives are related to specific energy requirements for metabolic processes in the cold and low or seasonally restricted food availability. Investigating effects of temperature on metabolic energy allocation at both cellular and whole animal level we focused on the energy requiring processes.

Which processes are influenced by temperature and at which level?

Comparing five high Antarctic and two sub Antarctic fish of similar ecotypes, we investigated whether the proportions of energy allocated to specific metabolic pathways in the cell underlie thermally induced changes. The fractional contributions of RNA and protein synthesis, ion regulation (Na^+/K^+ ATPase) and ATP synthetase to energy turnover were measured at temperatures ranging from 0 to 15°C. At the whole organism level energy uptake and dissipation at maximum food availability as well as growth were studied at temperatures between 4 and 6 °C in an Antarctic and a boreal eelpout.

cellular energy budget

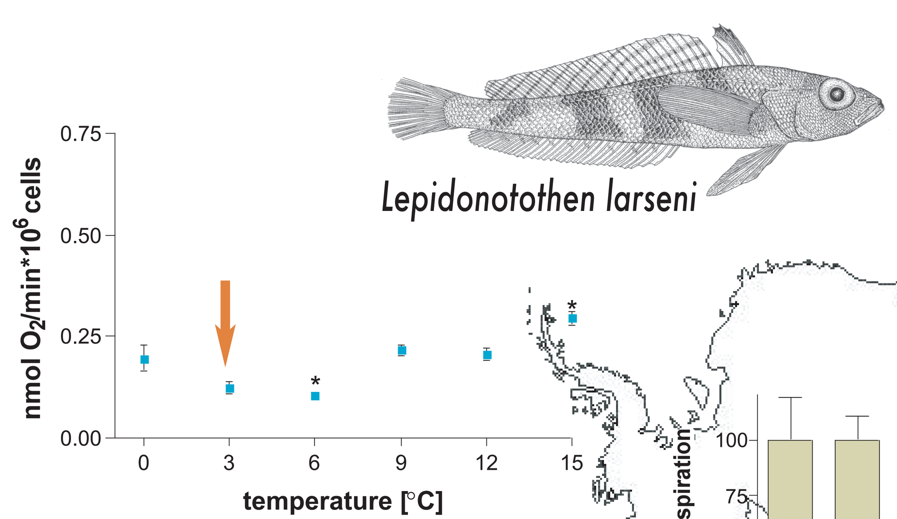


Figure 1: Respiration rates of hepatocytes of *Lepidonotothen larseni*, representing sub-Antarctic species, measured between 0 and 15°C. * denote significant differences in respiration compared to cells at 0°C. Respiration increased significantly only above 12°C, indicating a wider range thermal tolerance of this sub- Antarctic species.

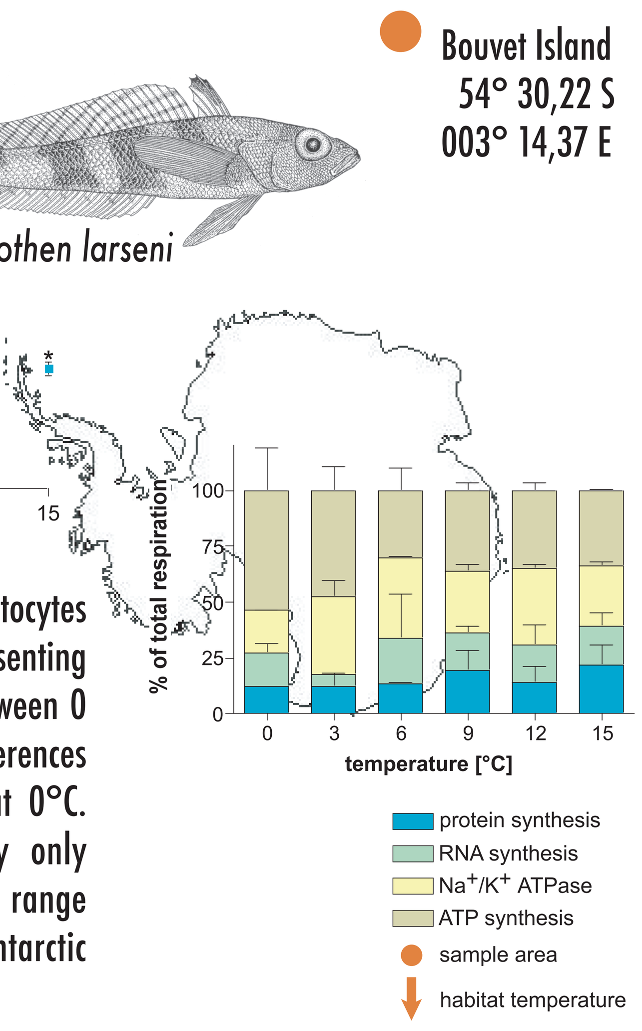


Figure 2: Cellular energy allocation to protein and RNA synthesis, ion regulation (Na^+/K^+ ATPase) and ATP synthetase in hepatocytes of *Lepidonotothen larseni*, measured between 0 and 15°C. Relative energy allocation did not change significantly with increasing temperatures, even beyond 12°C.

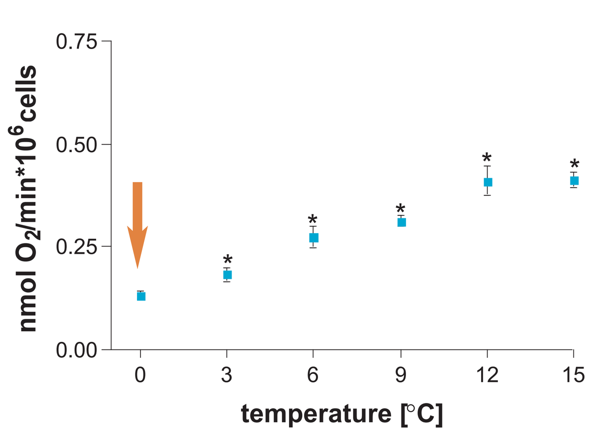
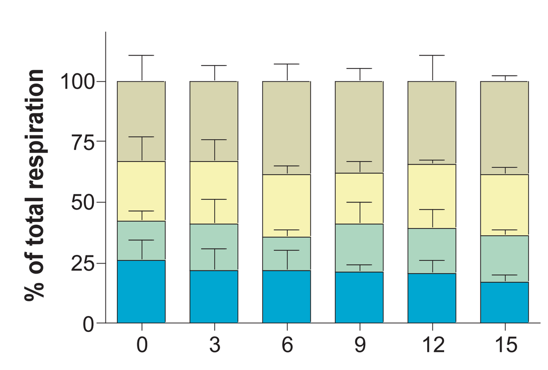


Figure 3: Cellular energy allocation to protein and RNA synthesis, ion regulation (Na^+/K^+ ATPase) and ATP synthetase in hepatocytes of *Trematomus eulepidotus*, measured between 0 and 15°C. Relative energy allocation does not change significantly with increasing temperatures.



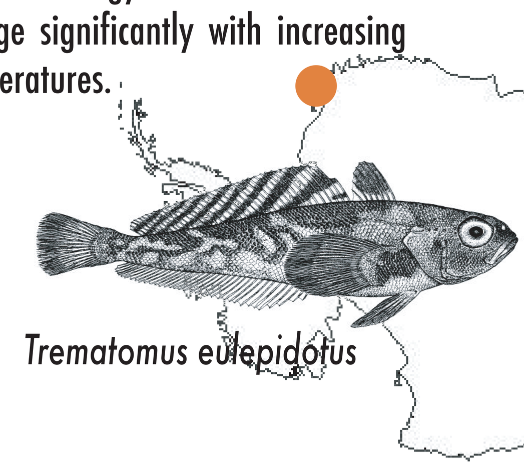


Figure 4: Respiration rates of hepatocytes of *Trematomus eulepidotus*, representing the high Antarctic notothenioids, measured between 0 and 15°C. * denote significant differences in respiration compared to cells at 0°C. Respiration increased significantly above 3°C.

whole organism energy budget

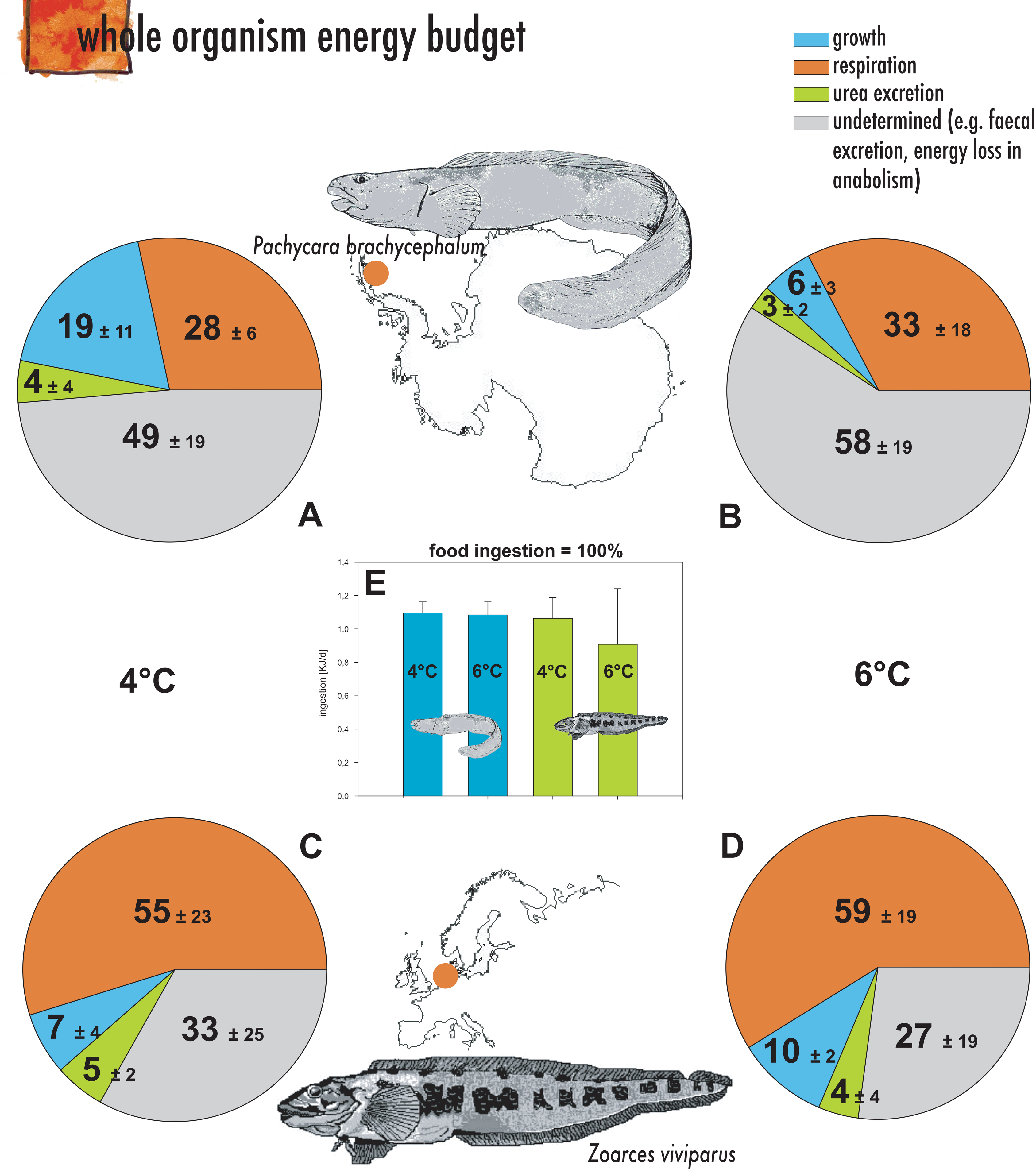


Figure 5.: Organismic energy allocation in the Antarctic eelpout *Pachycara brachycephalum* (A, B) and the boreal eelpout *Zoarces viviparus* (C,D) at 4 and 6°C. Food ingestion is for both species at these temperatures the same (E) and was normalizied to 100% for the pie charts[1]. During this acclimation to 6 °C, energy allocated to growth decreased significantly in *P. brachycephalum*, while it was increased in *Z. viviparus*.

conclusions

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

At the whole organism level, we observed a decrease in energy allocated to growth towards ecological temperature limits.

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 energy (oxygen, glucose), restrictions in energy turnover and shifts in allocation do not become evident at the cellular level. Regulative mechanisms hence appear to be located at higher systemic levels and funnel energy into growth and other organismic processes and thus build the basis for biogeographical distribution.

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

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References:
1) Cui & Liu (1990) Comp. Biochem. Physiol., 97A, no. 3, 381-384 ; 2) Mark et al. (2002) Am. J. Physiol. 283: R1254-1262.