Oxygen Supply Capacity of Atlantic Stingray (Hypanus sabinus) and Hardhead Catfish (Ariopsis felis) Across Temperature

FSU | FLORIDA STATE UNIVERSITY

FSU UNDERGRADUATE RESEARCH OPPORTUNITY PROGRAM
CENTER FOR UNDERGRADUATE RESEARCH & ACADEMIC ENGAGEMENT

FLORIDA STATE UNIVERSITY FSUCML Est. 1949 COASTAL & MARINE LABORATORY

Leith Schieferdecker, Brantley Bellamy, and Dr. Alyssa Andres

Background

Temperature strongly influences physiological processes in ectotherms, and environmental shifts can alter an organism's ability to derive energy and perform basic life functions, threatening loss of habitat and population success as conditions become physiologically unsustainable. This is particularly relevant for coastal species that dwell in the Northeastern Gulf of Mexico, among the fastest warming locations in the world.

Temperature is also known to alter the ability of organisms to supply oxygen to tissues in support of energy needs. Because oxygen is required for almost all life functions, from digestion to movement to reproduction, oxygen delivery is a key component of performance and survival of fishes in an ara of climate change. While oxygen supply is known to increase with temperature in ectotherms to support increased oxygen and energy demands at higher temperatures, failure to meet oxygen demands at a critical temperature has also been indicated as a primary limiting factor of thermal tolerance in several fish species. In addition, rising water temperatures worsen deoxygenation of ocean waters, threatening a mismatch of oxygen supply and demand as conditions become unsustainable in the wild.

We studied the effects of temperature on oxygen supply in two species native to the Northeastern Gulf of Mexico, the Atlantic Stingray (Hypanus sabinus) and Hardhead Catfish (Ariopsis felis), both coastal, benthic-associated ectotherms in a region of high warming. Using energetic measurements and blood physiology we investigated temperature sensitivity of oxygen supply and one potential mechanism for the potential to increase oxygen delivery as temperatures rise, over a range of temperatures for each species.

Hematocrit Methodology

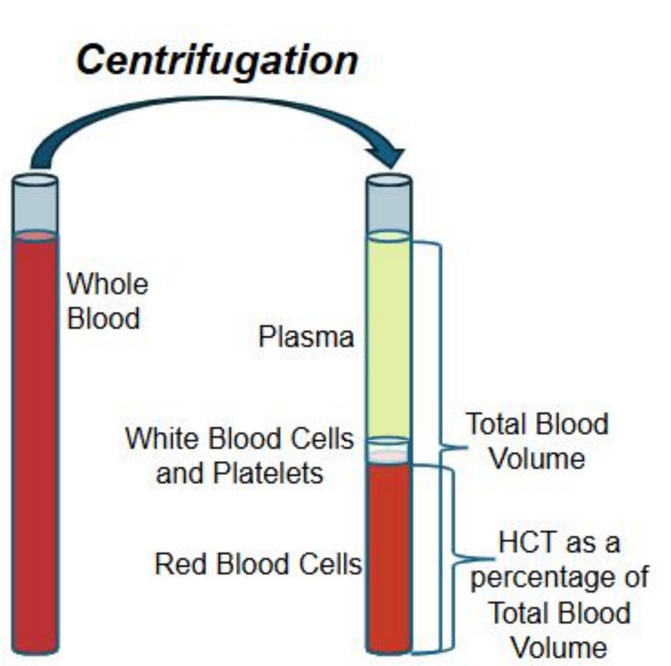

Figure 1

Hematocrit, the ratio of red blood cell volume to total blood volume, is one representative measure of the oxygen carrying capacity in the blood. To measure hematocrit, whole blood was collected at each temperature of acclimation. The sample was then centrifuged in order to separate the red blood cells so that hematocrit could be determined. Because red blood cells carry oxygen, a sample with a greater HCT may indicate a greater oxygen carrying capacity in the blood.

Terminology

- **MO_2**: metabolic rate of oxygen consumption
- **MMR**: Maximum Metabolic Rate – highest metabolic rate measured
- **SMR**: Resting Metabolic Rate – lowest rate needed to sustain conscious organism at rest
- **PcSMR**: Critical oxygen level – low oxygen level that limits resting metabolic rate, a level at which survival is time limited
- **AS**: Aerobic Scope – represented as the difference/quotient of MMR and SMR, energetic scope for all life activities
- **Alpha (α)**: Oxygen supply capacity – a measure of the maximum ability to supply oxygen to respiring tissues
- **HCT**: Hematocrit – Ratio of red blood cell volume to total blood volume

Respirometry Methodology

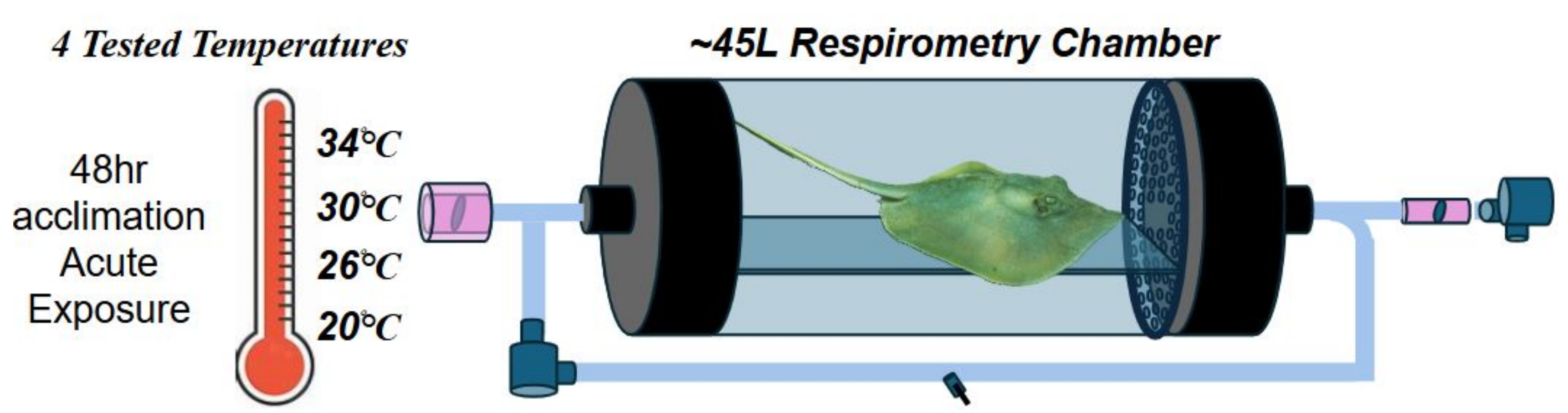

Figure 2

Intermittent respirometry with 10 minute closed measure periods was used to determine rates of fish oxygen consumption.

- To achieve both maximum energy demands and lowest energy demands the fish was first chased to exhaustion and then immediately placed in the respirometry chamber. This was followed by undisturbed rest in the chamber for 24 hours.
- The highest metabolic rate measured, usually occurring during the initial recovery from the chase, was the MMR.
- SMR was taken as the average of the lowest 10% of MO_2 measures after the first 5 hours of the trial.
- After 24 hours, intermittent flushing to reoxygenate the chamber after each closed measure period was ceased (no new, oxygenated water is being introduced to the chamber). O_2 was depleted until PcSMR was reached (another place at which fish maximally supply oxygen to their bodies
- The slope of the linear regression of the decline of oxygen in each closed measure period (O_2 vs Time) was used to calculate MO_2 for each 10 min closed measure in MMR-SMR-PcSMR trial
- Thermal sensitivity (E) of all metrics were taken from Arrhenius relationships for all metrics

Results

Hematocrit (HCT) of Hardhead Catfish and Atlantic Stingray at a range of temperatures

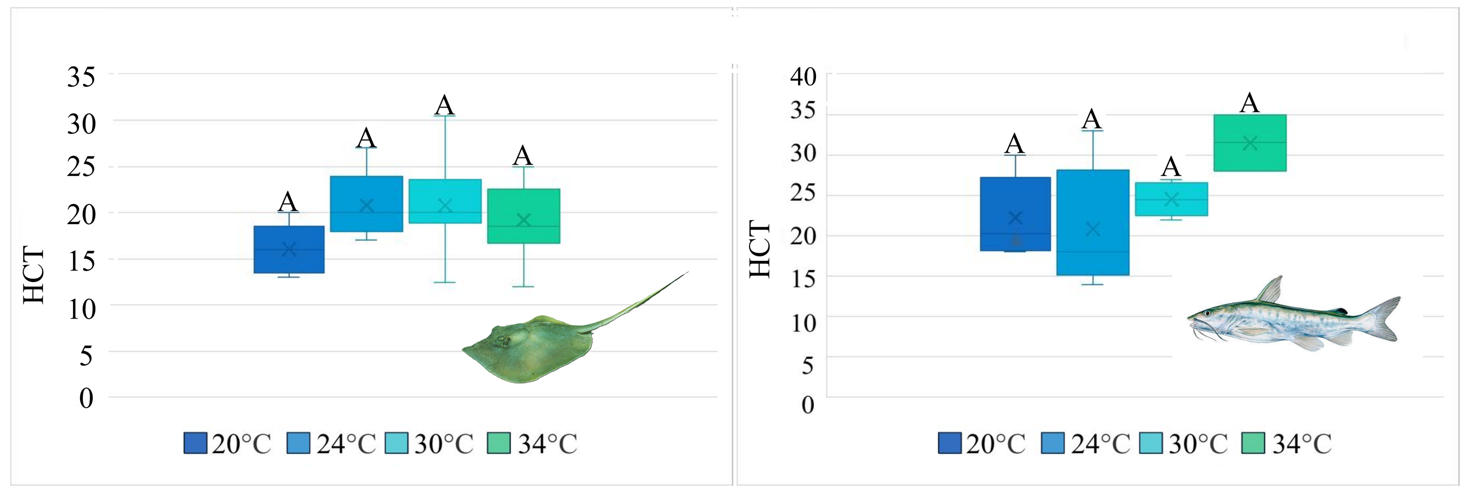

Figure 3

In the figure above, HCT box and whisker plots denote min, max, median, and quartiles of HCT across temperature. **No statistically significant thermal trend in HCT has been demonstrated for either species thus far. An increased sample size is needed in future research. Different letters above boxes represent statistically significantly different groups.**

Oxygen Supply Capacity and Low Oxygen Tolerance:

*Analysis is still ongoing, but initial findings indicate that tolerance to low oxygen is higher at low temperatures and oxygen supply capacity did increase with increasing temperature. As temperatures increased, so did oxygen consumption in our respirometry tests.

Discussion

Despite a trend in oxygen supply capacity increasing with temperature, there was no trend in HCT with increasing temperature. This suggests that in both species the animal's body does make changes to oxygen supply mechanics with an increase in temperature, but these changes likely do not extend to changing the concentration of red blood cells in the bloodstream. The fact that there is no trend in HCT with temperature could indicate more efficient ways of combating increased temperatures than changing HCT. A larger sample size and more data would be needed to confirm these theories. In general, fish metabolic rates increase with temperature and activity. To maintain these metabolic rate increases, oxygen supply capacity must increase to supply muscles and tissues with enough oxygen to function correctly. A limitation in oxygen supply capacity has not been found in our temperature tests thus far. The increase in metabolic rate and oxygen consumption in correspondence with increased temperature explains a low tolerance to oxygen decreases at higher temperatures. As temperature increases, the animals need more oxygen to maintain normal metabolic function, so reduced oxygen levels are more detrimental.

Acknowledgements: FSU Provost Postdoctoral Fellowship Program, Minorities in Shark Sciences (MISS) for funding to attend SICB 2025, FSU Coastal and Marine Laboratory staff, FSU/MISS 2024 interns, FSU Directed Independent Study students, FSU provost postdoctoral fellowship

Resources: Desforges, J.E., Birnie-Gauvin, K., Jutfelt, F., Gilmour, K.M., Eliason, E.J., Dressler, T.L.,McKenzie, D.J., Bates, A.E., Lawrence, M.J., Fangue, N. and Cooke, S.J., 2023. The ecological relevance of critical thermal maxima methodology for fishes. Journal of Fish Biology, 102(5), pp.1000-1016; Deutsch, C., Penn, J.L., & Seibel, B. (2020). Metabolic trait diversity shapes marine biogeography. Nature, 585(7826), 557-562. doi: https://doi.org/10.1038/s41586-020-2721-y; Fangue, N. A., & Bennett, W. A. (2003). Thermal tolerance responses of laboratory acclimated and seasonally acclimatized Atlantic stingray, Dasyatis sabina. Copeia, 2003(2), 315-325.; Morley, J. W., R. L. Selden, R. J. Latour, T. L. Frölicher, R. J. Seagraves, M. L. Pinsky. 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. Plos One 13:e0196127; Nguyen, K.D.T., Morley, S.A., Lai, C.H., Clark, M.S., Tan, K.S., Bates, A.E., & Peck, L.S. (2011). Upper temperature limits of tropical marine ectotherms: global warming implications. PLoS One, 6(12), e29340; Hochachka, P. W., & Somero, G. N. (2002). Biochemical adaptation: mechanism and process in physiological evolution. Oxford university press.