Effects of Hypoxia on Blood Osmolarity in Antarctic Fish Species

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BACKGROUND

- Temperature is increasing in the Southern Ocean surrounding Antarctica and as a result, oxygen levels are decreasing (1).
- White-blooded fish lack hemoglobin while red-blooded fish have hemoglobin allowing for larger oxygen carrying capacity (1)
- To improve oxygen uptake, fish may remodel their gills to increase the gill surface area which results in a loss of the interlamellar cell mass (ILCM) (2). See Figure 1
- Gill remodeling reduces the ability to regulate blood osmolarity because loss of ILCM increases the surface area for ions to diffuse (3).
- To observe if Antarctic fish are affected by hypoxia, we measured their blood osmolarity.

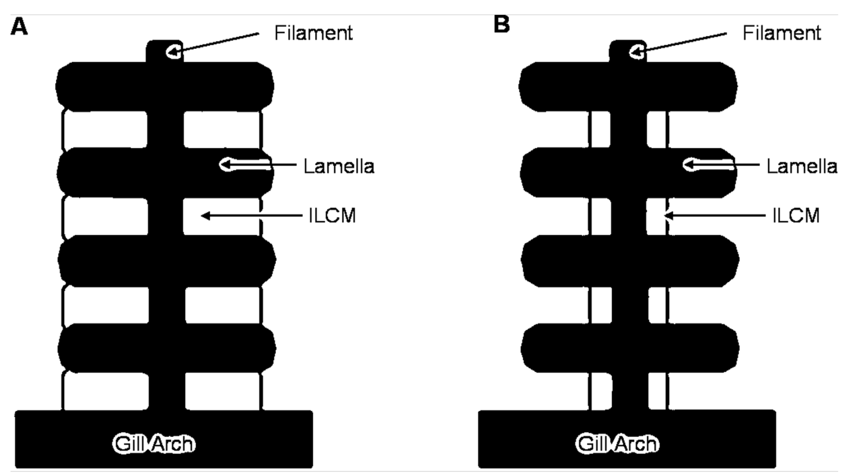

Figure 1: Image showing gill remodeling due to hypoxia. ILCM=interlamellar cell mass. Photo credit: B.T. Douglas, 2013

Hypothesis: Because white-blooded fish lack hemoglobin, I hypothesized that in response to hypoxia blood osmolarity will be higher in white-blooded fish rather than red-blooded fish due to greater gill remodeling required to increase oxygen uptake in white-blooded fish.

METHODS

Red-Blooded Fish
- *Gobionotothen gibberifrons* (GIB)
- *Notothenia coriiceps* (COR)

White-Blooded Fish
- *Chaenocephalus aceratus* (ACE)
- *Pseudochaenichthys georgianus* (GEO)

Figure 2: Photo credit: T. Moylan & K. O'Brien. Image of red fish blood and white fish blood

- Acclimated to hypoxia for 48 hr and 5 days (COR)
- Fish exposed to Incipient Lethal Oxygen Saturation (ILOS)
- Dissolved oxygen levels determined from measurements of oxygen critical level for each species
- Fish held at approximately 15% above oxygen critical level (60% for 5-day hypoxia acclimation)
- Fish held in normoxia with a dissolved oxygen level of 100%
- Blood obtained immediately after the animal is euthanized and is chilled for 24 hr to allow blood coagulation
- Blood Osmolarity measured using Vapro Pressure Osmometer
- Fish were captured off the southwestern shore of Low Island (63°30′S,62°42′W) and in Dallmann Bay (64°08′S,62°40′W) in austral winter of 2023

DATA ANALYSIS

- Two-way ANOVA analysis followed by a Tukey's multiple comparisons test to determine significance for blood osmolarity among species and in response to ILOS and 48hr hypoxia acclimation
- One-way ANOVA analysis followed by Tukey's multiple comparisons test to determine significance in response to 5-day hypoxia acclimation

RESULTS

Red-blooded *G. gibberifrons* increased blood osmolarity in response to ILOS while white-blooded fish showed no difference in response to ILOS treatment.

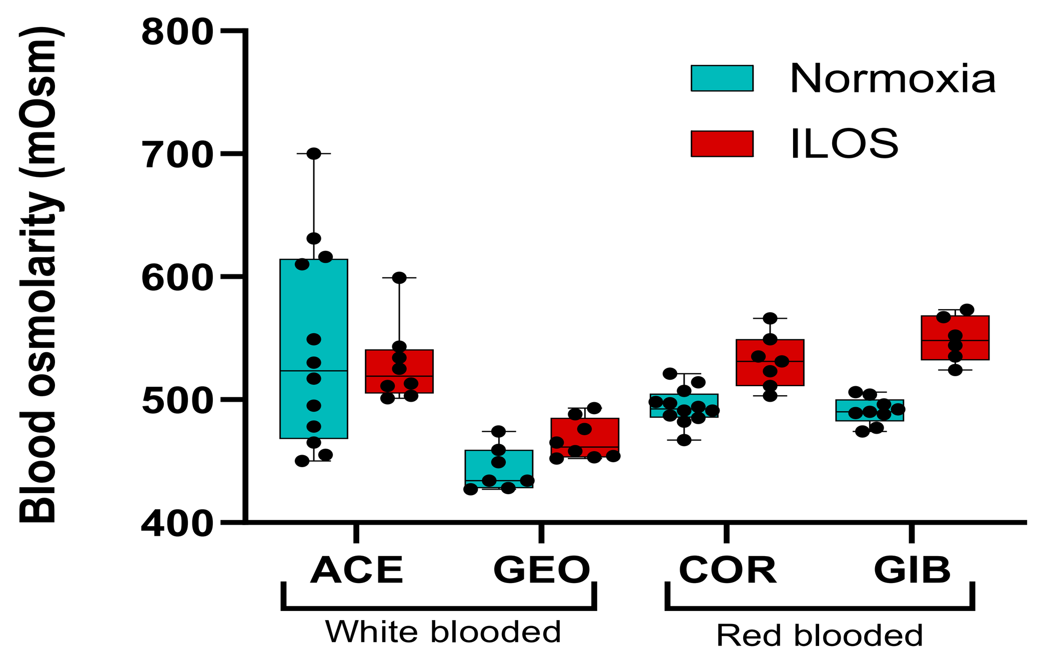

Figure 3: Boxes represent the interquartile ranges of osmolarity; whiskers represent minimum and maximum mean osmolarity. The dots represent individual measurements (N=6-12).

***N. coriiceps* increased blood osmolarity in response to 48hr hypoxia acclimation while *C. aceratus* decreased blood osmolarity.**

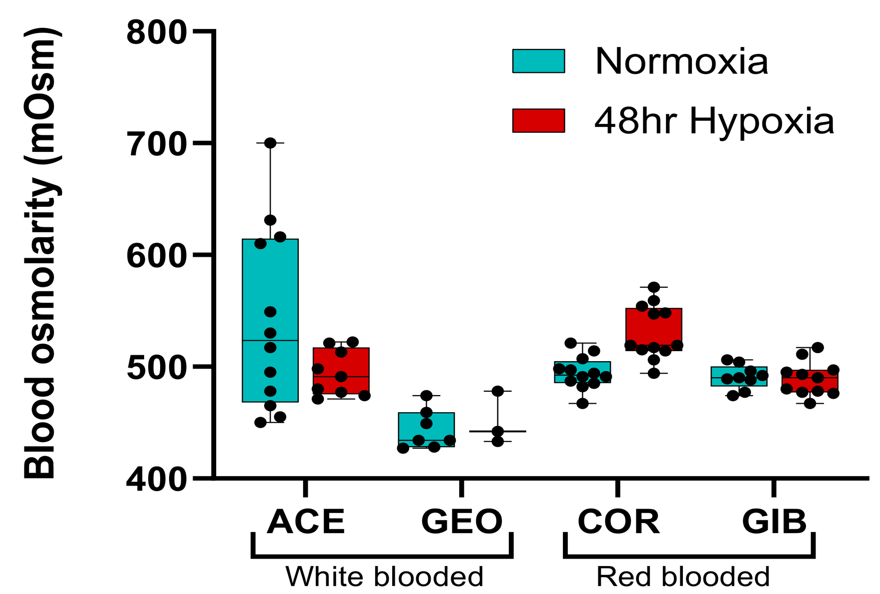

Figure 4: Boxes represent the interquartile ranges of osmolarity; whiskers represent minimum and maximum mean osmolarity. The dots represent individual measurements (N=3-12).

***N. coriiceps* increased blood osmolarity in response to 48hr acclimation but not 5-day acclimation to hypoxia.**

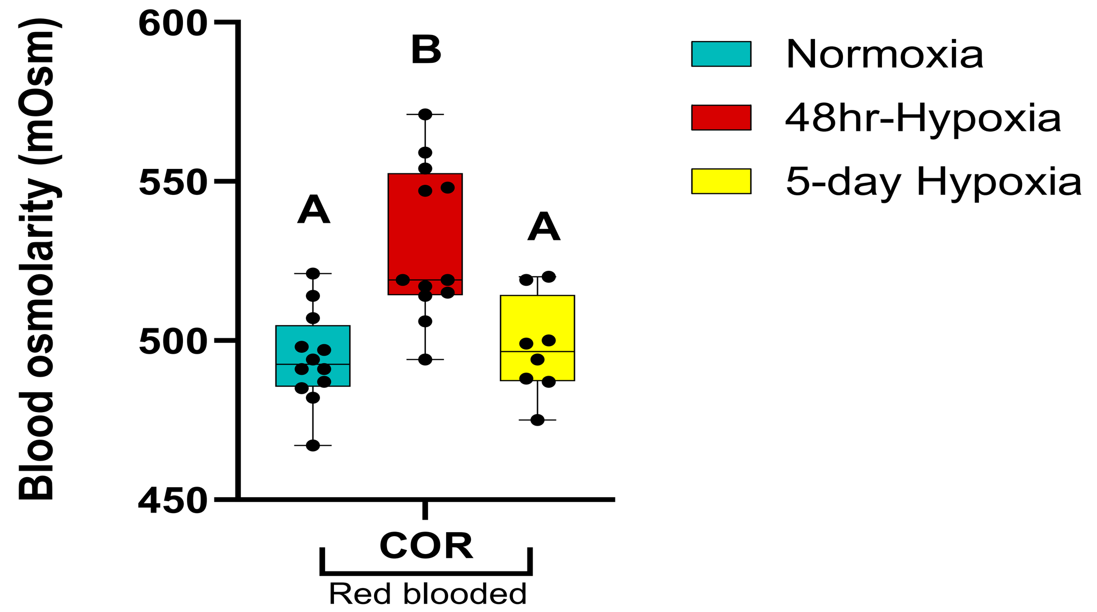

Figure 5: Boxes represent the interquartile ranges of osmolarity; whiskers represent minimum and maximum mean osmolarity. The dots represent individual measurements (N=8-12).

CONCLUSIONS

- Due to a lower metabolic rate than red-blooded fish, white-blooded fish have a lower demand for oxygen which may be why they showed no significant response in blood osmolarity to hypoxia acclimation.
- G. gibberifrons can tolerate lower oxygen levels than the other fish species and may have remodeled their gills to a greater extent to increase oxygen uptake resulting in the increase in blood osmolarity.
- N. coriiceps may be able to regulate blood osmolarity if given enough time to acclimate to hypoxia, as the ILCM can be shed quickly and regrow within days.

MOVING FORWARD

- To lower variation in blood osmolarity measurements, use the same individuals in normoxia and hypoxia by collecting blood through a cannula.
- Quantify ILCM loss in Antarctic fish due to gill remodeling that occurs in response to hypoxia to observe the affect hypoxia has on gill composition.

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Photo Credit: A. Snyder (Left) and K. O'Brien (Right)