The TMEP-Lab: Understanding Tropical Marine Animal Physiology with the Goal of Improving Fisheries Management and Conservation

Laboratorio TMEP: Entendiendo la Fisiología de los Animales Marinos Tropicales Para Mejorar el Manejo de las Pesquerías y la Conservación.

Laboratoire TMEP: Compréhension de la Physiologie des Tropicale Animaux Marins pour L'Amélioration de la Gestion des Pêches et de la Conservation

KURT GAMPERL[1], NICK D. HIGGS[2], REBECCA, H M. SANDRELLI[1], EMMA S. PORTER[1] and KATHY A. CLOW[1]
[1] *Dept of Ocean Sciences, Memorial University, NL. Canada*
kgamperl@mun.ca, r.sandrelli@mun.ca, esporter@mun.ca, kclow@mun.ca;
[2]*Cape Eleuthera Institute, The Island School, Eleuthera, The Bahamas.*

EXTENDED ABSTRACT

Climate change is a global phenomenon that is having significant impacts on many ecosystems, and is threatening the health and productivity of marine species. Understanding how animals function can contribute significantly to the management and conservation of marine species and ecosystems, and will allow for more accurate predictions of the potential impacts of environmental pressures. However, we only have a limited understanding of climate change effects on tropical marine organisms (including species endemic to the Bahamas) as compared to those from temperate and polar regions, and how to protect and ensure the sustainability of these species.

The above was the motivation for establishing the 'Tropical Marine Ecophysiology Laboratory' (TMEP-Lab) at The Island School's Cape Eleuthera Institute (CEI) in 2022/2023, a partnership between The Island School and Memorial University of Newfoundland (Canada). The goals of this lab / facility are to: 1) Perform long-term measurements of water conditions in various coastal habitats on Eleuthera. 2) Conduct lab- and field-based experiments on various fish and invertebrate species to understand how climate change-related alterations in environmental parameters (e.g., rising average ocean temperatures, hypoxia, heat waves, cold-shocks, acidification) may be / are affecting their physiology, ecology and population dynamics. 3) Work collaboratively with local fishers and communities to understand the impacts of climate change, and to better protect these valuable resources. 4) Train the marine biologists of the future, and hopefully, attract other scientists to CEI to conduct marine ecophysiology research.

The infrastructure that comprises the TMEP-Lab is housed within the CEI's existing facilities, and includes:

i) Data loggers for measuring temperature, oxygen levels and salinity, and a flow meter for measuring current velocity in various environments;

i) Multiple respirometers and fiber optic systems for measuring the metabolism of fish and invertebrates at rest, and of fish when swimming at various speeds (these systems capable of making measurements on life-stages from fry/larvae to adult); and blood flow meters, blood pressure monitoring equipment, and blood sampling/measurement equipment to assess cardiovascular physiology, function and health. Metabolism and heart function are two of the most important determinants of the temperature and environmental limits of aquatic organisms (Eliason and Antilla, 2017; Farrell, 2009);

iii) An ultracold (-80^{o}C) freezer, refrigerated centrifuge, plate reader etc. for measuring biochemical parameters and biomarkers of animal stress and health;

IV. Transmitters, hydrophones and associated equipment that will allow for the recording of animal location, temperature and depth, in addition to their physiology (i.e., heart rate and activity), in natural habitats and/or semi-enclosed environments.

One of our first research goals was to determine how temperature and oxygen levels vary in mangrove creeks at different times of the year, as this environment is an important nursery habitat for many marine fishes. Thus, we deployed PME miniDOT® dissolved oxygen loggers in several mangrove creeks on Cape Eleuthera in the late summer and winter of 2022/2023. As expected, temperature varied by ~ 6-8^{o}C (10 – 14^{o}F) over the day. However, water oxygen levels ranged from approx. 140% air saturation during the day to only 40% air saturation at night. In the context of climate change this is interesting, as research suggests that hyperoxia may protect fish from the negative effects of warming temperatures, and that this is related to increased metabolic capacity and heart function (McArley et al., 2020).

To examine this question, we fitted subadult (~ 200 - 400 g) schoolmaster snapper (*Lutjanus apodus*) with Transonic®

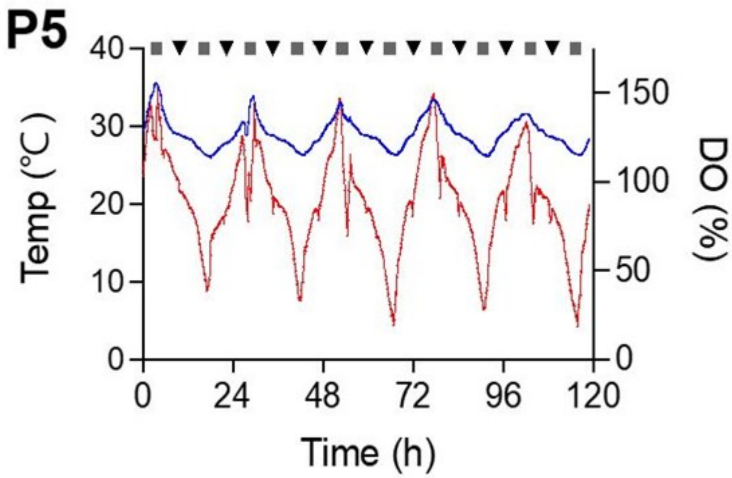

Figure 1. The temperature (□; **Blue**) and dissolved oxygen saturation (%; **Red**) profile recorded by a miniDOT Clear® logger deployed in Kemps Creek for 120 h from October 17th to 22th, 2022. Grey squares indicate low tide and black triangles indicate high tide. Time 0 = noon.

flow probes around their ventral aorta to measure heart function (cardiac output, heart rate and stroke volume). Then, we measured these parameters and the fish's metabolic rate as temperature was increased from their holding temperature (29°C / ~89°F) at 1°C h^{-1} until they reached their critical thermal maximum (CT_{Max}) under normoxic (100% air Sat.) and hyperoxic (150% air Sat.) conditions. The hypothesis was that hyperoxia would enhance the fish's acute thermal tolerance, and that this would be reflected in improved heart function and metabolic capacity.

Surprisingly, the thermal tolerance (CT_{Max}) of snapper did not differ at the two oxygen levels (39.3 ± 0.2°C; ~ 103°F), and neither did their cardiorespiratory physiology. This is likely because these fish have already adapted to these fluctuating oxygen conditions, and thus, unlike some other fish species they do not have physiological capacity (plasticity) remaining that would allow them to benefit from the high oxygen levels; i.e. hyperoxia does not provide them with refuge when exposed to acutely increasing water temperatures.

ACKNOWLEDGEMENT

This research was funded by a Natural Sciences and Engineering Research Council of Canada Grant to A.K. Gamperl (#2022-03790), and the Cape Eleuthera Institute (The Island School) contributed to the establishment of the TMEP-Lab. We thank Eric Schneider and other members of The Island School for support in setting up the TMEP-Lab. Finally, we acknowledge the assistance of the Island School's 2022 fall Fish Physiology Class in collecting the presented environmental data.

KEYWORDS: Marine Research, Ecophysiology, Climate Change, Cardiac Function, Metabolic Capacity

Table 1. Acute thermal tolerance (CTMax) and cardiorespiratory parameters in schoolmaster snapper (*Lutjanus apodus*) under normoxic and hyperoxic conditions.

	Normoxic 100 %	Hyperoxic 150 %
RMR	210.8 ± 17.5ᵃ	203.9 ± 19.7ᵃ
MMR	485.3 ± 59.3ᵃ	585.1 ± 39.7ᵃ
Aerobic scope	274.5 ± 49.3ᵃ	381.2 ± 33.2ᵃ
f_H max	161.8 ± 6.9ᵃ	159.7 ± 12.4ᵃ
f_H scope	68.0 ± 7.4ᵃ	76.6 ± 9.5a
$\dot{Q}$ max	66.1 ± 5.4ᵃ	66.1 ± 8.6ᵃ
$\dot{Q}$ scope	30.8 ± 3.8ᵃ	34.8 ± 5.0ᵃ
CT_{Max}	**39.1 ± 0.2ᵃ**	**39.4 ± 0.1ᵃ**

RMR, resting metabolic rate; MMR, maximum metabolic rate; Aerobic scope = MMR – RMR; $\dot{Q}$, cardiac output; f_H, heart rate; max., maximum, scope = maximum – resting.

LITERATURE CITED

Eliason, E.K. and K. Anttila. 2017. Temperature and the cardiovascular system. Pages 235-297. In: A.K. Gamperl, T.E. Gillis, A.P. Farrell and C.J. Brauner (eds.). The Cardiovascular System: Development, Plasticity and Physiological Responses Fish Physiology; Fish Physiology Volume 36B. Academic Press, London.

Farrell A.P., E.J. Eliason, E. Sandblom and T.D. Clark. 2009. Fish cardiorespiratory physiology in an era of climate change. Canadian Journal of Zoology 87: 835–851.

McArley, T.J., E. Sandblom and N.A. Herbert (2021). Fish and hyperoxia—From cardiorespiratory and biochemical adjustments to aquaculture and ecophysiology implications. Fish and Fisheries. 2022:324–355.