The Effects of Climate Change Induced Temperature Increases on Bonefish (*Albula vulpes*) Swimming Performance and Energetics.

Anna Marsh, Ashley Ryan, Charlie Mauck, Marcus Gould, Shanika Foster, Willis Zetter

Introduction

Climate Change is defined as an identifiable change in the state of the climate (IPCC 2007). It is predicted that ocean surface water temperatures will increase by 0.2°C per decade according to greenhouse gas emission scenarios (Figure 1). This temperature change will affect many ecosystems however, tropical mangrove habitats will be particularly vulnerable because of their shallow nature and exposure to storms (IPCC 2007). How will changing temperatures affect the energetics of fish species located in these habitats?

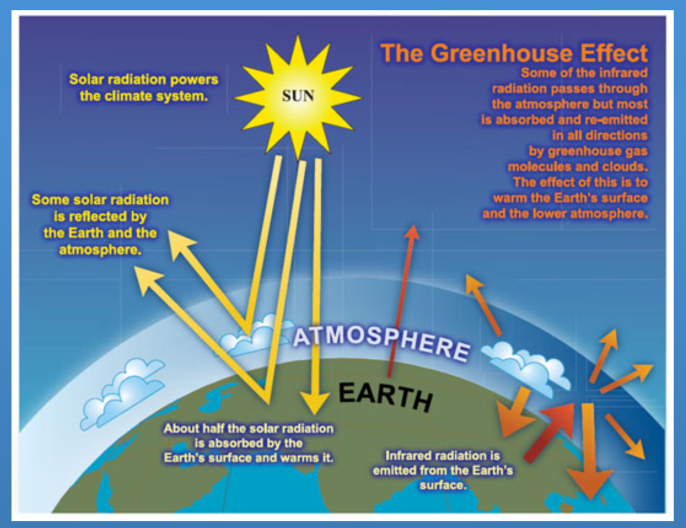


Figure 1. Diagram of the greenhouse gas effect, a contributing factor to climate change.

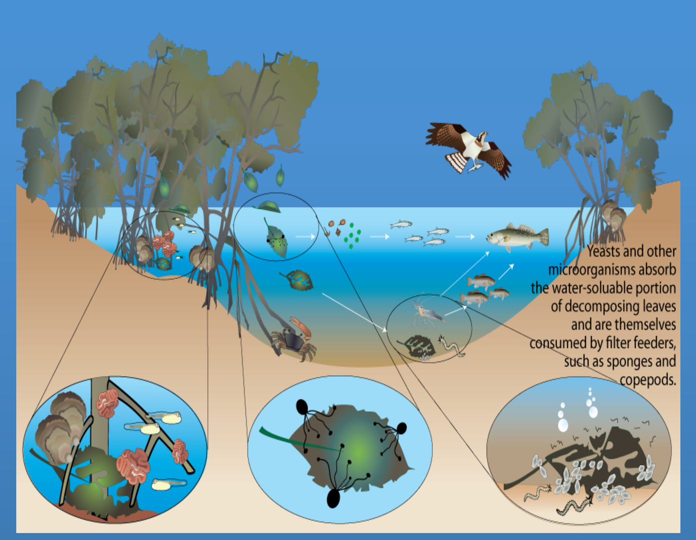


Figure 2. An illustration of a mangrove habitat food web, where bonefish play an important ecological roll.

Bonefish inhabit tidal creeks and mangrove flats. They are economically important because bonefish fly-fishing tourism contributes approximately **$141 million** annually to The Bahamas (Fedler 2010). They are also a significant ecological component of the marine food web and contribute to nutrient export in and around their mangrove creek habitats (Figure 2). However, in recent years, coastal development, overfishing, and especially climate change have been threatening bonefish populations (Danylchuk et al. 2004).

Water Temperature is the "master" environmental factor influencing the biology of fish (Brett 1971). Species located in tropical regions are sensitive to just a couple degree temperature increases, due to their evolution in thermally stable environments (Donelson et al. 2011). At high temperatures that exceed the thermal optimum of fish, they experience changes in energy allocation (Figure 3). Changing this energy allocation away from crucial fitness/ survival mechanisms can potentially result in population decreases for bonefish (Portner and Farrel, 2008).

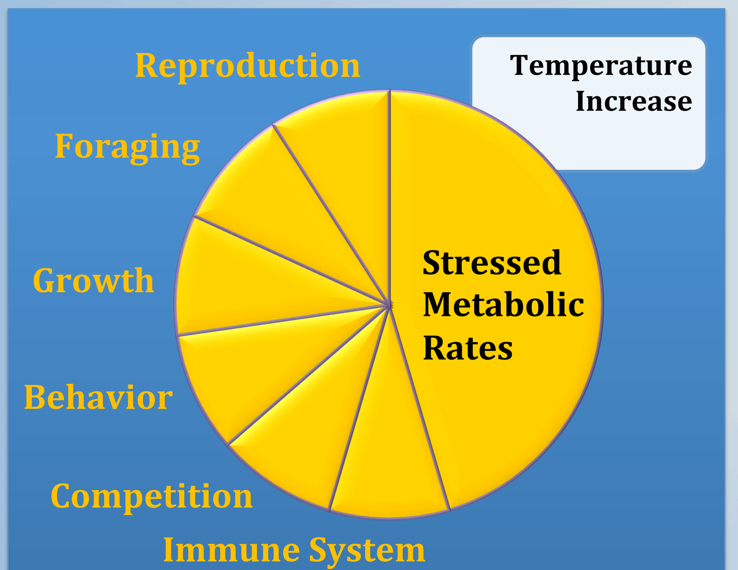


Figure 3. Energy allocation with temperature increases. Under optimal conditions, energy is evenly allocated

Purpose

To determine the role of temperature on bonefish swimming performance and energetics.

Hypothesis

As temperatures exceed bonefish thermal optimum, both swimming performance and scope of activity will decrease.

Methods

Bonefish Capture

Figure 4. A seine net was placed across the mouth of a mangrove creek at high tide.

Figure 5. At low tide, fish were encircled in the net and placed into a flow through cage.

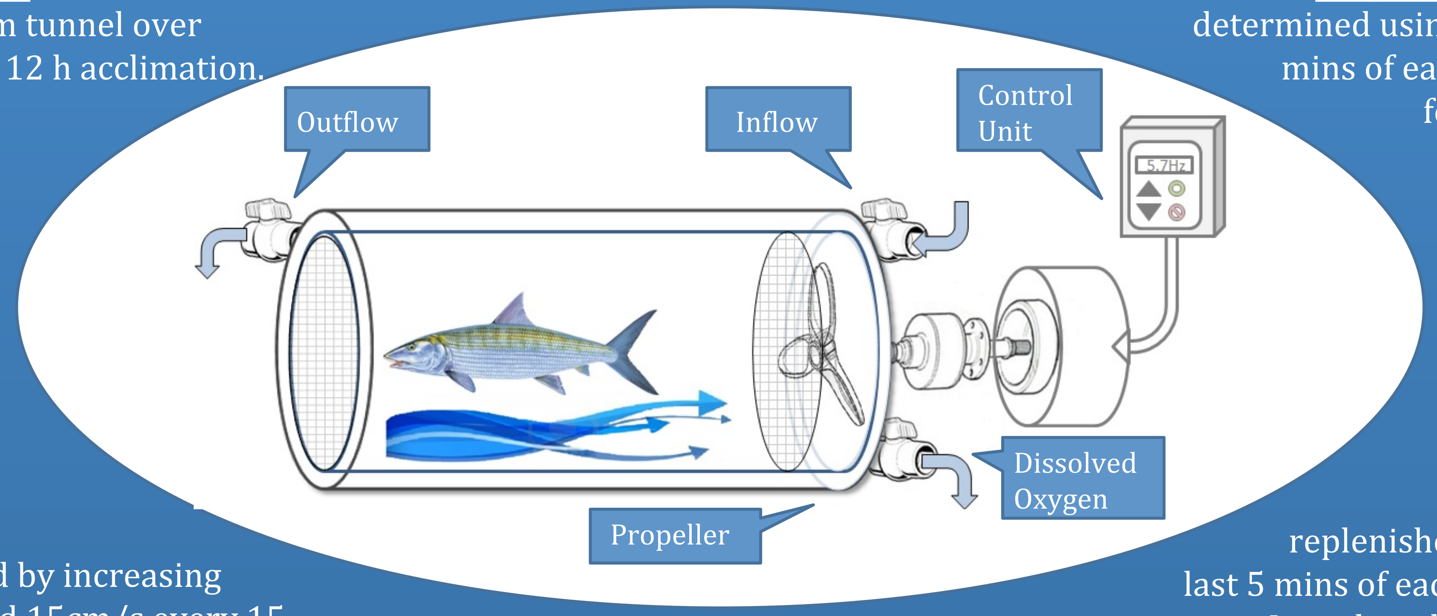
Figure 6. Fish were then transported by boat back to the CEI wet lab, with frequent water changes.

Figure 7. Fish waited in their new temporary home for swim tunnel experimentation.

Swim Tunnel Protocol

Acclimation: Fish were left in the swim tunnel over night for a 12 h acclimation.

Scope of Activity was determined using the first 10 mins of each increment for measuring metabolic rates.



Swimming Speed was determined by increasing water speed 15cm/s every 15 mins until exhaustion.

Oxygen was replenished during the last 5 mins of each increment. Length and weight were measured before fish release.

Results

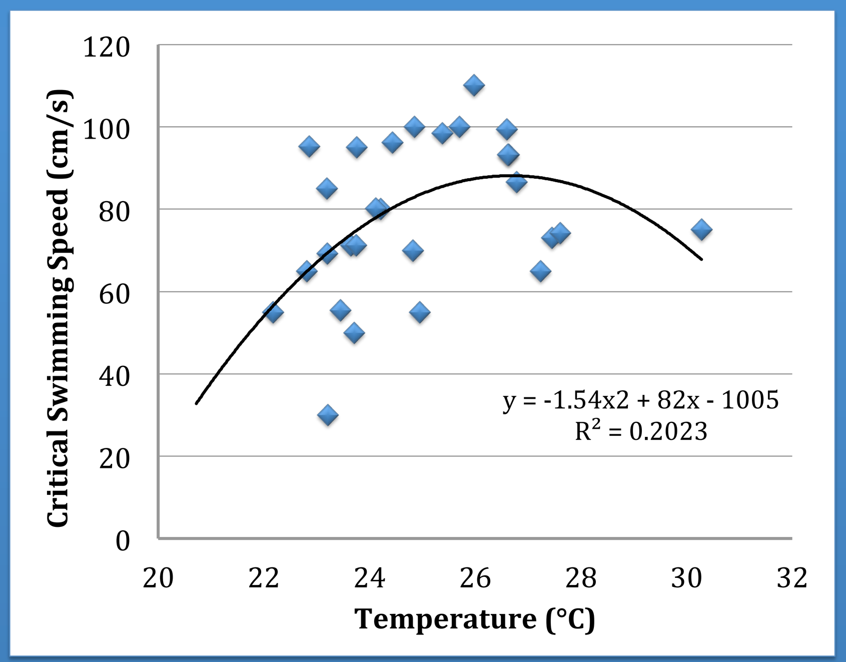


Figure 8. The relationship between bonefish critical swimming speed (cm/s) and water temperature (°C).

Critical swimming speed (Ucrit) was calculated using Ucrit=Ui+(ti/tiixUii), where Ui is the water velocity of the last complete increment (cm/s), Uii is the water velocity increment (15cm/s), ti is the time the fish swam at the last water velocity (m), and tii is the period of each water velocity (15m). A polynomial line of best fit was used to assess trends in the data.

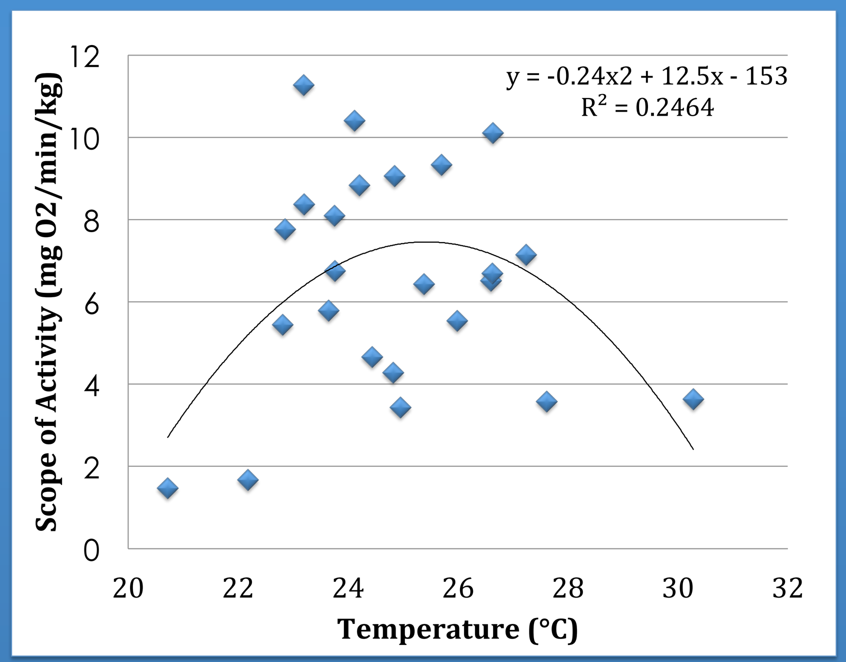


Figure 9. The relationship between scope of activity (mgO2/ min/kg) and temperature (°C).

The scope of activity was found by subtracting the routine from the maximum O2 consumption. Oxygen consumption was calculated using MO2=Δ[O2]v/mt, where [O2] is the oxygen consumption (mgO2/L), v is the swim tunnel volume (L), m is the fish weight (kg), and t is time (m). A polynomial line of best fit was used to assess trends in the data.

Discussion

Figure 10. Fly-fishing for bonefish in a flats ecosystem in The Bahamas.

From the **Results** it was determined that the optimal temperature for bonefish

- swimming speed is 26.6°C (Figure 8)
- scope of activity is 25.5°C (Figure 9).

As hypothesized, when temperatures exceed this thermal optimum of approximately 26°C, both bonefish swimming performance and scope of activity decline. These results suggest a range of temperatures under which bonefish experience varying levels of performance, also known as a thermal window. Data collection will continue throughout the summer to complete the range of extreme temperatures the bonefish are exposed to and tested at.

Future Research should include completing the bonefish thermal window as well as determining thermal windows of species in other habitats. Determining bonefish critical temperatures would complete their thermal window and further the understanding of how they will be affected by temperature changes. Additionally determining thermal windows of other species in different habitats would allow a global understanding of how climate change will affect marine species and how they compare to bonefish (Figure 11).

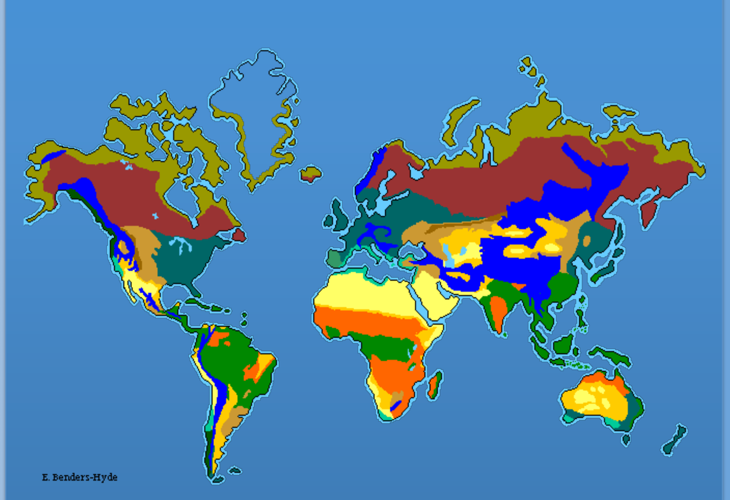


Figure 11. A global map illustrating habitat differences where thermal windows could be determined for representative species.

Figure 12. A recently caught bonefish from fly fishing in the flats.

The **Implications** of this research are that with increased temperatures, bonefish and other flats species will undergo a change in energy allocation (Figure 3) creating a decline in fitness. This decline in fitness will eventually affect future populations of bonefish. Due to both the ecological and economic importance of bonefish (Figure 12), it is critical to protect the zones that favor their thermal optimum in order to ensure their survival. This data increases the capacity to provide critical solutions for the conservation and management of sustainable bonefish fisheries.

Literature Cited

Danylchuk, A. J., Danylchuk, S. E., Cooke, S. J., Goldberg, T. L., Koppelman, J., Philipp, D. P. 2004. Ecology and management of bonefish (*Albula* spp) in the Bahamian Archipelago. Ecology and Management of Bonefish.

Donelson, J. M., Munday, P. L., McCormick, M. I., Nilsson, G. R. 2011. Acclimation to predicted ocean warming through developmental plasticity in a tropical reef fish. Global Change Biology. 17: 1712-1719.

Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R., Davidson, O., Hare, W., Huq, S., Karoly, D., Kattsov, V., Kundzewicz, Z., Liu, J., Lohmann, U., Manning, M., Matsuno, T., Menne, B., Metz, B., Mirza, M., Nicholls, N., Nurse, L., Pachauri, R., Palutikof, J., Parry, M., Qin, D., Ravindranath, N., Reisinger, A., Ren, J., Riahi, K., Rosenzweig, C., Rusticucci, M., Schneider, S., Sokona, Y., Solomon, S., Stott, P., Stouffer, R., Sugiyama, T., Swart, R., Tirpak, D., Vogel, C., Yohe, G. 2007. Climate change 2007: synthesis report. The Intergovernmental Panel on Climate Change 1-52.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon *(Oncorhynchus nerka).* American Zoologist. 11: 99-113.

Fedler, T. 2010. The economic impact of flats fishing in The Bahamas. The Bahamian Flats Fishing Alliance: 1-20.

Karl, T. and Trenberth, K. 2003. Modern global climate change. Science 302: 1719-1723.

Portner, H. O. and Farrell, A. P. 2008. Physiology and climate change. Science. 322: 690-692.

Pörtner, H. O. 2002. Climate change and temperature dependent biography: systematic to molecular hierarchy of thermal tolerance in animals. Comparative Biochemistry and Physiology. 132A: 739-761.

Acknowledgements We'd Like to thank The Cape Eleuthera Foundation for this amazing opportunity and Liane Nowell for her unbelievable help and guidance throughout our research. We couldn't have done it without you!