The Effects of Climate Change on the Swimming Performance of Bonefish (*Albula vulpes*) Using a Swim Tunnel

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Introduction

Climate Change

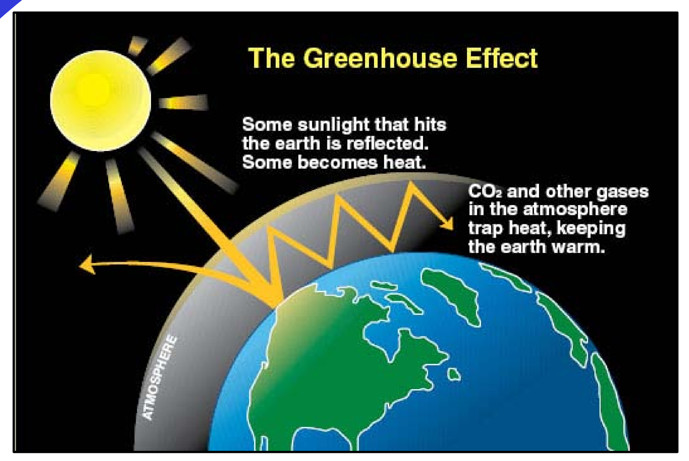

Figure 1. The greenhouse effect is a natural process where some of the suns radiant heat is captured in the lower atmosphere, maintaining the earth's surface temperature. However, rising concentrations of greenhouse gases from human carbon emissions are trapping heat, causing global warming (Karl and Trenbert 2003).

Due to climate change ocean temperatures are predicted to increase 2°C by 2050 and 3 °C by 2080 (IPCC 2007). Although changes in climate are common throughout history and fish are usually able to adapt, the rate of change of this human induced global warming is too extreme for fish adaptation. Knowing how these water temperature increases will affect fish is instrumental to their management and conservation.

Bonefish

Bonefish are important for many reasons. The recreational bonefishing industry has become a popular activity that is estimated to generate $141 million annually in The Bahamas. Ecologically, they are also important for nutrient transport in the food web. Additionally, many people in The Bahamas bonefish guide as their profession, which holds cultural significance (Danylchuk et al. 2004).

Figure 2. A bonefish caught on a fly rod.

Mangroves

Figure 3. Red mangroves. Especially vulnerable to climate change due to their shallow tropical nature (IPCC 2007).

In addition to being the primary habitat for bonefish, tidal mangrove creeks provide various other ecosystem services such as; acting as a juvenile fish nursery, preventing erosion, filtering water, protecting coastlines from storms, and sequestering CO2, which is particularly important for mitigating climate change (Danylchuk et al. 2004).

Swimming Performance & Scope of Activity

Swimming Performance (Ucrit)
- Critical maximum swimming speed
- Implications for predator escape

Scope of Activity
- Maximum metabolic rate (MMR) – routine metabolic rate (RMR)
- Implications for energy allocation

(Tierney 2011; Lee et al. 2003)

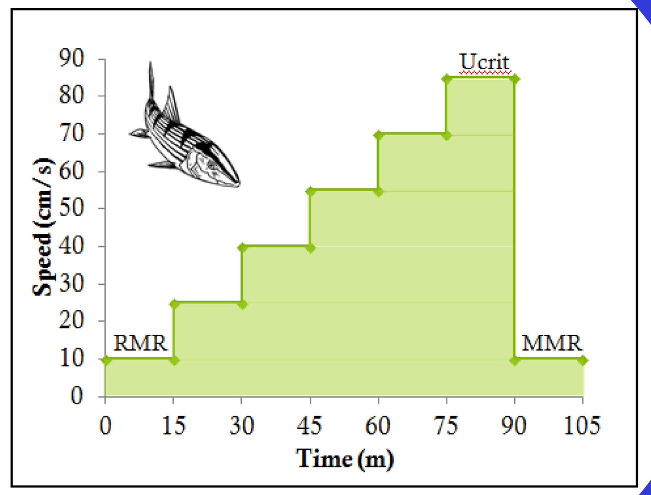

Figure 4. Ucrit and scope of activity protocol: 15cm/s water speed increments every 15 minutes until exhaustion.

Purpose & Hypothesis

Purpose: To determine the effects of water temperature on the swimming performance and scope of activity of bonefish.

Hypothesis: If water temperature increases with climate change then both the swimming performance and scope of activity of bonefish will decrease.

Methodology

Figure 5. Seine net across creek mouth .

Figure 6. Bonefish in holding pen before transportation.

Fish Collection:
Bonefish were captured from nearby tidal creeks on an outgoing tide using a large seine net, and transported back to CEI. Once at CEI, bonefish were transferred to large, aerated holding tanks where they were given a minimum of 24 hours to acclimate to laboratory conditions.

Swim Tunnel Protocol
Fish were left in the swim tunnel overnight to recover at a water speed of 10cm/s. The following day, the experiment was performed by increasing water speed in 15cm/s increments every 15 minutes until exhaustion (Lee et al. 2003) (Figure 4).

Exhaustion is the point when the fish's tail touches the back grid for more than 10 seconds.

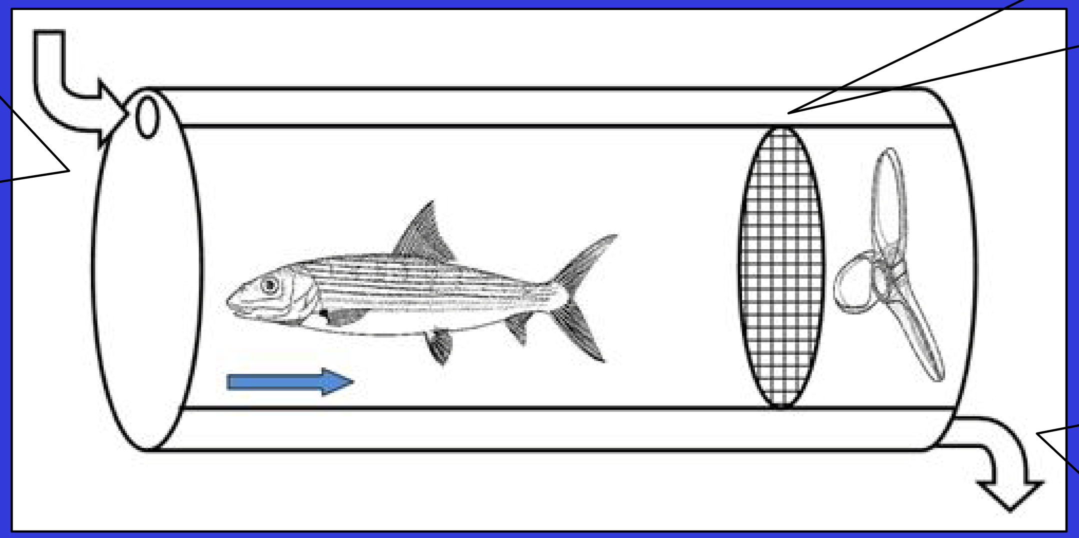

Figure 7. Swim tunnel diagram. Blue arrow depicts direction of water flow. Corner arrows depict inflow and outflow.

The first 10 minutes of each water speed increment was used for measuring metabolic rates by having the swim tunnel as a closed system. The last 5 minutes was used to replenish oxygen in the water by creating a flow through system.

Results

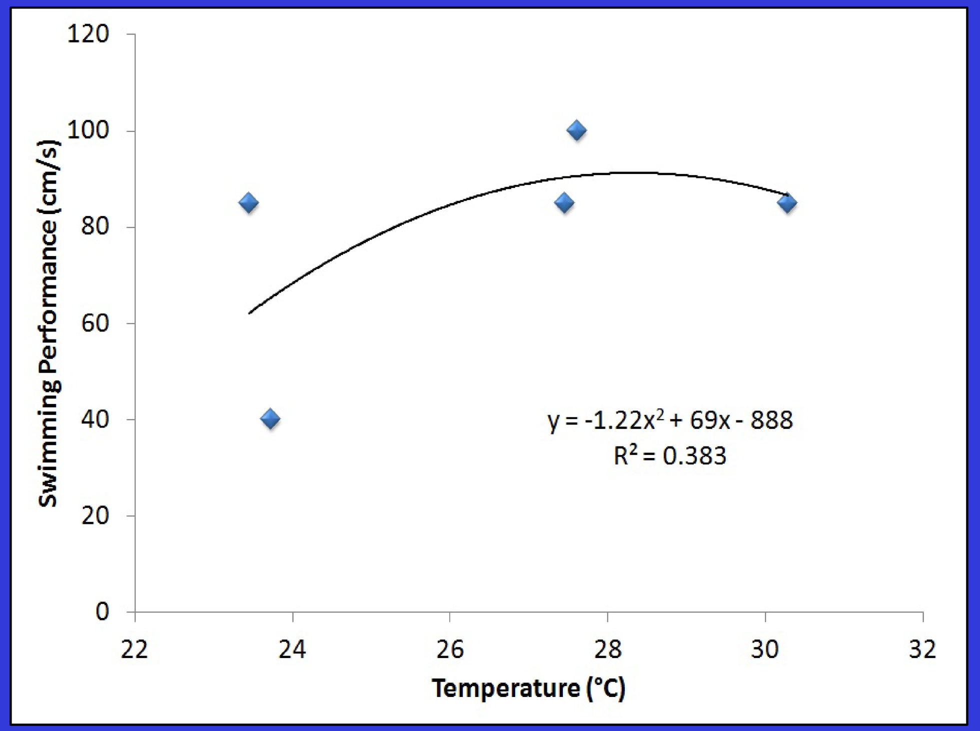

Figure 8. The relationship between swimming performance and temperature. The fastest bonefish swam at 100cm/s.

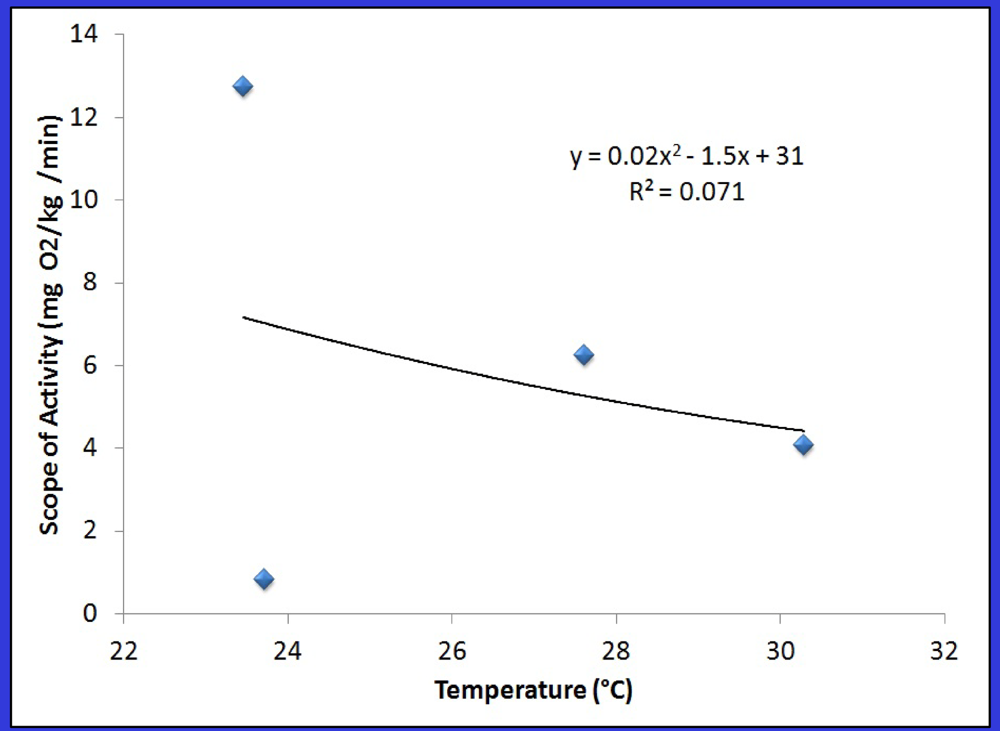

Figure 9. The relationship between scope of activity and temperature.

Swimming performance was measured as $U_{crit} = U_f + t_f/t_i * U_i$, where U_{crit} = max swimming speed, U_f = max water speed, t_f= time spent in last speed interval, t_i= length of each interval (15m), U_i = velocity of each interval (15cm/s).

Scope of activity was measured as MMR – RMR and
$MO_2 = \Delta[O_2]V / mt$
where $\Delta[O_2]$ = decrease in oxygen (mg O_2/L), V = volume of water in swim tunnel (L), m = fish weight (kg), t = time (min).

Discussion

Results Analysis

The results support the hypothesis that:
1) As temperature increases beyond the bonefish optimum temperature, swimming performance will decrease (Fig 8).
2) As temperature increases, scope of activity (the window between routine and maximum metabolic rates) will decrease (Fig 9).

Figure 10. Bonefish in The Bahamas

Implications

This study has implications for various aspects of bonefish survival. Since swimming performance decreases with temperature increases, this might affect a bonefishes ability to escape predators. It was also found that with temperature increases the scope of activity will decrease which has implications for energy allocation. If metabolic rates increase, bonefish will be expending more energy on basic survival and less energy on foraging, reproducing, and growing (Lee et al. 2003). This can all potentially lead to future population declines.

Figure 11. Juvenile lemon shark eating a bonefish that could escape.

Importance of Research

Water temperature is the "master" environmental factor influencing the biology of fish. This research has provided important information on the thermal physiology of bonefish. Modeling bonefish energetics with respect to climate change will facilitate management strategies and conservation of bonefish. Considering bonefish are a crucial part of the local ecosystem and The Bahamian economy, research should be conducted to ensure their survival (Nurse 2011).

Figure 12. Bonefish fly fishing in tropical flats.

Acknowledgements & Literature Cited

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