The Effects of Ocean Acidification on the Metabolic Rate and Swimming Performance of Bonefish (*Albula vulpes*)

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Introduction

Global Climate Change can be defined as any change in climate over time. Before the Industrial Revolution, CO_2 concentrations were at a value of 280 parts per million (ppm), driving that level up to 385 ppm in 2008. Temperatures are rising at the fastest rate they ever have in the past 1,000 years.

Coastal flats are classified as shallow marine environments including tidal creeks, lagoons and mangrove swamps. These environments are vital to the entire marine ecosystem because of their roles as nurseries for juvenile reef fish.

Ocean acidity resulting from increased CO_2 in the atmosphere may have negative impacts on fish. The average pH of the oceans has dropped by 0.1 and there has been a 30% increase in hydrogen ion concentration. When fish ventilate their gills, these ions diffuse through their gills and into their blood stream, creating and imbalance in their acid-base chemistry. This may increase the stress levels of fish, causing them to consume more oxygen, which in turn makes it difficult for the fish to carry out life processes.

A species of fish that may be affected by these three factors is the bonefish. Bonefish also play a key role in local economies of the Bahamian Archipelago. Because of their strength and difficulty to catch, anglers travel to the Bahamas for recreational fishing.

The purpose of this study was to test the effects of global climate change caused by anthropogenically produced CO_2 on Bonefish. The test will measure both the oxygen consumption and the swimming performance of bonefish when they are exposed to incremental decreases in pH, which are the values predicted by the IPCC for the next 100 years. It was hypothesized that as pH decreased the swimming performance of Bonefish would decrease while their metabolic rate increased.

Figure 1. The four acclimation tanks. The clear tubes (which are attached to airstones) is the mode by which the CO2 diffuses into the water.

Methods

Bonefish were collected with a seine net from Starved Creek in the spring of 2010, in Southern Eleuthera. They were transported back to the Cape Eleuthera Institute wet laboratory, where they were transferred to holding tanks.

Bonefish remained in the holding tanks for a minimum of 48 hours before being transferred to their acclimation tanks. Tank pH was adjusted over a 24-hour period to predicted ocean acidification levels in 100 years made by the Intergovernmental Panel on Climate Change. The pH levels in the acclamation tanks were 7.8, 7.6, and 7.4. The bonefish were acclimated for a minimum of 7 days to the following pH treatment: 7.8, 7.6, and 7.4. Fish were not fed 48 hours prior to testing.

The volume and weight of each fish was recorded before they were loaded into respirometry chambers, and this process is exemplified in figure 2. AutoResp4 software recorded oxygen consumption overnight during alternating recirculation and flush periods (Figure 3). During the recirculation period, water flows past a dissolved oxygen probe in a closed system. The six lowest oxygen consumption values collected during the recirculation period with $r^2 > 0.95$ were averaged. Water from the surrounding tank is pumped through the chamber during the flush period in order to refresh the water.

The following day, fish were transferred to a saltwater pool, with 3 parallel lines each 37 cm apart, and were exercised by pinching their caudal fins. The number of times a fish crossed a line and time until exhaustion was recorded. Fish were considered exhausted when they did not burst swim after 2 consecutive caudal pinches. Total and fork length of the bonefish was recorded, after which fish were recovered and released.

Figure 2. Catching bonefish out of holding tanks to find weight and volume and then put them into repirometry tubes.

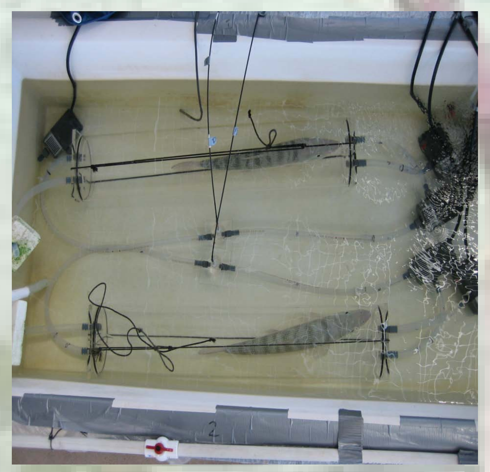

Figure 3. Bonefish in respirometry gear. This is how their oxygen consumption is recorded.

Results

As pH decreased the amount of oxygen consumption within the Bonefish increased for the control group to the 7.6 treatment, but the 7.4 treatment declined in oxygen consumption. The control group consumed 156 mg O2 kg-1 h-1, the 7.8 treatment consumed 165 mg O2 kg-1 h-1, the 7.6 treatment consumed 205 mg O2 kg-1 h-1, and the 7.4 treatment consumed 158 mg O2 kg-1 h-1. As pH decreased, the distance swum by the bonefish also decreased, excluding the 7.4 pH treatment. The number of lines traveled was 144 lines for the control fish, 125 lines for the 7.8 treatment, 118 lines for the 7.6 pH treatment, and 175 lines for the 7.4 treatment. The swimming performance speed of bonefish had no association with pH level from the control data to the 7.4 treatment data. The control group mean time until exhaustion was 144 seconds, the 7.8 treatment lasted until 117 seconds, the 7.6 treatment lasted 138 seconds and the 7.4 treatment lasted 154 seconds. By using the ANOBA statistical test we determined that the pH level of the water is insignificant since our results were higher than the .05 figure.

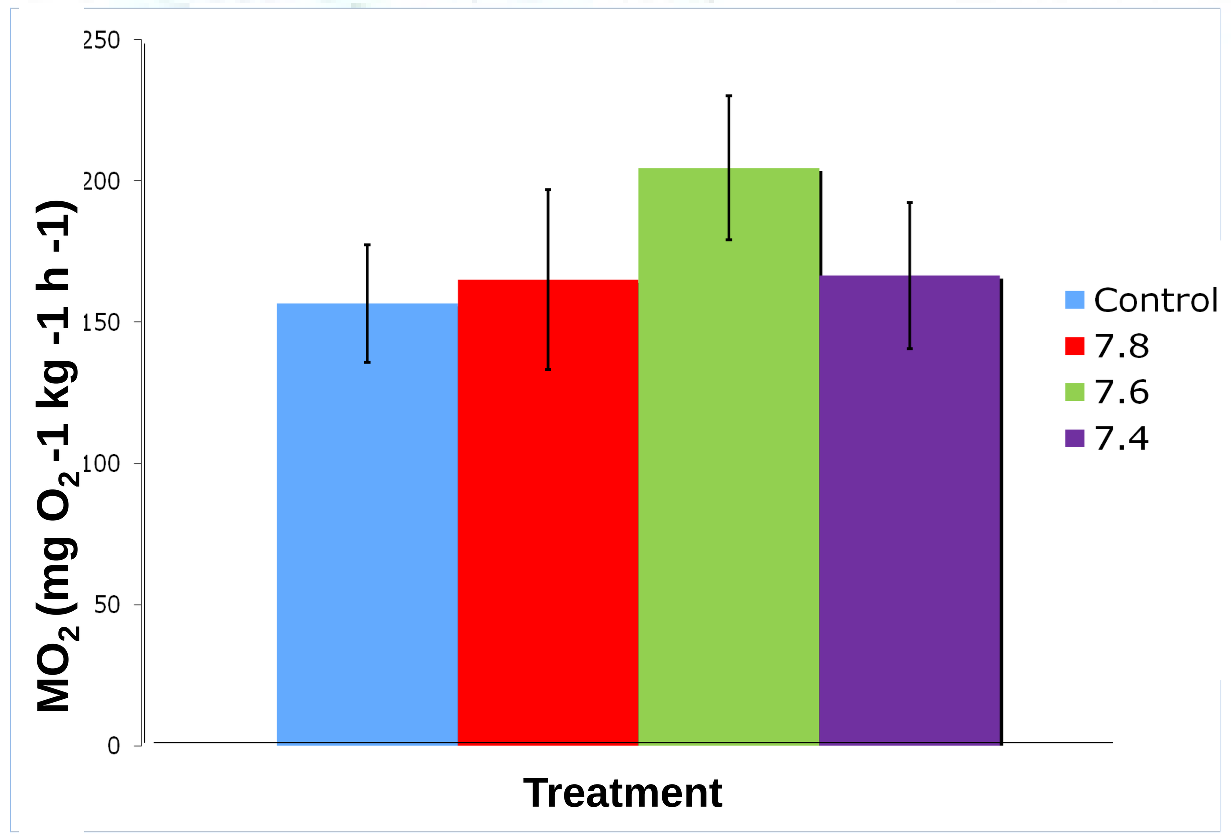

Figure 4. **Oxygen consumption of bonefish**. This graph illustrates the amount of oxygen consumed by the bonefish in the respirometry tubes. The sample size of bonefish was 8 for the control, 7.8 treatment and 7.6 treatment, but for the 7.4 treatment it was 7 fish. The Standard Deviation was ±32.8.

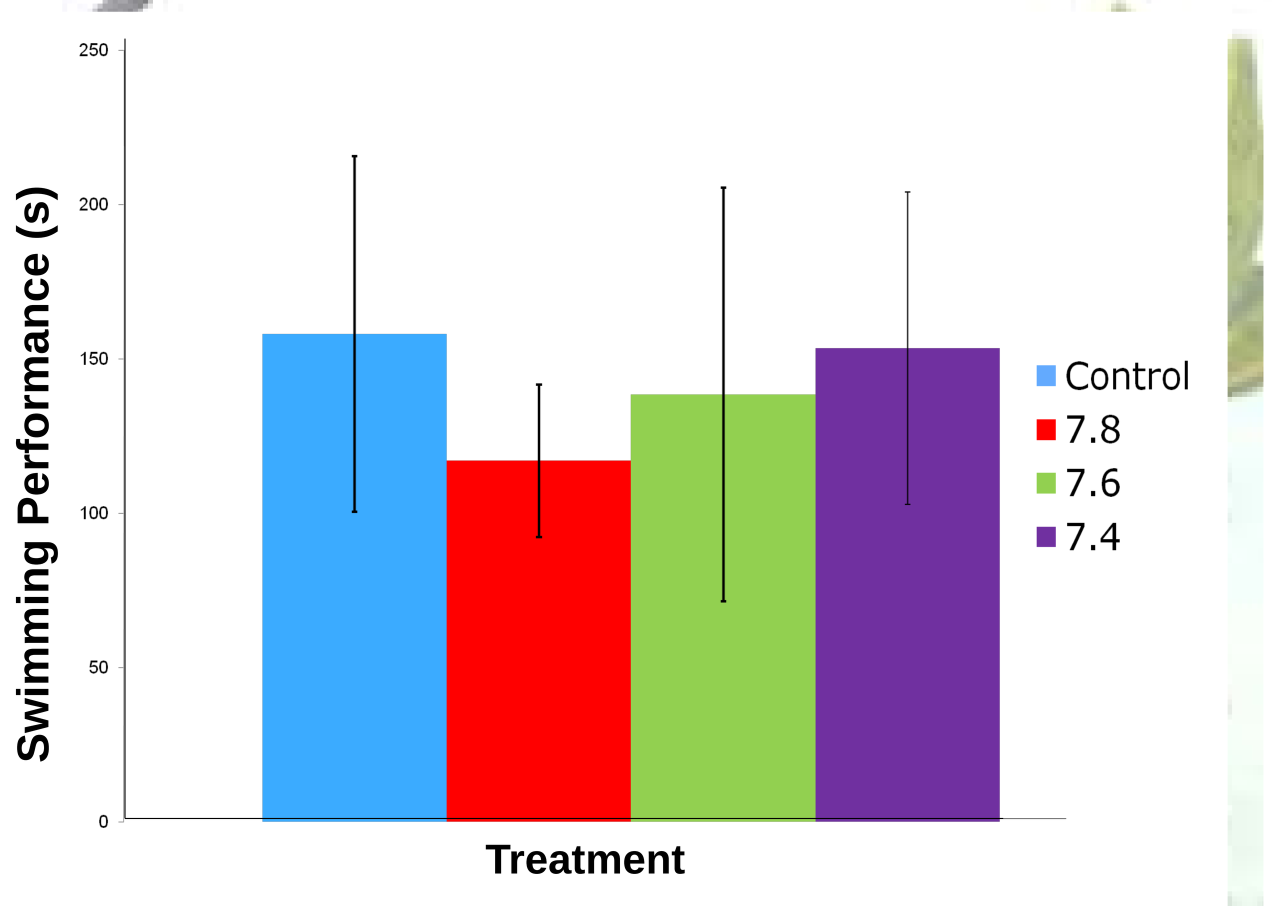

Figure 5. **Time swum until exhaustion for bonefish**. This graph illustrates the time swum by the bonefish as measured in seconds while swimming in an exercise pool. The sample size of bonefish was 8 for the control, 7.8 treatment and 7.6 treatment, but for the 7.4 treatment it was 7 fish. The standard Deviation was ±64.3

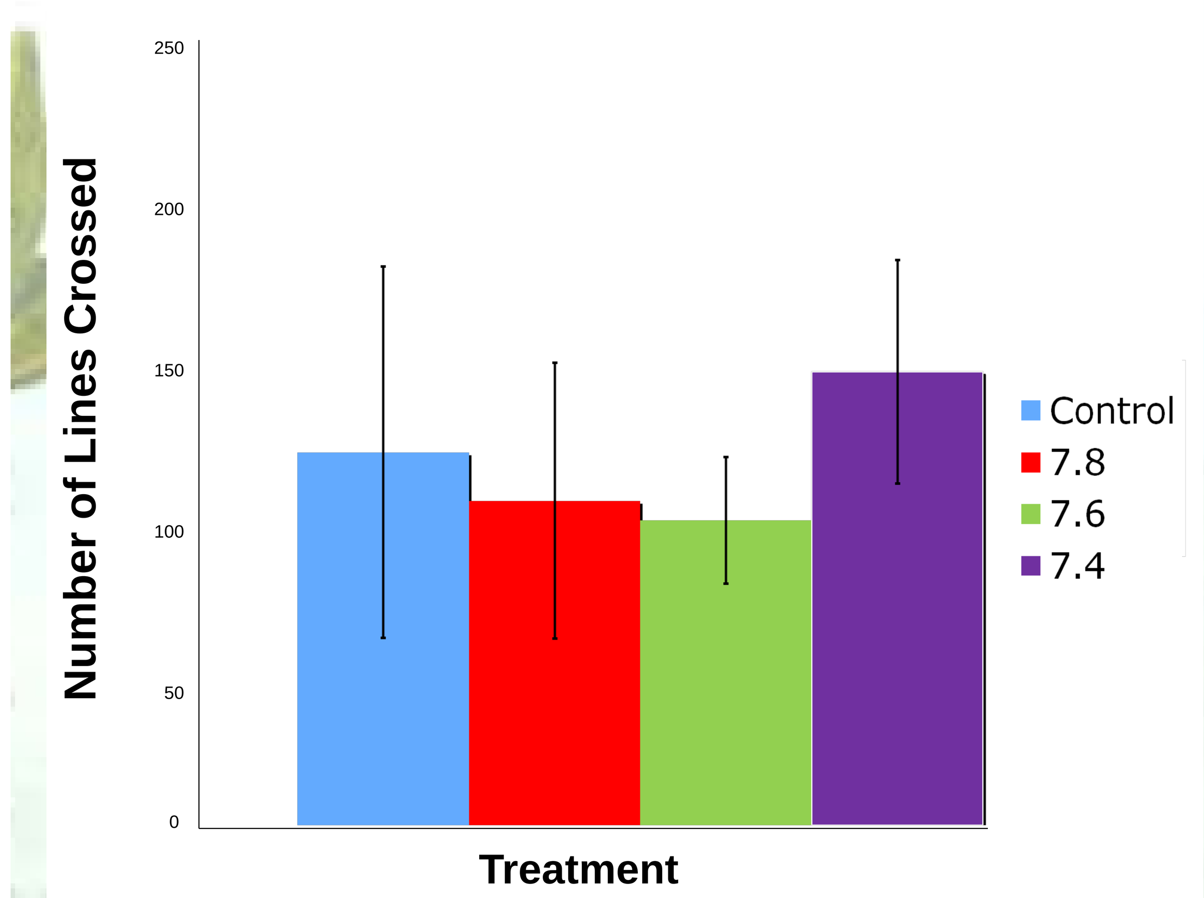

Figure 6. **Distance travelled by bonefish before exhaustion**. This graph illustrates the distance travelled by the bonefish as measured in the number of lines crossed in an exercise pool. The sample size of bonefish was 8 for the control, 7.8 treatment and 7.6 treatment, but for the 7.4 treatment it was 7 fish. . The Standard Deviation was ±43.7

Discussion

Increased acidity affects marine organisms and their performance on many levels, ranging from individual survival to the health of the ecosystem (Brierly and Kingsford, 2009). However, this study demonstrated that ocean acidification did not affect the swimming performance of bonefish.

- No significant trends between the three treatment groups and the control
- **Hypothesis refuted**.

Potential reasons for bonefish resilience in this range of pH levels include their typical habitat and the isolated climate change stressor that was tested.

One reason for bonefish tolerance of various pH levels is their shallow habitat, which experience daily tidal flow, and therefore **experience a range of depths, temperatures, salinities, and pH levels**. As a part of those ecosystems bonefish must be able to tolerate that range of water conditions and therefore might be able to withstand ocean acidification. Cardinalfish however, a reef-dwelling species that inhabits a more stable habitat and a smaller range of water conditions, showed an increase in oxygen consumption with increased acidity (Munday et al, 2009). From this one can conclude that **intertidal-dwelling organisms may be less susceptible to the effects of climate change than reef-dwelling species**. Another factor is that a sole climate change stressor (pH) was tested, when in reality it is most likely that multiple stressors will be changing at the same time.

If global climate change continues at its current rate, there is a high likelihood that it will affect the flats (figures 7 &8) that bonefish inhabit if not the bonefish population itself, which will severely affect the **economic and political health of the Bahamas**.

- Bonefish angling represents over $141 million dollars of revenue per annum in the Bahamas (Danylchuk et al., 2008)
- Up to $3,500 per trip on Eleuthera alone.

Future research includes:

- Combined effect of *multiple* climate change stressors (pH, salinity, temperature, etc.) on bonefish. Equipment necessary is shown in figure 9.
- Effects of same stressors on the entire flats ecosystem → crucial to the health of the bonefish population as it affects the habitat, predators and prey of bonefish.

Figure 7 and 8. Mangrove and Shallow Reef habitats, respectively. These two bonefish habitats are susceptible to the effects of global climate change, and influence the performance of bonefish.

Figure 9. These tubs can used for future testing on the potential effects of global climate change on flats, mangroves, and tidal creeks

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