The metabolic response of bonefish (*Albula* spp.) in the Bahamian Archipelago to increased ocean temperature and acidity caused by global climate change

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INTRODUCTION

Global climate change is an issue that impacts a wide range of marine ecosystems, thereby generating unnatural and potentially harmful behavioral and physiological responses from the organisms of these ecosystems (Karl and Trenberth 2003). Climate change is largely influenced by human interference with the earth's atmospheric composition (Karl and Trenberth 2003). The effects of a global warming trend are evident due to recent changes in global weather patterns, temperatures, and precipitation levels (Brierley and Kingsford 2009). Projected warming patterns for the future raise even more concern about the ecological and also socio-economic consequences of climate change (Walther *et al.* 2002).

One of the major ecological groups impacted by climate change is the marine environment. Little research has been conducted on tropical marine ecosystems, and they are therefore the hardest aquatic habitats to evaluate in terms of tropical fishes' reactions to climate change (Roessig *et al.* 2004). One study highlighted the effects of global warming on fish physiology. This experiment on tropical coral reef fish in Australia found that combined variables of augmented water temperature and acidity increased the oxygen consumption and mortality rates of fish. When dealing with stressors, fish allocate less energy to basic survival behaviors such as foraging, escaping predators, and reproducing (Munday *et al.* 2009).

Bonefish are critical contributors to the tropical flats ecosystems of the Bahamian Archipelago (Danylchuk *et al.*). In addition, recreational bonefish angling generates 141 million dollars annually for the Bahamian economy (Danylchuk *et al.*). Despite the ecological and economic importance of bonefish, relatively little information is known about this species. The purpose of this study was to examine how climate change affects the metabolic rates of bonefish (*Albula* spp.). The hypothesis was that if exposed to increased temperature and acidity treatments, bonefish would have escalated oxygen consumption rates and stress levels.

Figure 1. Seine net encircled around a school of bonefish for collection and return to CEI wet labs.

Figure 2. A bonefish angler in a Bahamian flats environment.

METHODOLOGY

This study was conducted at the Cape Eleuthera Institute (CEI) on Eleuthera, The Bahamas during the fall of 2010. Using a seine net, bonefish (*Albula* spp.) from local tidal creeks were caught and transported to the CEI wet labs. The water in the acclimation tank was adjusted over a 24 hour period from normal ocean temperature and acidity levels (30°C and 8.1pH, respectively) to higher levels of 33°, 34° or 7.8, 7.6, 7.4 pH. Heaters were immersed in the water to increase temperature, and carbon dioxide was bubbled into the water to increase acidity. Conditions were regulated by means of a pH controller monitor and a thermostat.

After an acclimation period of 7 days, the weights and volumes of fish were taken, as these two factors affect the metabolic rate of each fish. The bonefish were then placed in respirometry chambers and their rates of oxygen consumption were measured (Figure 3). The respirometer consists of four individual chambers placed in a tank, and each chamber is outfitted with an oxygen probe that allows for simultaneous monitoring of oxygen consumption from 4 fish (Figure 4). Data on the standard metabolic rate of bonefish was collected overnight when there were few disturbances (Munday *et al.* 2009).

Immediately following the respirometry period, the bonefish were moved to an exercise tank where predatory activity was simulated (Figure 5). The amount of time that it took each fish to become exhausted was measured. Bonefish were then tagged and released.

One-way ANOVA tests were performed in order to determine whether the oxygen consumption and swimming performance of control bonefish differed significantly from that of the treatment bonefish. A one-way ANOVA was also used to determine if there were significant differences between fish lengths between different treatment groups.

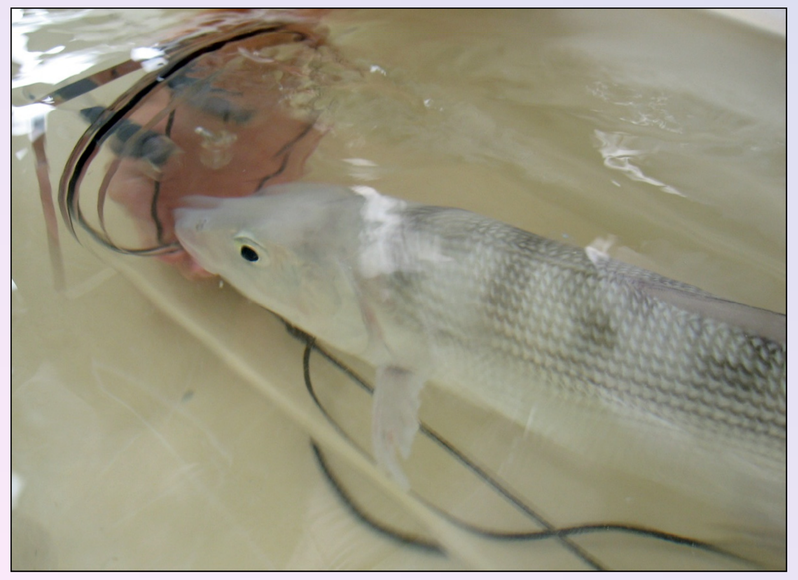

Figure 3. Bonefish in a respirometry chamber.

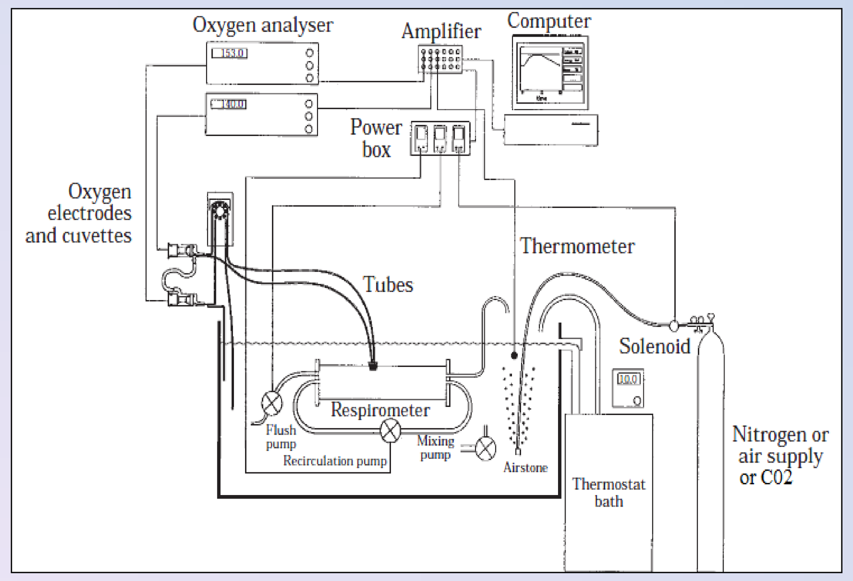

Figure 4. Diagram representing the setup of the respirometry equipment.

RESULTS

An increase in temperature or acidity did not have any significant affect on the metabolic rates of bonefish (Table 1). There was not a significant difference between the amounts of oxygen consumed by control bonefish at the 30ºC temperature level, and treatment bonefish at the increased levels of 33ºC and 34ºC (Figure 6). An increase in the CO_2 acidification of the water also did not have a significant impact on the oxygen consumption of the bonefish. The average oxygen consumption rates associated with different acidity levels were too closely related to show any significant distinction between the control at 8.1 pH and treatment groups of 7.8, 7.6 and 7.4 pH (Figure 7). In both the temperature and acidity treatment groups, there was no considerable difference in the size of fish between the separate treatment groups (Table 1).

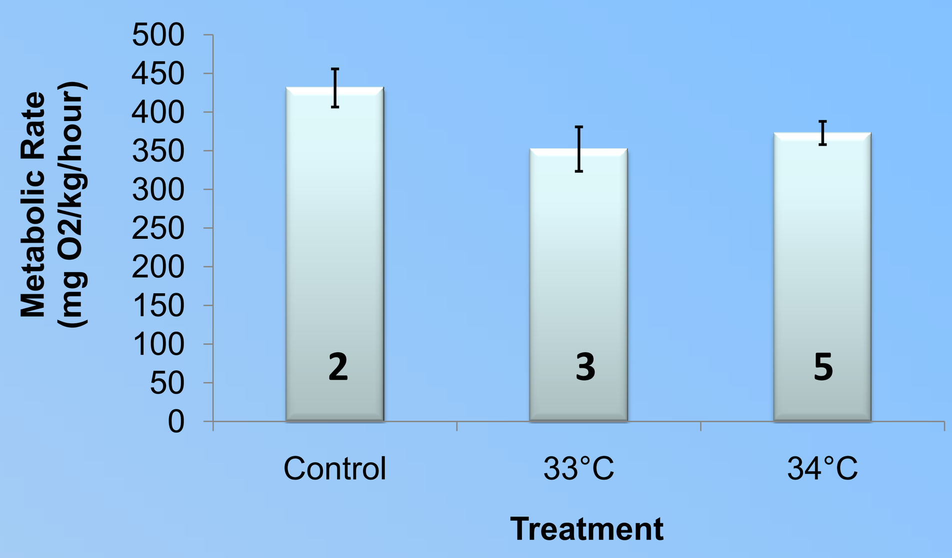

Figure 6. The average oxygen consumption rates of each temperature treatment group of bonefish. The error bars represent ± 1 SE. Sample sizes are shown within graph bars.

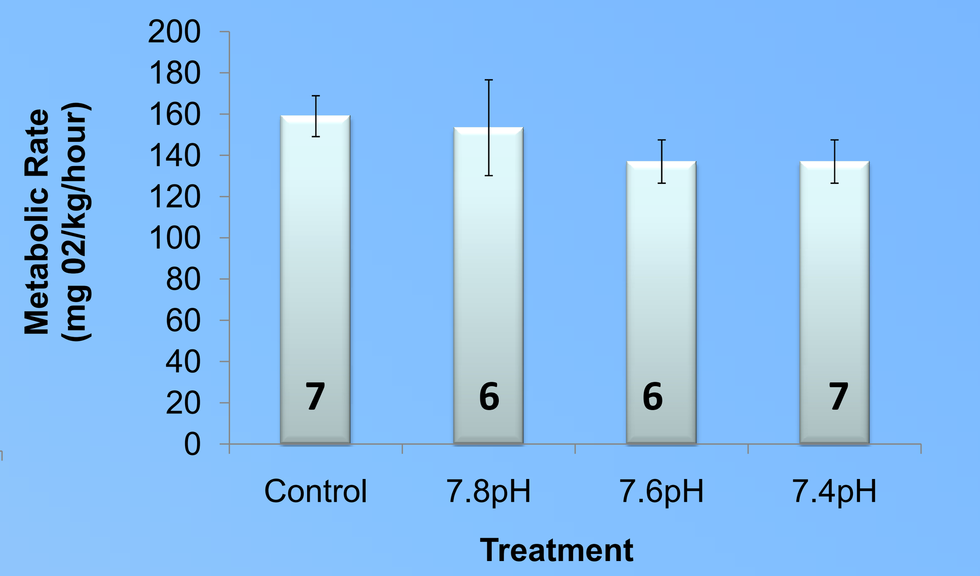

Figure 7. The average oxygen consumption rates of each acidity treatment group of bonefish. The error bars represent ± 1 SE. Sample sizes are shown within graph bars.

The data collected during the exercise period for the bonefish revealed similar results to the findings on the fishes' oxygen consumption. There was no significant variation between the number of seconds that it took the control bonefish and the treatment fish of both temperature and acidity treatments to become exhausted while swimming, as supported by statistical analyses (Table 1, Figures 8 and 9, respectively).

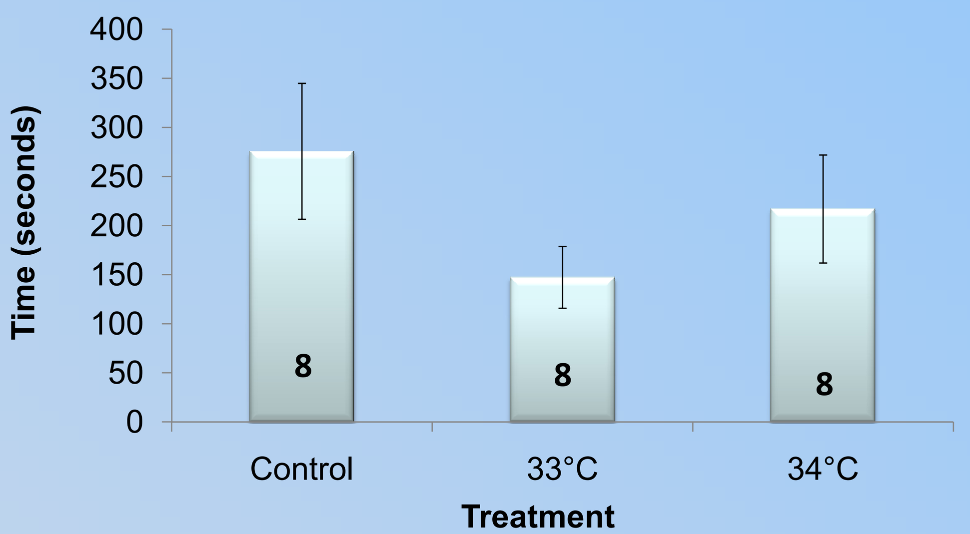

Figure 8. The average time (seconds) that it took each temperature treatment group of bonefish to become exhausted during the exercise period. The error bars represent ± 1 SE. Sample sizes are shown within graph bars.

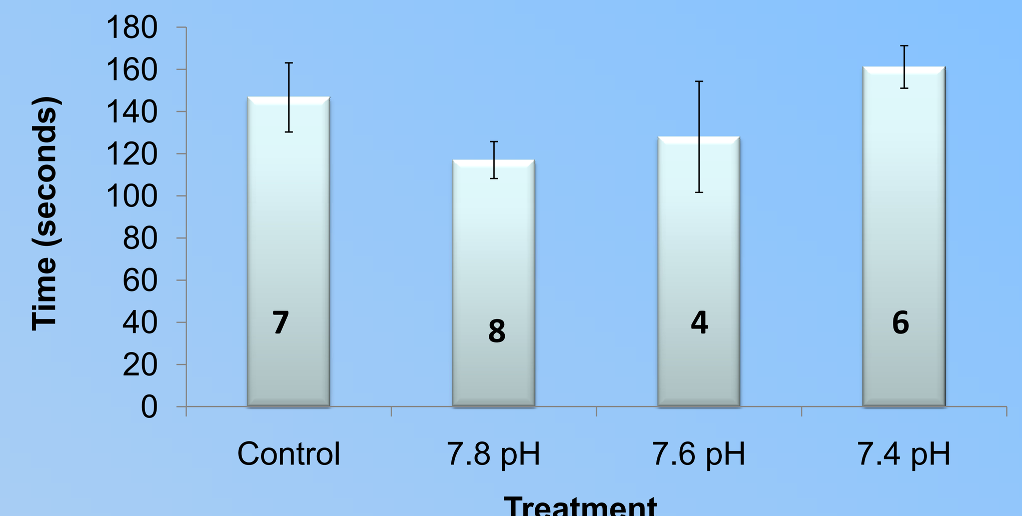

Figure 9. The average time (seconds) that it took each acidity treatment group of bonefish to become exhausted during the exercise period. The error bars represent ± 1 SE. Sample sizes are shown within graph bars.

Table 1. Results from statistical tests showing differences in dissolved O_2 concentrations between treatment groups

Treatment	F value	P value
Temperature (respirometry data)	$F_{2,8}$= 0.2974	P > 0.7506
pH (respirometry data)	$F_{3,22}$= 0.7678	P > 0.5243
Temperature (swimming performance)	$F_{2,21}$= 1.7359	P > 0.05
pH (swimming performance)	$F_{3,21}$= 0.5313	P > 0.05

Figure 5. Bonefish during the predation simulation.

DISCUSSION

According to the results of this study, increased water temperatures and acidities produced no significant change in the oxygen consumption rates of bonefish. The exercise data showed that the swimming performance of the bonefish was also not impacted by exposure to the treatment variables.

Treatment bonefish were expected to exhibit increased oxygen consumption rates when exposed to temperatures and acidities higher than ambient ocean levels. The results of the study do not support this hypothesis. These results also disagree with findings of related studies, such as the experiment conducted on coral reef fish in Australia (Munday *et al.* 2009).

The conclusions of this study suggest that bonefish are very adaptable to variations in natural water conditions caused by anthropogenic climate change. This high tolerance of bonefish can be attributed to the relatively "harsh" environments that these fish inhabit. The shallow water and near-shore location of mangrove flats ecosystems expose these habitats to perturbations like acid rain and changes in temperature due to tidal shifts. Consequently, the marine species of flats ecosystems, namely bonefish, have developed a high resilience to the disturbances of climate change (Alongi 2007).

Further research needs to be conducted on tropical fishes' oxygen consumption in order to improve understanding of the impacts of climate change on these fish. Future studies could include focusing on a wider variety of tropical fish species and locations, increasing the magnitude of treatment variables, or exposing fish to combined treatment variables. Future experiments should also increase the number of fish in each treatment group, as the bonefish sample sizes for this study were much smaller than ideal.

Figure 10. A bonefish in the shallow flats environment.

Figure 11. Mangrove flats ecosystem in the Bahamian Archipelago.

Figure 12. Snorkeling in a local flats tidal creek.

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