pH or Predation? The Impacts of Global Climate Change on Flats Fishes

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Introduction

Global climate change is affecting ecosystems throughout the world. Since the industrial revolution, anthropogenic CO2 emissions have increased exponentially, correlating with an unprecedented increase in atmospheric temperature. In addition to atmospheric changes, increased CO2 emissions are impacting ocean surface waters, particularly in regards to ocean acidity. This is a process in which the ocean absorbs CO2 from the atmosphere, creating carbonic acid, increasing the acidity of the ocean. Regionally, seawater is predicted to decrease from a pH of 8.1 to 7.8 (Dixson, Munday & Jones 2010). In more temperate waters, changing ocean pH and temperature have been documented to impact fishes through differences in migratory patterns, geographical distributions, food web interactions, and phenology (Portner & Farrell 2008). However, little is known about the impact of changing ocean pH on Caribbean nearshore habitats. Of particular concern are the nearshore and coastal habitats of The Bahamas, and the fishes which inhabit these habitats.

Comprised of mangroves, flats, sea grass beds and patch reef, or what is referred to as the **I**nterconnected **H**abitat **M**osaic (IHM), these neo-tropical nearshore communities are highly connected and linked by both biotic (fish movement) and abiotic (current, nutrient flow) factors (Sheaves 2005). The fishes studied, checkered puffer, schoolmaster snapper and bonefish, are part of this important interconnected movement. These fishes are economically and ecologically important, and are representative of the flats ecosystem. Due to the high connectivity of the IHM, fish in all ecosystems will be affected by a change in one.


Fig. 1


Fig.2c

Fig. 1: Mangrove habitat where fishes are collected, and an important part of the IHM.
Fig. 2: (a) Bonefish (b) Checkered Puffer fish ©Schoolmaster Snapper

Methods

Bonefish, checkered puffer and schoolmaster snapper were collected from Page Creek and Airport Flats in South Eleuthera using block seines and hook and line (Fig. 3). Using a shuttle box (Fig. 4) a fish is placed in the manipulated side, which is the tank that pH is lowered in, and left to acclimate for one hour. When the trial starts the pH is lowered by an interval of 0.2 pH units every two minutes on the manipulated side. The fish's typical behaviors, swimming and resting, and stressed behaviors or stressed behaviors such as searching for an exit or shuttling between the ambient and manipulated sides are monitored and recorded using a web cam. The trial ends when the fish shuttles to the ambient side and remains there for four minutes or loses equilibrium (losing consciousness). To test how this pH avoidance threshold changes under the threat of predation, the trial is repeated with a juvenile lemon shark in the ambient side of the shuttle box , this shows the lowest pH the fish will endure before it changes its natural behavior and risks predation or death. The same measurements and methods are utilized for both trials.


Fig. 3

Fig. 3: A block seine net was used to block off mangrove channels during intertidal times and collect fishes.

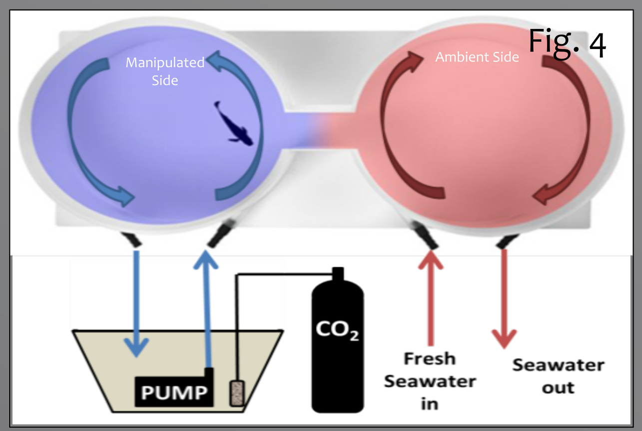


Fig. 4: Shuttle box schematic. A shuttle box was used to run pH trials and control and predator trials.

Purpose and Hypothesis

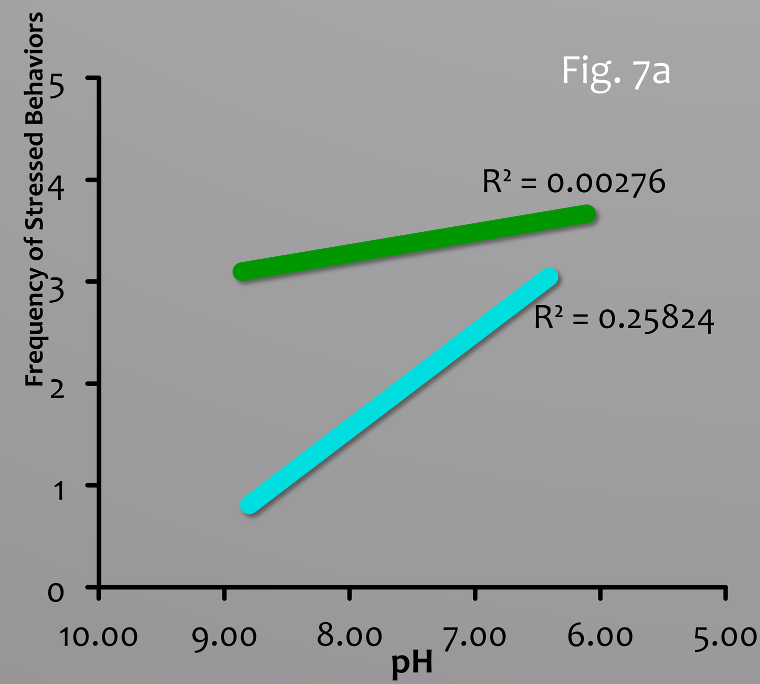
Purpose: The purpose of the experiment is to determine how global climate change-induced decreases in ocean pH might affect the behavior of economically and ecologically important flats fish.

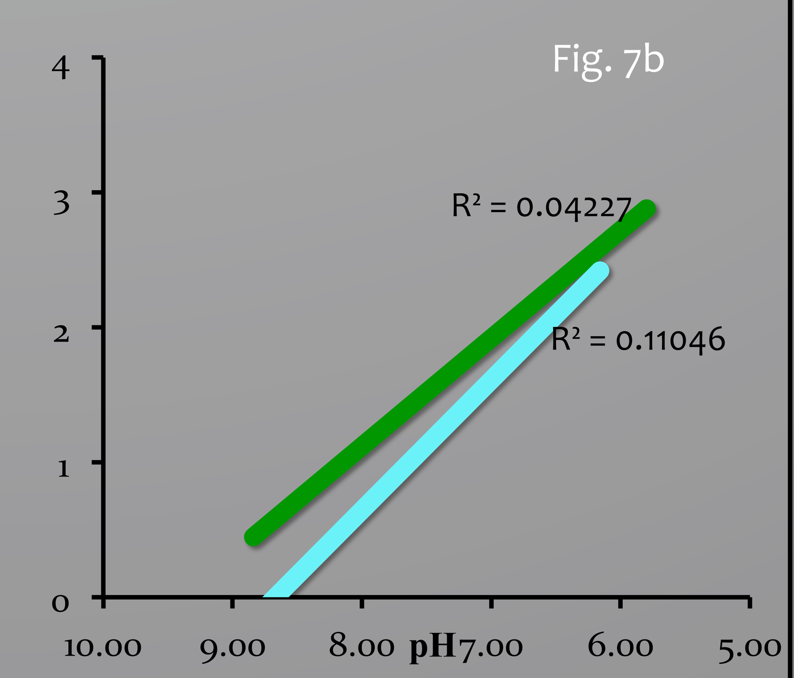
Hypothesis 1: Fishes will exhibit a pH limit, at which they will migrate from their preferred habitat. This means at a certain point fishes will not be able to withstand or live in certain water conditions and they will have to search for a new habitat containing optimal water conditions.

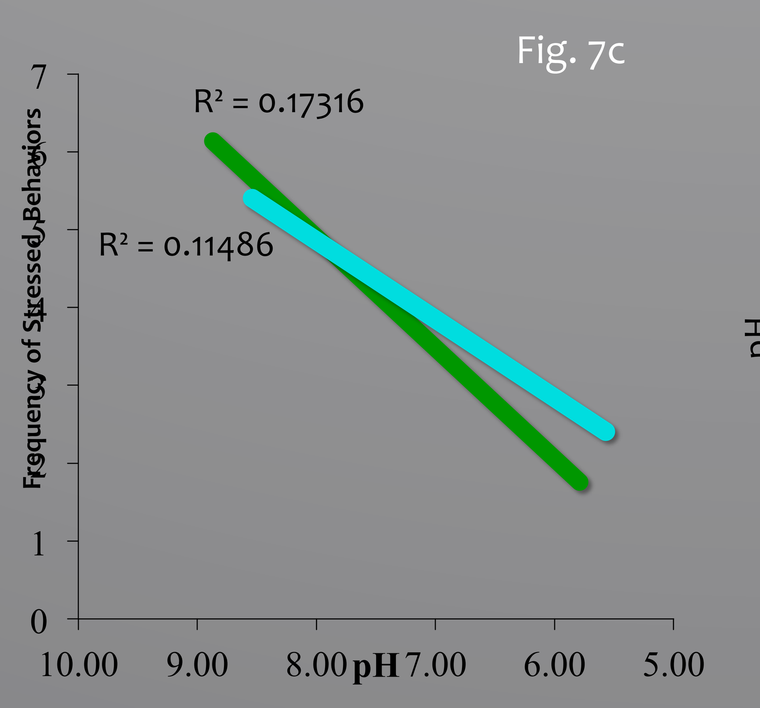
Hypothesis 2: Fishes will withstand a greater decrease in pH in the presence of a predator. This will happen because the fish will be under more pressure to stay in the manipulated tank and not risk predation.

Results

Following shuttle box trials, checkered puffer and bonefish demonstrated an increased frequency of stressed behaviors as pH decreased and the seawater became more acidic (R^2 = 0.0028, Fig. 7a; R2 = 0.0423, Fig. 7b). Additionally, stressed behaviors became more frequent at a faster rate for both checkered puffer and bonefish when a predator was present (R^2= 0.25824, Fig. 7a; R^2= 0.11046, Fig. 7b). Schoolmaster snapper exhibited a decrease in stressed behaviors as the pH decreased in both the control and predator trials (R^2 = 0.1732, R^2 = 0.1149.; Fig. 7c). Schoolmaster snapper and checkered puffer showed a tendency to withstand a significantly lower shuttle pH level in the presence of a predator (*p* = 0.2311; *p* = >0.0001, respectively; Fig. 10). However, bonefish showed similar shuttle pH for both control and predator trials (*p* = 0.5028; Fig, 8).







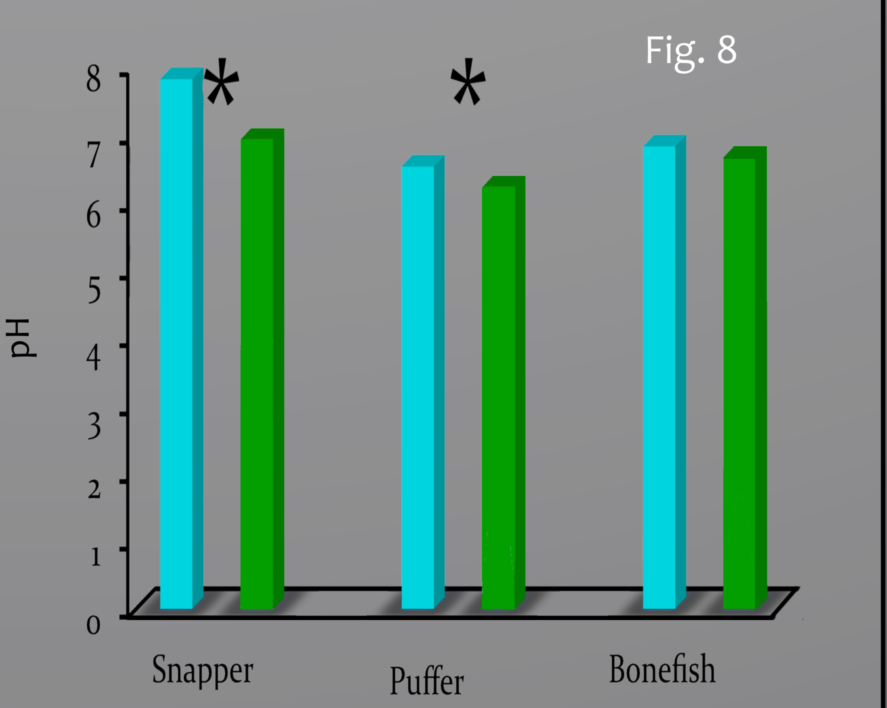


Fig. 7. Linear regression depicting the frequency of stressed behaviors exhibited by a) checkered puffer, b) bonefish and c) schoolmaster snapper, as pH decreased during shuttlebox trials. Control trials are represented by cyan (blue) regression lines, and predator trials are represented by green regression line.

Fig. 8. The mean pH level at which fish shuttle from the manipulated pH side to the ambient seawater side of shuttlebox. Checkered puffer and schoolmaster snapper shuttled at significantly lower pH when a predator was present ([p= <0.001], [p=0.0147]), respectively). Cyan represents control trials, and green represents predator trials.

Discussion

It was hypothesized that decreasing pH, per climate change forecasts (Dixson, Munday, & Jones. 2010.), will impact the behaviors of flats fishes. Checkered puffer and bonefish exhibited an increase in the frequency of stressed behaviors as pH decreased. An increase in stressed behaviors can lead to change in feeding patterns and limited reproductive success (Portner & Farrel). Schoolmaster snapper had decreased stressed behaviors in both control and predator trials. As pH decreased, schoolmaster snapper spent increasingly more time in the center corridor between the ambient and manipulated tank, likely because it is mimicking their natural behavior to take refuge in the prop roots of the mangrove forest (Fig. 9) (Sheaves 2005).

The checkered puffer and schoolmaster snapper showed a significant difference in shuttle pH between control and predator trials, meaning these fishes withstood a lower pH in order to avoid predation. The checkered puffer spends its life in the mangrove systems so it has a much higher pH resilience. Additionally, schoolmaster snapper spend their juvenile life in the mangrove systems and withstood a lower pH in the presence of a predator, so the schoolmaster snapper will be more likely to stay in the mangroves throughout its juvenile life. Bonefish had a tendency to lose equilibrium; due to migrating in and out of the mangroves during intertidal times, they are always in their optimal water conditions, giving them a much smaller physiological window (Fig. 10). If pH continues to decrease in the ocean the snapper and bonefish will be more likely to permanently migrate out of the mangrove systems, and it is expected the puffer will stay and risk physiological impacts.

Based on the results found, checkered puffer, schoolmaster snapper, and bonefish will be negatively impacted by ocean acidification and their stressed behaviors will cause a decrease in their ecological and economic benefits. Impacts on fishes living in the IHM can cause cascading through other interconnected habitats (Sheaves, 2005). Bonefish impacts will be especially detrimental economically, currently supporting a sport-fishing industry of about $141 million annually. These results suggest that if the pH continues to decrease, bonefish will migrate to deeper water with more risks of predation, so they will be harder to find and less abundant to sport fishermen. The results display that fishes will be negatively affected by oceanic acidification. Further research can be conducted on different species and regions. In order to try to reduce the expected impacts of climate change uniform mangrove policy can be created, shorelines protected, and decreased human emissions.


Fig. 9


Fig. 10

Fig.9: Snapper take refuge from predators in the mangrove roots, which is mimicked in shuttle box trials.

Fig.10: Bonefish is pushed beyond physiological limits and loses equilibrium during a trial; the fish has lost consciousness and needs to be removed immediately.

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