Survival of the Fittest: Florida Keys vs Flower Garden Banks coral, *Montastraea cavernosa*

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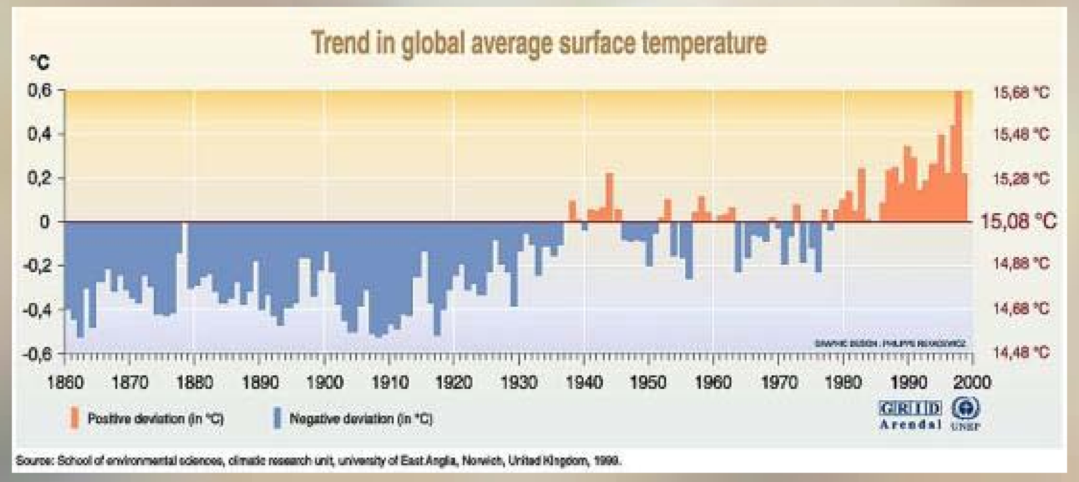
Abstract

Climate change is causing corals world-wide to bleach. We hypothesize that coral exposed to short durations of repetitive events of high heat stress are better adapted than corals lacking similar experiences. In this study, we compare populations of *Montastraea cavernosa* (Linnaeus, 1767) from the Florida Keys (FKs) to coral from the Flower Garden Banks (FGB). Coral from the FKs are known to experience frequent annual events of high temperatures whilst coral from the FGB have had fewer exposures to anomalous temperatures. Our data show that coral from the FKs lost significantly (ANOVA; $p < 0.01$) fewer viable, dead, and/or necrotic symbiont cells across all experimental temperatures than coral from the FGB. The mean percentage of viable expelled cells observed at 35ºC was significantly lower than those at 27ºC and 31ºC ($p < 0.05$, Games-Hollow *post-hoc* tests). The mean percentage of necrotic cells lost was greatest at 35ºC ($p < 0.01$, Games-Hollow *post hoc* test) culminating in the greatest loss (40%) within 24 h. There was no significant variation in the loss of apoptotic or post-apoptotic (ANOVA; $p > 0.05$) cells between temperatures or time. Our data indicated that *M. cavernosa* from FKs may be less susceptible to heat stress and bleaching than coral at the FGB. We speculate that this 'fitness' is a regional adaptation likely associated with numerous temperature anomalies.

Introduction

Mean global sea-water temperatures (SWTs) have increased by ~0.5°C over the past century and are expected to continue to rise over the next several decades (IPCC, 2007).



There have been numerous studies in the Caribbean on the causes and mechanisms of coral bleaching (e.g., Baker et al., 1997; Oppen and Lough, 2009) including the probability that some corals can "cope" with heat stress better than their symbionts (Sammarco and Strychar, 2009), and that this may be related to their evolutionary age and/or their prior experiences to specific stressors (Reich and Hickey, 2005; Florida DEP, 2009). Here, we ask whether corals in the Florida Keys (FKs) are better adapted for long-term survival vs. those in the Flower Garden Banks (FGB) because of prior exposure to such stresses (e.g., bleaching) through time, in terms of frequency and level.

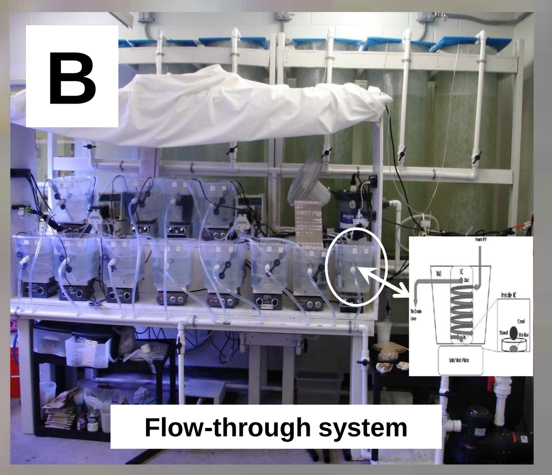
Methods

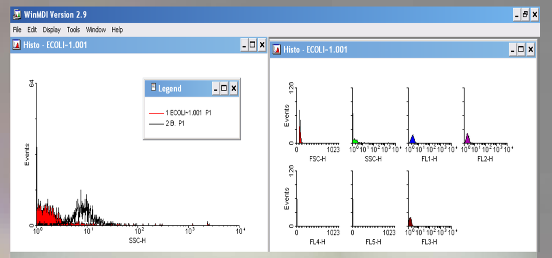
Considered one of the more susceptible species to thermal stress (Schmahl et al., 2008), *Montastraea cavernosa* (A) samples were collected from FKs and FGB and transported to Texas A&M University – Corpus Christi.

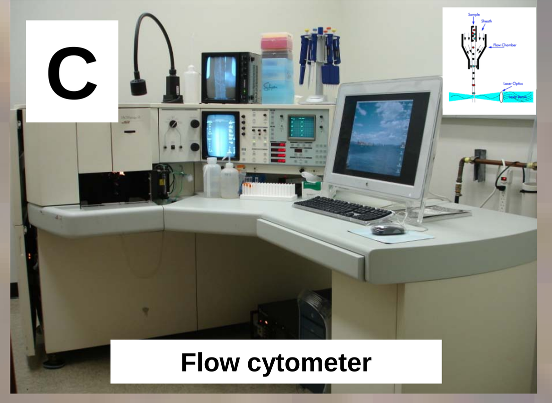
A flow through sea water system (B) delivered filtered oxygenated seawater at a constant flow rate of 12.5 mL min^{-1} to individual incubation containers (IC), each housed within a thermally controlled water jacket.

Each IC contained one coral fragment ~2.5 cm^2. Eight coral replicates at each of three temperatures (27ºC, 31ºC, and 35ºC) were examined for each site (FCs and FGB); two experimental replicates were conducted for each site. Seawater samples (50 mL) were obtained every 6 h over 72 h from each IC and centrifuged to concentrate the samples into two 1 mL aliquots. One aliquot was used for light microscopy to determine zooxanthellar density, mitotic index, and viability. The second aliquot was examined using flow cytometry (C) to differentiate between four cell death categories: viable, necrotic, apoptotic, and post-apoptotic.

Statistical analysis consisted of a Model I, repeated-measures, three-way orthogonal experimental design. All data were tested for significant variation due to sphericity using the Greenhouse-Guyser or the Huynh-Feldt correction. Since the data lacked sphericity, Tukey's and Games-Hollow *post hoc* tests were applied after analysis *via* GLM repeated measure ANOVAs to examine differences between individual means. Data displaying significant variations over time were Bonferroni-corrected.







Results

Coral collected from FKs lost significantly (ANOVA; $p < 0.01$) fewer viable, dead, and/or necrotic symbiont cells across all experimental temperatures than coral from the FGB. The mean percentage of viable expelled cells observed at 35ºC was significantly lower than those at 27ºC and 31ºC ($p < 0.05$, Games-Hollow *post-hoc* tests). The mean percentage of necrotic cells expelled was greatest at 35ºC ($p < 0.01$, Games-Hollow *post hoc* test) culminating in the greatest loss (40%) within 24 h. There was no significant variation in the loss of apoptotic or post-apoptotic (ANOVA; $p > 0.05$) cells between temperatures or time.

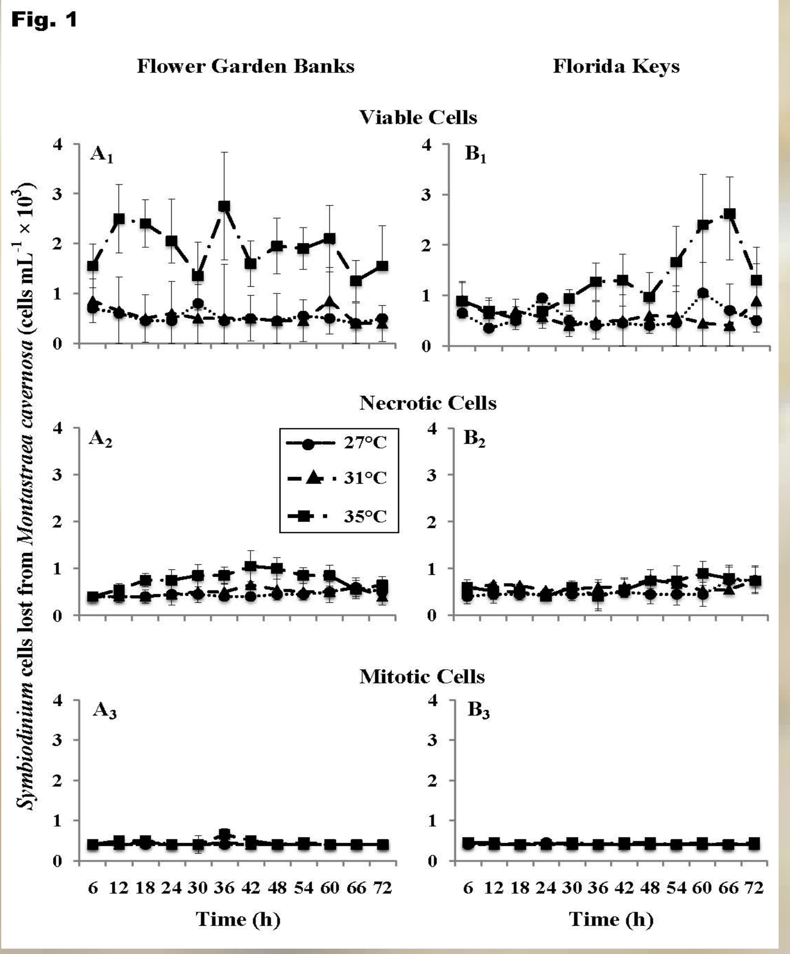


Fig 1. Hemocytometry data showing the mean temporal loss of viable (A_1, B_1), necrotic (A_2, B_2), and mitotic (A_3, B_3) zooxanthellae cells (× 10^3 mL^{-1}) expelled from *Montastraea cavernosa* collected from Flower Garden Banks (FGB) and the Florida Keys (FKs). Error bars represent 95% confidence intervals (n_i = 8); some error bars are too small to be seen.

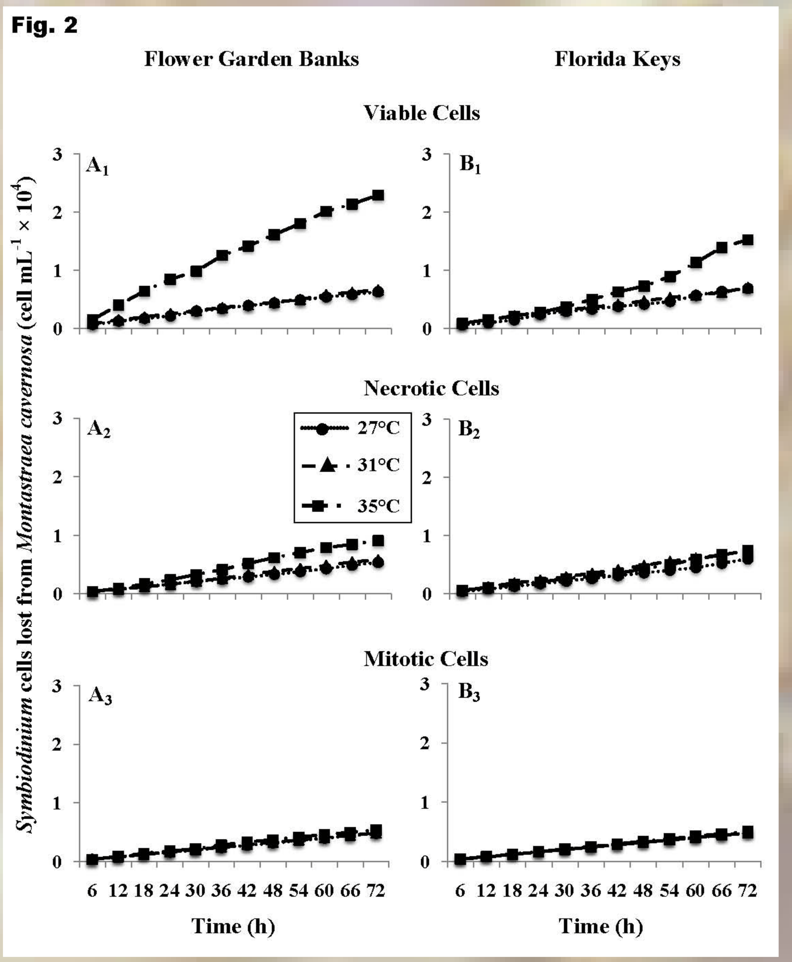


Fig 2. Hemocytometry data showing the mean cumulative loss of viable (A_1, B_1), necrotic (A_2, B_2), and mitotic (A_3, B_3) zooxanthellae cells (× 10^3 mL^{-1}) expelled from *Montastraea cavernosa* collected from Flower Garden Banks (FGB) and the Florida Keys (FKs). Error bars represent 95% confidence intervals (n_i = 8); some error bars are too small to be seen. Note how cumulative graphs illustrate the effect of temperature on overall depletion of a coral's *Symbiodinium* complement over 72 h.

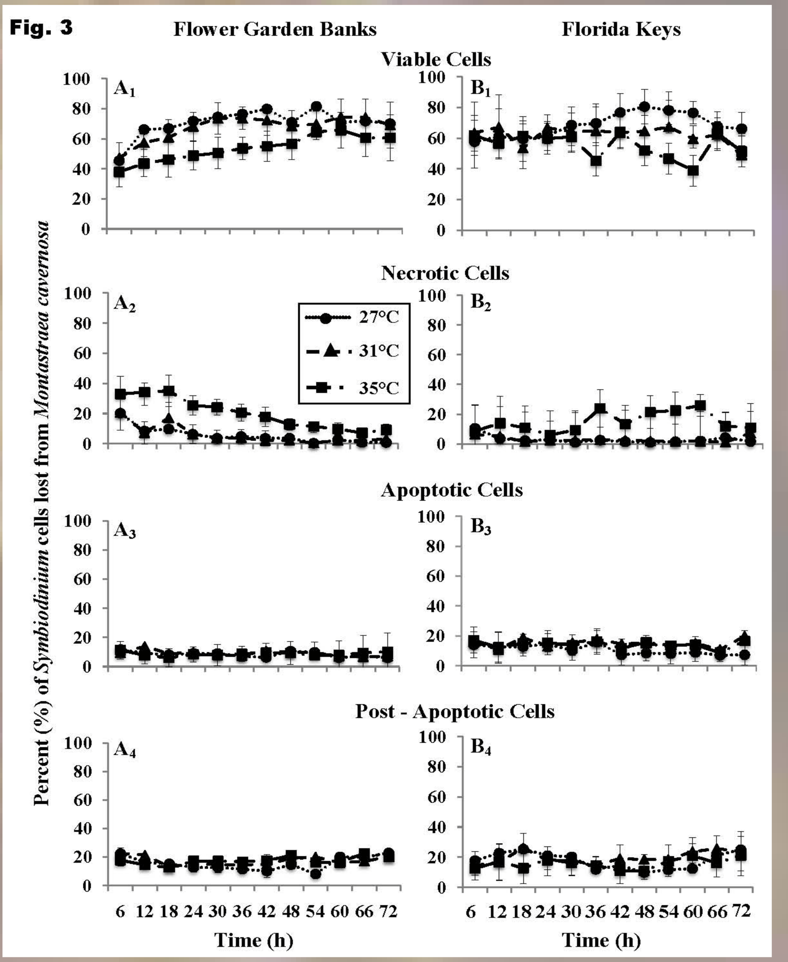


Fig 3. Flow cytometry data showing mean temporal loss expressed as percent (%) of viable (A_1, B_1), necrotic (A_2, B_2), apoptotic (A_3, B_3), and post-apoptotic (A_4, B_4) *Symbiodinium* cells expelled from *Montastraea cavernosa* collected from Flower Garden Banks (FGB) and the Florida Keys (FKs). Error bars represent 95% confidence intervals (n_i = 8); some error bars are too small to be seen.

Conclusion

***Montastraea cavernosa* from Florida Keys (FKs) may be less susceptible to heat stress and bleaching than coral at the Flower Garden Banks (FGB). We speculate that this 'fitness' is a regional adaptation possibly associated with numerous temperature anomalies.**

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