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Forecasting Mass Coral Bleaching Events: Development of *Acropora cervicornis* Model and Methods Comparison with NOAA Coral Reef Watch Program

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Introduction

- In today's warming ocean, significantly high SST can cause corals to lose their symbiotic zooxanthellae in a process called **"coral bleaching"**.
  - This effectively starves the coral and often results in death.
- Many coral researchers are focused on predicting and modeling corals' chances of survival over the coming years of ocean warming that could lead to a series of mass bleaching events.
- One such method, developed by NOAA Coral Reef Watch (CRW), uses the concept of a **"bleaching threshold"** - the temperature above which thermal stress will lead to significant bleaching.
- The second major bleaching parameter is the amount of accumulated heat stress, measured in **degree heating days (DHD)** for this study.
- CRW recommends a bleaching threshold of MMM + 1 and a DHD of 28-56; these bleaching parameters are broad and not species specific.
- Corals of different species have different responses to thermal stress and therefore, they likely have different bleaching parameters as well.
  - Additionally, genetic adaptations within a species are being seen to have an effect on thermal tolerance.
- **This study aimed to create models that can forecast the decadal percent chance of a mass bleaching event ocurrence through the end of the century under three different RCP emission scenarios.**
- **We intended to create the models using experimentally derived bleaching parameters for *Acropora cervicornis*, and to compare the efficacy of those models with models created using CRW's**

Methods

- Models were created using a 27-year in-situ SST dataset containing daily average values from Molasses Reef, FL.
- Experimental values for bleaching threshold and critical DHD were obtained from Dr. Chris Langdon's recent heat stress experiments with *Acropora cervicornis*.

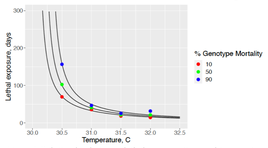

Figure 1: Relationship between lethal exposure time and temperature for 10% (red), 50% (green) and 90% (blue) genotype mortality

- Projected increases in SST per decade, per RCP scenario were obtained from a recent IPCC report.
- In total, 5 models were created, each using altered bleaching parameters
  - The general framework for all models was the same and is as follows:
- The temp. dataset was treated as a set of 27 "test years"; for each "test year", the proposed increase in SST for that decade and RCP scenario was added; prior, the dataset was detrended on a year to year scale.
  - DHD values were calculated for each day, and summed at the end of the test year.
  - If the cumulative value was greater than the critical DHD value being tested, that test year was marked as having a mass bleaching event
- The percent chances were calculated by dividing the number of test years that had cumulative DHD's exceeding the critical values by 27.

Models using experimentally derived bleaching parameters are more accurarte than those that used NOAA CRW's.

Results

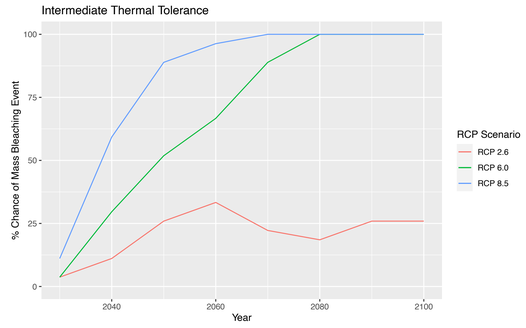

Figure 2: Results from model #1, which used experimentally determined values, derived from 50% genotype mortality in Figure 1, for the bleaching threshold (30.17°C) and critical DHD (33 °C-days). Results represent the decadal % chance of a mass bleaching event through the end of the century, under each of the 3 RCP scenarios tested.

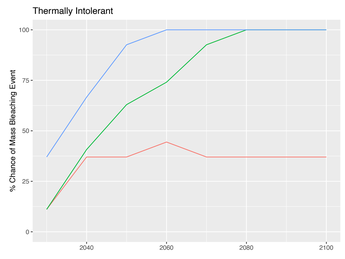

Figure 3: Results from model #2, which used experimentally determined values, derived from 10% genotype mortality in Figure 1, for the bleaching threshold (30.07°C) and critical DHD (30.2°C-days).

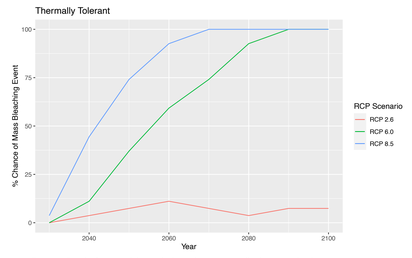

Figure 4: Results from model #3, which used experimentally determined values, derived from 90% genotype mortality in Figure 1, for the bleaching threshold (30.27°C) and critical DHD (36.3°C-days).

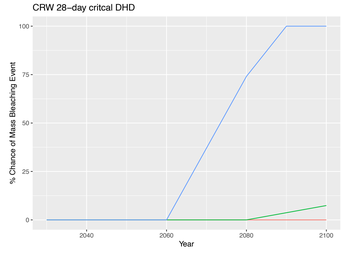

Figure 5: Results from model #4, which used the CRW's recommended values for the bleaching threshold (31.82°C) and critical DHD (28°C-days).

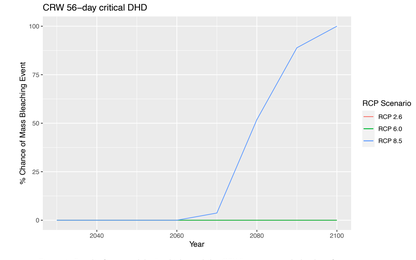

Figure 6: Results from model #5, which used the CRW's recommended values for the bleaching threshold (31.82°C) and critical DHD (56°C-days).

Conclusions

- Overall, high genetic thermal tolerance reduced the percent chances of a mass bleaching event occurrence, and vice versa.
- Selection for genetic thermal tolerance could change the trajectory of these curves through the end of the century or delay the onset of the 100% chance mark.
- Preliminary analysis showed us that the CRW's proposed bleaching threshold is too modest to capture any of the thermal stress present in the 27-year dataset; our experimentally determined threshold (from 50% genet mortality) is much more reliable.

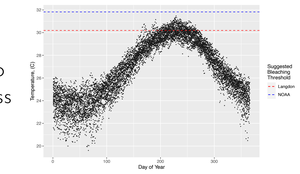

Figure 7: Entire dataset of daily SST values. 'NOAA' refers to the CRW programs's recommended threshold of MMM + 1°C and 'Langdon' refers to the experimentally determined threshold.

- Model results created using CRW bleaching parameters are much less realistic, showing almost no percent chance of mass bleaching through the end of the century in RCP 2.6 & 6.0, with only a delayed response in 8.5.
- Changing the CRW critical DHD had little effect, showing that it was the excessively high bleaching threshold that tainted those models' results.
- **Experimentally determined bleaching thresholds, that are species and region specific, have a greater capacity to accurately predict mass bleaching events.**

Anticipated Benefits

- It is our hope that this study demonstrates the need for more species specific bleaching prameters to be derived from similar heat stress experiments like those that Dr. Chris Langdon performed.
- If researchers around the world provided CRW with experimentally derived parameters for all threatened species of coral, monitoring and forecasting programs could be much more accurate and effective.
- By helping to improve coral bleaching prediction efforts, we hope to provide researchers involved in restoration projects a more informed assessment of which species would make promising candidates for these studies.

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