Determining marine heatwave baselines

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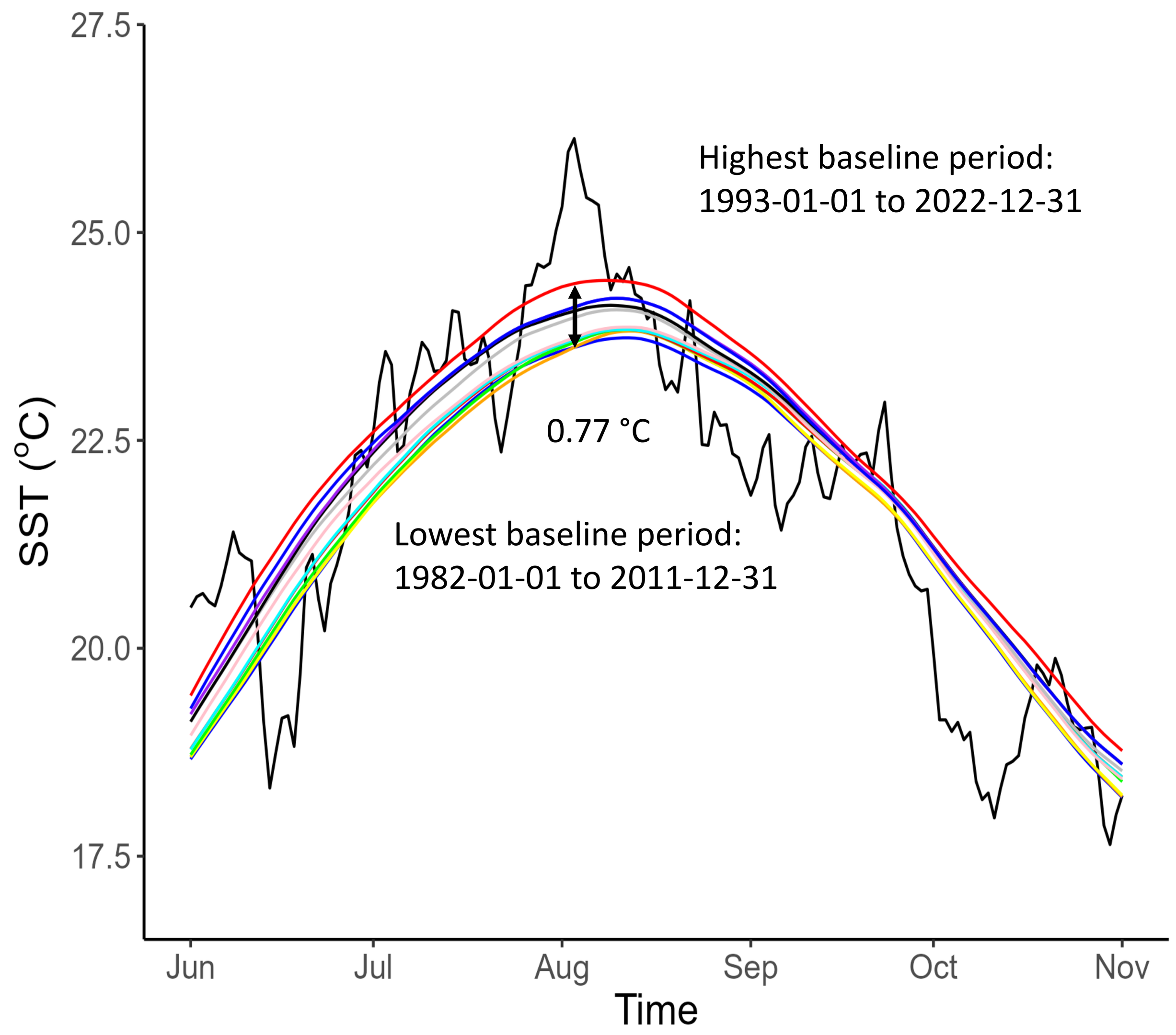
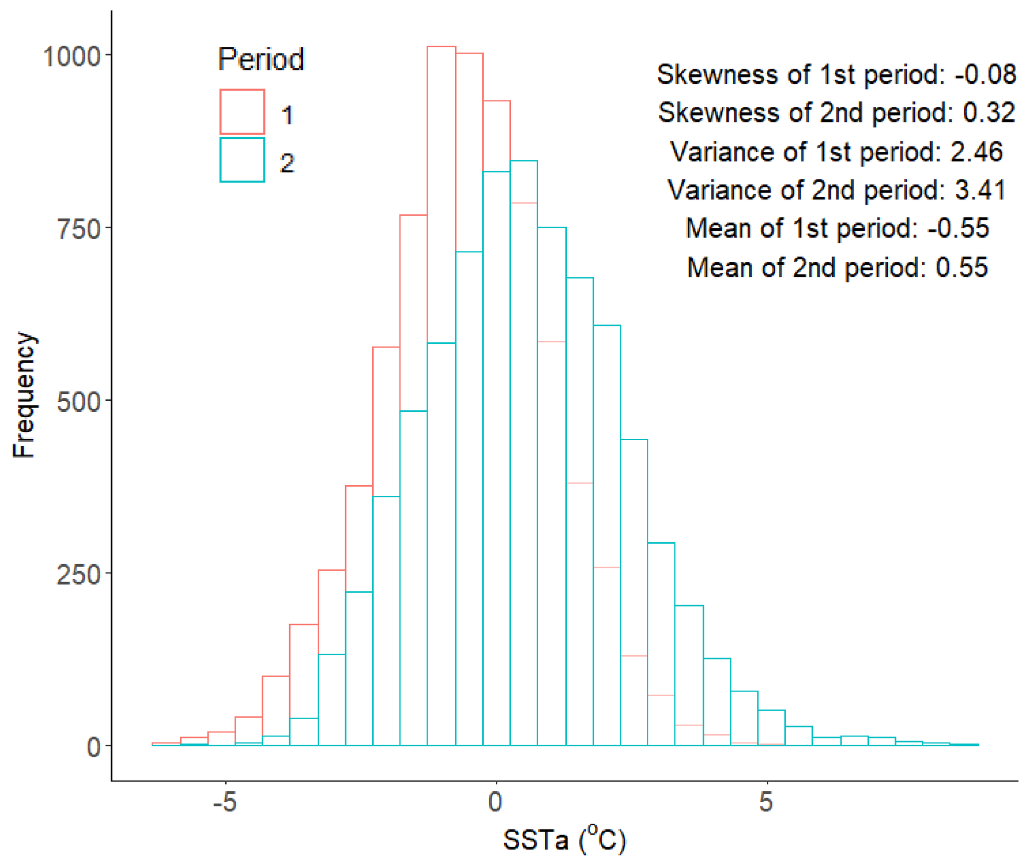
Purpose

- Marine heatwaves (MHWs) – discrete and prolonged warm ocean temperature extremes – can cause severe harm to marine ecosystems with estimated economic losses of up to hundreds of millions of dollars[1]
- Under global warming, MHWs have increased in frequency and duration over the past century[2]
- These trends are expected to continue if the ocean temperatures keep rising[3]
- However, the increasing occurrence of MHWs is based upon an important underlying assumption: under the most used statistical definition of a MHW[4], the trends have typically been assessed relative to a baseline over a fixed period
- If the baseline is kept fixed, oceanic regions can potentially reach an apparent permanent MHW state due to global warming, which violates the MHW definition
- Should we keep the baseline fixed or shift it? There are valid reasons for both, depending on the research context
- Typically, a fixed baseline is appropriate for studying the ecological impacts of MHWs, while a shifting baseline is suitable for investigating the physical drivers of MHWs. However, there are still many questions that remain





Objective 1

Impact of skewness trends on marine heatwave and marine coldspell trends

- The study of the physical drivers of MHWs under global warming typically involves disentangling changes in the variability of the SST from changes in its mean
- However, most studies to date have ignored another important characteristic of the SSTa distribution: the skewness

Methods

- Using OISST data, we will plot the spatial distribution of the SSTa skewness trends to investigate how the skewness is changing under global warming
- Then, we will use an AR (autoregressive) model to simulate SST with stationary (i.e., constant) mean and variance, but with the SSTa skewness changing in line with what is seen in observations
- An ensemble of MHW and MCS trends can thus be computed, which enables us to check for statistical significance of trends in MHW and MCS properties that arise solely due to the changes in skewness
- The next steps will be to determine the extent to which global warming is impacting the skewness of the SSTa distribution, and the consequence of using different MHW baselines on the skewness

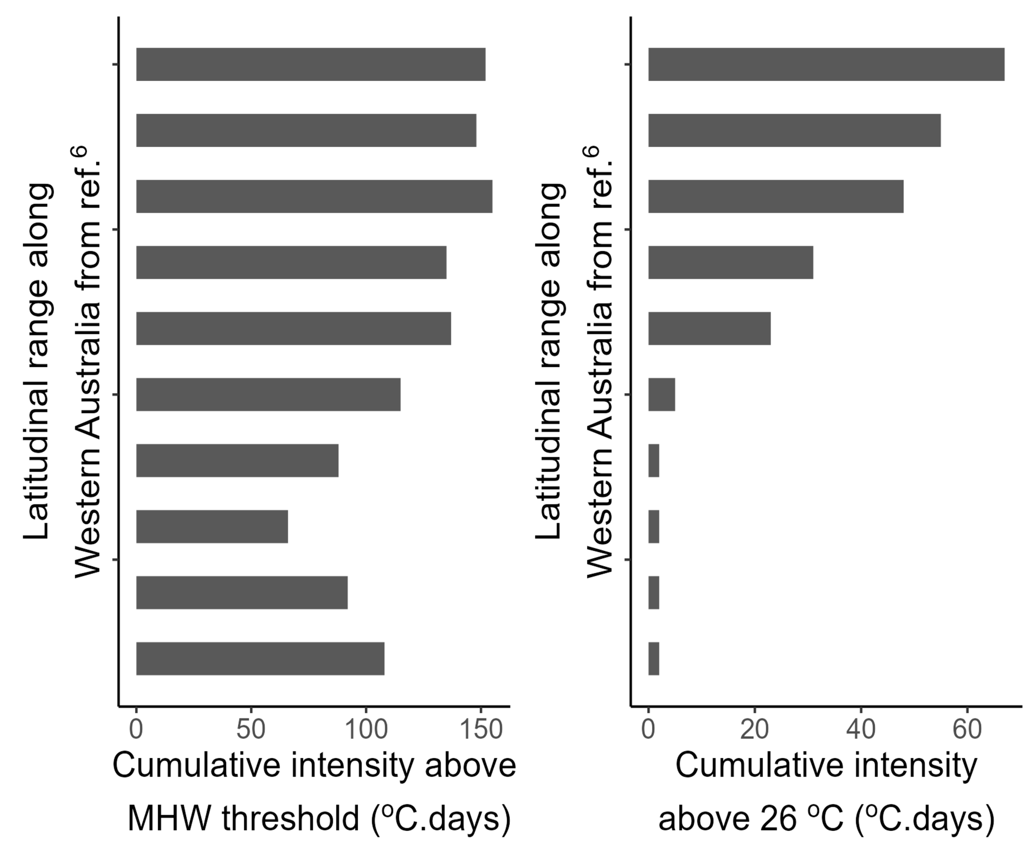
Methods

- Consider both the upper thermal threshold (or the thermal tolerance breadth, TTB) and the latitudinal range of marine organisms
- Repeat the analysis from ref.[6] using coral bleaching/mortality data across the Great Barrier Reef (GBR) to confirm the results obtained
- Analyse how the within-species TTBs vary with latitude, for both *Ecklonia radiata* and corals
- Investigate how the within-species TTBs vary across season
- Use these results to tweak the Hobday et al. (2016) MHW definition[4] such that MHWs under this definition can better reflect the biological impacts. This can be achieved by changing the percentile threshold as a function of latitude and the TTBs

Objective 2

A framework to link the MHW definition to biological impacts

- The Hobday et al. (2016) MHW definition[4] is a statistical one[5]
- The primary intent underpinning the development of this definition was to provide a consistent MHW framework for ecological research[4]
- Yet, there is often a mismatch between MHW events under this definition and the associated ecological impacts



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Objective 3

Determine MHW baselines using SLiM 3

- Determine how fast MHW baselines are required to be changed by estimating the adaptation timescales of marine species using a forward evolutionary software called SLiM 3 (Ref.[7])
- SLiM 3 uses a simple scripting language called Eidos that allows any evolutionary scenario to be modelled
- Results from Objective 2 will be used to parametrize the model

Methods

- Our SLiM 3 model will follow the approach of ref.[8], who also used the same software to estimate the adaptation potential of a particular coral genus (*Acropora*)
- Contrary to the model in ref.[8] which used a yearly temporal resolution, our model will use a daily resolution to allow for MHWs to be simulated
- The model in ref.[8] also computed the fitness of corals based on the difference between the phenotype (i.e., the thermal optimum based on the genetic makeup of the QTLs) and the current environmental temperature (at yearly resolution)
- Our model will use the results from Objective 2 to determine the relationship between the extent of biological impacts and MHWs (at daily resolution)