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# Predicting seagrass decline due to cumulative stressors

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A B S T R A C T

Seagrass ecosystems are increasingly subjected to multiple interacting stressors, making the consequent trajectories difficult to predict. Here, we present a new process-based model of seagrass decline in response to cumulative light and temperature stress. The model is calibrated to laboratory datasets for Great Barrier Reef seagrasses using Bayesian inference. Our model, which is fit to both physiological and morphological data, supports the hypothesis that physiological carbon loss rate controls the shoot density decline rate of seagrasses. The model predicts the time to complete shoot loss, and a new, generalisable, cumulative stress index that indicates the potential seagrass shoot density decline based on the time period of cumulative stress. All model predictions include uncertainty estimates based on uncertainty in the model fit to the data. The calibrated model is packaged into a computer program that can forecast the potential declines of seagrasses due to cumulative light and temperature stress.

## 1. Introduction

Seagrasses are critical habitats for conservation (Unsworth et al., 2018) since they form the foundation of many temperate and tropical shallow water ecosystems worldwide (Hughes et al., 2009). Globally, seagrass loss is accelerating (Waycott et al., 2009), and the cumulative impacts of multiple stressors (Grech et al., 2011; Brown et al., 2014; Ontoria et al., 2019) play an important role in determining current and future seagrass ecosystem state (Unsworth et al., 2015; Griffiths et al., 2020). For the effects of single stressors on seagrass ecosystems, threshold values can be identified (Lee et al., 2007) which are easily communicable to managers, including minimum light requirements (Erftemeijer and Lewis, 2006; Collier et al., 2016; Chartrand et al., 2016), upper temperature limits (Pedersen et al., 2016; Adams et al., 2017; Collier et al., 2017), upper wave energy limits (Uhrin and Turner, 2018), and timescales of change (Adams et al., 2015; Lambert et al., 2019) and decline (O'Brien et al., 2018). These individual thresholds can be directly used to suggest when seagrass is at risk of substantial decline, but may not capture the potential declines caused by synergistic interactions between stressors that individually do not surpass a threshold. Predicting seagrass decline due to cumulative stressors requires knowledge of how the timescales of loss for seagrass quantitatively depend on these stressors, although this relationship may be complicated for multiple interacting stressors. The problem of synergistic interactions can be addressed by developing a mathematical model that takes into account the nonlinear interactions between stressors and outputs the cumulative impact of these stressors on seagrass decline. It is not feasible to take into account every possible

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