Capturing qualitative reef dynamics across decadal timescales

K. Brown [a,b], **A.L. Jenner** [a,b], **R.P. Araujo** [a] **and P. Corry** [a,b]

[a] *School of Mathematical Sciences, Queensland University of Technology, Brisbane, Australia*
[b] *Centre for Data Science, Queensland University of Technology, Brisbane, Australia*
Email: kaitlyn.brown@hdr.qut.edu.au

Abstract: Ecosystems such as coral reefs naturally exhibit transitory fluctuations caused by various exogenous factors including seasonality, natural disasters, and other abiotic disturbances. Consequently, the effects of anthropogenic climate change are most observable over decadal timescales. Current popular models, such as ReefMod (Bozec et al., 2022; Ortiz et al., 2014) and CoCoNet (Condie et al., 2018), are adept at capturing the fluctuations of reef processes when calibrated to dense sets of high-dimensional data. However, the availability and reliability of long-term reef-related data is notably inhibited. Consequently, these models can exhibit significant uncertainty in parametrisation across larger timescales, undermining their predictive capacity. Many models are unable to accurately capture the effects of ongoing ecosystem under the assumption of sparse, uncertain data.

To address these challenges, we present a novel deterministic modelling framework that describes coral reef dynamics via a system of ordinary differential equations. Bleaching dynamics are captured via a set of discrete state variables that correspond to bleaching states of a coral population. Initially, we calibrated the model to historical coral cover data, under the assumption of a static parametrisation. The resulting parametrisations raised a number of concerns with respect to the practical identifiability of the model. In response to these results, we introduced temporal variance in the parameter that controls the process of bleaching. This was achieved via a rudimentary segmentation algorithm that identified distinct periods of growth and decline in the historical coral cover observations. We used Bayesian inference, implemented via a Markov Chain Monte Carlo algorithm, to recalibrate the model and quantify the uncertainty in the parameters. Parameter distributions were estimated for multiple reefs, spanning the Great Barrier Reef, with sparse data across decadal timescales. Our preliminary findings indicate that, even under an unsophisticated temporal segmentation scheme and calibration to sparse empirical data, this novel modelling framework is able to effectively capture the qualitative variation in reef dynamics under ongoing disturbances, spanning multiple decades.

REFERENCES

Bozec, Y. M., Hock, K., Mason, R. A. B., Baird, M. E., Castro-Sanguino, C., Condie, S. A., Puotinen, M., Thopson, A., Mumby, P. J., 2022. Cumulative impacts across Australia's Great Barrier Reef: a mechanistic evaluation. Ecological Monographs, 92(1), e01494.

Condie, S. A., Plagányi, É. E., Morello, E. B., Hock, K., Beeden, R., 2018. Great Barrier Reef recovery through multiple interventions. Conservation Biology, 32(6), 1356–1367.

Ortiz, J. C., Bozec, Y. M., Wolff, N. H., Doropoulos, C., Mumby, P. J., 2014. Global disparity in the ecological benefits of reducing carbon emissions for coral reefs. Nature Climate Change, 4(12), 1090–1094.

Keywords: *Coral reefs, dynamics, long-term behaviour, ecosystem modelling, climate change*