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Interpretable Sensitivity Analysis of a Coral Ecosystem Model: An Assessment of CoralBlox with Shapley Effects

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Abstract: Sensitivity Analysis (SA) has been successfully used in recent decades to assess the contribution of a model's inputs to the variance of some quantity of interest (Pianosi et al. 2016). Sobol' indices are the most commonly used metrics used in this kind of analysis (Owen 2014), where the *first-order indices* (or *main effect*) measures the direct contribution of each input individually to the overall variance in the quantity of interest, and the *total-order indices* (or *total effect*) measures the contribution of each input considering both its direct effect and its interactions with other inputs (Pianosi et al. 2016; Owen 2014). One limitation of the Sobol' method is that its indices do not sum up to the model's total variance (Owen 2014). An alternative approach addresses this issue by using a Game Theory concept called Shapley values to calculate the so called Shapley effects. Each Shapley effect measures an input's contribution to the model's total variance considering both its direct effect and interaction with every other set of inputs (Owen 2014; Goda 2021). Different from the Sobol' indices, the Shapley effects are demonstrated to sum to the model's total variance (Owen 2014).

Here we present the result of a SA applied to CoralBlox (Ribeiro de Almeida et al. 2024; Iwanaga et al. 2023). CoralBlox is an ecological model for predicting coral cover on the Great Barrier Reef developed by the Decision Support team at the Australian Institute of Marine Science (AIMS). It includes 208 inputs of interest, representing ecological and environmental aspects of the coral ecosystem. These include reef carrying capacity, initial coral cover and composition, and heat stress. The adopted method for estimating Shapley values is based on the work presented in Goda (2021) and implemented in the Julia programming language (Ribeiro de Almeida 2025).

Our analysis revealed that coral habitable area, initial coral cover and coral composition, heat stress, and reef depth were the most influential inputs for the quantities of interest considered. By identifying the most influential factors, the result of the sensitivity analysis can inform where future research can focus to increase future coral cover predictions. These findings can also directly inform targeted management strategies, thereby strengthening model-based decision support for the Great Barrier Reef.

Keywords: *Sensitivity Analysis, Decision Support, Ecological Modelling*

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