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Identifying intervention options that promote coral reef resilience under climate uncertainty

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Abstract: The Great Barrier Reef is experiencing severe heat stress due to climate change, with mass bleaching events becoming more frequent (GBRMPA et al. 2025). At the same time, there is high uncertainty about future environmental conditions, the efficacy of different interventions to support coral reefs, and which locations should be prioritised to receive these interventions.

In this study, we apply pathway diversity, a recent approach to measuring resilience, to explore the resilience of coral seeding interventions using the ADRIA-CoralBlox model. Specifically, we assess 1) which management decisions promote high pathway diversity and 2) how pathway diversity is affected by uncertainty in environmental and intervention parameters. The Adaptive Dynamic Reef Intervention Algorithms (ADRIA) model supports reef restoration and adaptation interventions through scenario exploration and is coupled with CoralBlox, a coral dynamics model (Iwanaga et al., 2023; Ribeiro de Almeida et al., 2024). Pathway diversity is an approach to operationalise resilience focused on assisting decision-making and addressing uncertainty. According to the approach, resilience is greater when decision-makers have more action pathways, defined as sequences of options taken by actors (Lade et al., 2020).

ADRIA-CoralBlox employs multi-criteria decision analysis to dynamically select intervention locations in response to changing conditions, balancing ecological, geophysical and spatial criteria. We defined five options representing different decision-maker preferences for selecting seeding intervention locations: heat stress, geographical spread, reef connectivity, functional diversity, and balanced. The options assign distinct weights to each criterion, with the balanced option weighting all criteria more evenly. We then model the transition probability between these options over time based on a cost analysis.

Our preliminary results show that pathway diversity is influenced by environmental parameters, such as representative concentration pathway (RCP) and degree heating weeks (DHW) projections, as well as intervention parameters, such as the intervention option and the volume of seeding. The geographical spread and balanced intervention options resulted in a higher pathway diversity across scenarios, while the functional diversity option led to a lower pathway diversity.

These preliminary findings suggest that the pathway diversity methodology can help identify intervention options that enhance the resilience of the Great Barrier Reef and have the potential to inform discussions with decision-makers aiming to improve the resilience of corals to climate change.

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