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Mangrove traits influencing coastal protection under varying environmental and eco-geomorphic conditions.

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Mangrove forests provide critical shoreline protection in tropical and sub-tropical regions through wave attenuation, soil accretion and floodwater storage. These protective mechanisms relate to both ecosystem functionality and persistence (Lovelock et al. 2024). Multiple studies over the past decades have effectively shown that mangrove forest extent can lead to reduced wave heights between 50-99%, with vegetative characteristics slowly being introduced as a critical element (Mclvor et al. 2013). Increasing evidence has identified that the eco-geomorphological conditions shape the consistency and scale of protection but have not been properly considered. Ecological, hydrodynamic and geomorphological processes which occur at various temporal and spatial scales influence species-specific interactions, functional type formations and habitat structure (Gijssman et al. 2021). Mangrove forests can develop into distinct ecotypes over time (Twilley and Rivera-Monroy 2009), directly influenced by tidal exchanges between the mangrove forests and nearshore environments, affecting the level of productivity within the mangroves (Mitsch and Gosselink 2015). These interactions influence the mangrove forest structure through variability in sediment deposition rates, biomass accumulation, seedling recruitment and overall forest productivity (van Hespen et al. 2023).

Since variations in eco-geomorphological features affect mangrove functionality and persistence at multiple scales, this research will investigate how these differences can affect the ability of mangroves to provide consistent coastal protection. Building on existing modelling approaches (Beselly, van Der Wegen, and Roelvink 2025), the aim is to design an ideal model capable of capturing nuanced interactions between mangrove ecosystems and the geomorphological features. For instance, predictive models (WAPROMAN), designed to capture wave propagation through a uniform forest, utilised drag coefficients (Mclvor et al. 2013), while a measure of mangrove forest extent seaward followed a mechanistic approach using the window of opportunity for seedling establishment predictions (van Hespen et al. 2023).

The current workflow will identify and isolate the key drivers and traits of crucial mangrove forests that affect mangrove functionality and persistence, for parameterisation. As a preliminary approach, these parameters will be integrated into a numerical model, incorporating elements from previous mechanistic and empirical approaches, modified to ascertain and accommodate the variability in mangrove eco-geomorphology and sediment dynamics (Gijssman et al. 2021). This process can facilitate the quantification of impact and identify key thresholds that these selected

attributes of mangrove forests have on the function and persistence related to long-term coastal protection. Through this integration of multiple layers of eco-geomorphological variability, this work offers insights into how mangrove systems work as Nature-based Solutions and how they thrive within our changing climate.