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Utilising satellite-derived maps to partition coral reefs into meaningful spatial units

Vanessa Haller-Bull[a], Anna Cresswell[a], Manuel Gonzalez-Rivero[a], Juan Ortiz[a]

[a] *Australian Institute of Marine Science*

Abstract: Within-reef variability in geomorphic zone, depth, and wave exposure create different ecological environments. The development of satellite technology has increased our capacity to map and model different physical, environmental and biological variables at fine spatial resolution. These maps are often available as gridded rasters or outlines of different zones but do not translate directly to spatial units relevant for management or ecological modelling. Our aim was to develop a methodology which could meaningfully partition coral reefs into spatial units that allow for the assumption of homogeneity of environmental conditions and ecological functions. The spatial units generated from a preliminary version of this workflow have already demonstrated practical utility through their application in metapopulation modelling (Ani et al. 2024, Cresswell et al. 2024). The main difficulty creating these spatial units is balancing the size required for modelling while keeping the environmental conditions as homogeneous as possible.

Our methodology follows a systematic workflow for partitioning coral reefs into ecologically meaningful spatial units. The workflow is designed to be reproducible and adaptable to different reef systems while maintaining ecological relevance. Several different publicly available mapping and modelling products are utilised in the workflow. A version of these products is available globally, although those utilised here are considered to have higher accuracy than many of the global products. The workflow spans the following steps:

1. The geographic boundaries of reefs were determined from a publicly available zonation map that depicts the distribution of geomorphic features such as reef crest, slopes, reef flats and lagoons (Roelfsema et al., 2021). It is well established that different geomorphic zones are formed by distinctive environmental conditions (Done, 1982). Each geomorphic zone is considered separately in the next steps.
2. Delauney triangulation was used to establish vertices (lines between centroids) between the pixels within a geomorphic zone of a given reef. Each vertex is assigned a weight (cost of making that connection) that is based on the physical distance and the depth differential between the two pixels.
3. The minimum spanning tree is calculated using these weights (*mst* function in *sfnetworks* R package). The minimum spanning tree represents the single path that connects all pixels with the smallest cost as calculated by the weights for each vertex that is used to create the path.
4. Next, we can cluster the pixels using single nucleotide polymorphism (SNP)-based kinship analysis (*skater* package in R). This analysis uses the bathymetric depth for each pixel to determine the optimal partition points along the path of the minimum spanning tree, with SNP-based kinship analysis providing a measure of genetic similarity to guide clustering. The number of clusters is not fixed and depends on the characteristics and number of pixels in the network.

Here, we present an application of the methodology utilising depth as a comparison with hierarchical clustering used commonly in landscape ecology. The results clearly show an improvement in the homogeneity of the environmental condition within each resulting site.

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