Objective mapping of complex marine landscapes

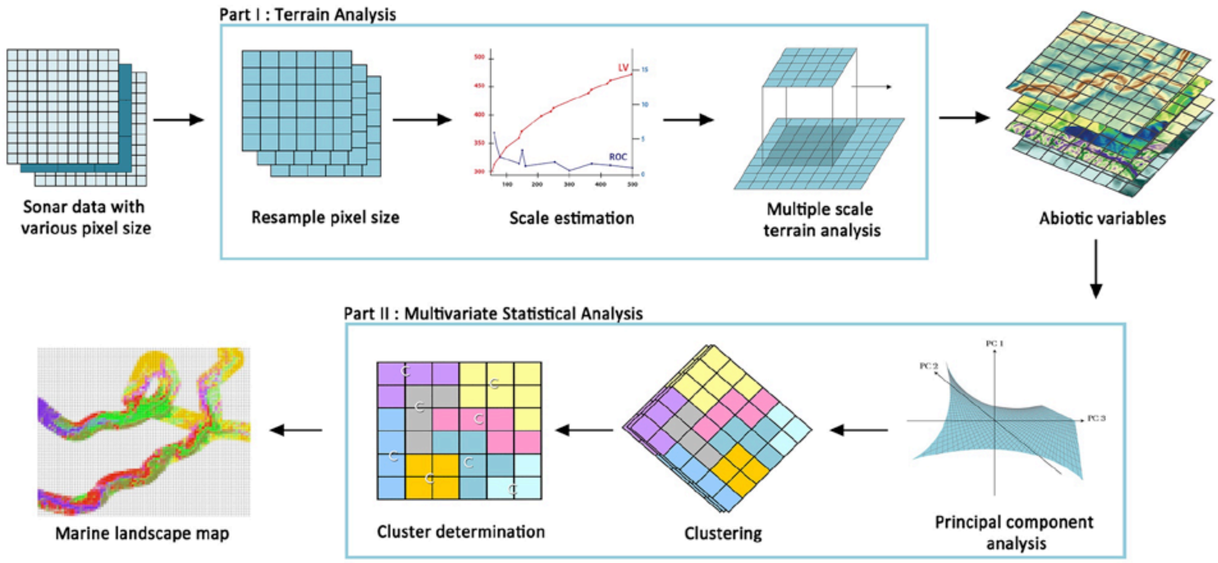
CODEMAP Protocol Factsheet 1

Aim Classification of the seafloor physical environment, based on statistical criteria rather than subjective decisions. Ideal for a (first-pass) mapping of terrain types and geomorphic features, either for their own intrinsic value, or as proxies for benthic habitat distribution. Especially useful for large areas where there is limited (biological) information.

Input Full coverage maps of all available physical terrain characteristics that have biological relevance (e.g. bathymetry, bottom current intensity, bottom water temperature, sediment type, …), and their derivatives (e.g. slope, Bathymetric Positioning Index), at the finest possible resolution.

Approach The method uses the ArcGIS and R software packages, and consists of the following steps:

- Resample all input data to a common pixel size, minimising interpolation of coarse grids (*ArcGIS*)
- Optional: multiple scale terrain analysis, establishing the scales of analysis based on the rate of change in local variance[2], (e.g. *ESP tool in eCognition*)
- Calculate derived environmental variables (e.g. slope, BPI,…) at appropriate scales (*ArcGIS*)
- Principal Component Analysis to reduce the number of input variables (*R*)
- Determination of the optimal number of clusters based on the Calinski-Harabash criterion or the elbow method[3] (*R, NbClust or fpc packages*)
- K-means clustering, characterisation of the clusters and mapping of the classification results (*R*)
- Assessment of classification confidence using confusion indices[3,4]



Flowchart of the Marine Landscape classification process (Ismail et al. (2015), after Verfaillie et al. (2009))

CODEMAP The ERC project "COmplex Deep-sea Environments: Mapping habitat heterogeneity As Proxy for biodiversity" (Starting Grant no 258482) ran from April 2011 till January 2017, and was aimed at the development of robust, integrated and fully 3-D methods to map complex deep-sea environments (submarine canyons, cold-water coral reefs, seamounts,…), in order to quantify habitat heterogeneity and use this as proxy to estimate the spatial distribution of benthic biodiversity. The outcomes of the project are summarised in a series of protocol factsheets, and can be found on www.codemap.eu

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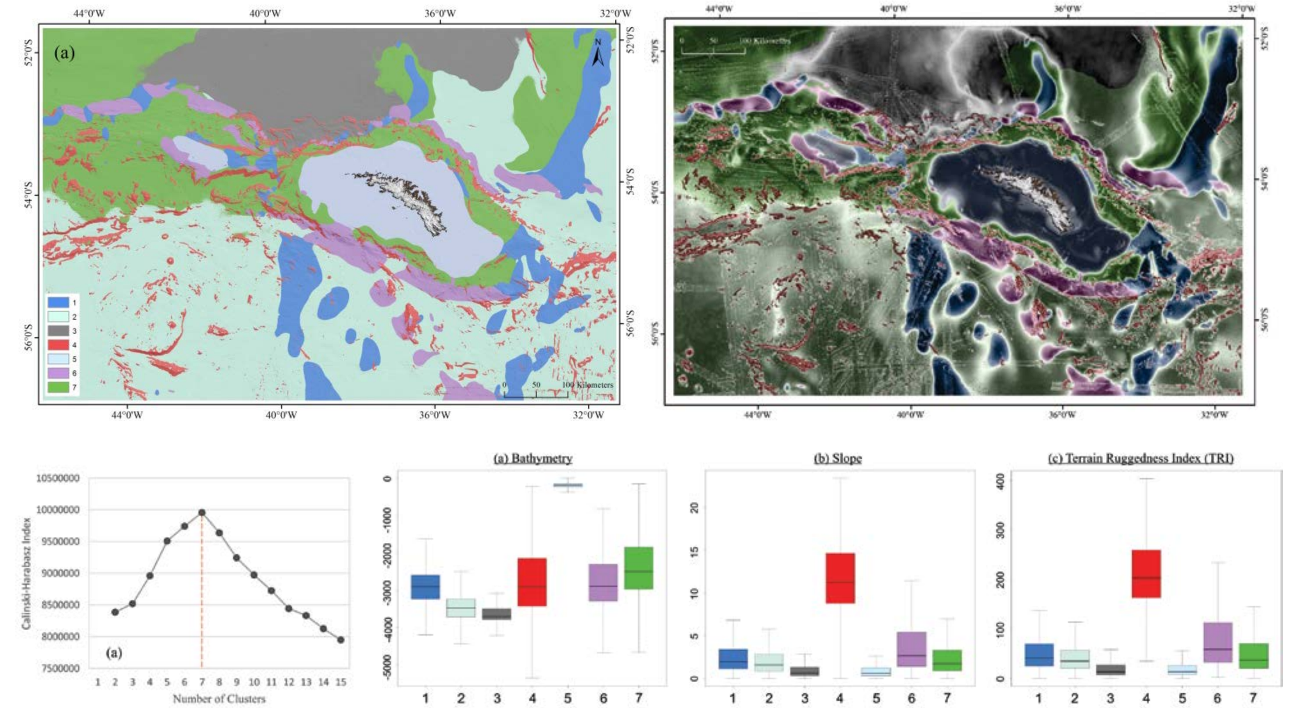

Classified Marine Landscape map of South Georgia, together with confusion map identifying zones with higher uncertainty (white). Calinski-Harabasz Index indicating the optimal number of clusters (7), together with a series of boxplots illustrating the main environmental characteristics of the 7 classes. After Hogg et al. (2016).

Background The 'ecological niche' is defined as the set of environmental conditions and necessary food resources that determine species occurrence[1]. Ecological Niche Theory therefore assumes that spatial variability in species distributions, and hence biodiversity, is ruled by spatial variation in environmental conditions. Mapping the different abiotic environments can thus be used as proxy for benthic habitat distribution.

Many species, however, react differently to environmental conditions at different scales. Establishing the scales at which natural variation occurs in the research area, and quantifying the terrain characteristics at those scales is important to capture the full set of environmental drivers of the benthic communities[7].

In addition, changes in environmental conditions are mostly gradual. As a result, the boundaries between habitats or communities are generally 'fuzzy'[5]. Providing this information with the seafloor classification as a confidence indicator helps marine spatial managers recognise the reality of the situation at the seafloor.

Further reading

[1]Chase JM, Leibold MA (2003) Ecological niches: linking classical and contemporary approaches. University of Chicago Press, Chicago, 212pp.

[2]Dragut L, Tiede D, Levick SR (2010) ESP: a tool to estimate scale parameter for multiresolution image segmentation of remotely sensed data. International Journal of Geographical Information Science 24:859-871

[3]Hogg et al. (2016) Landscape mapping at sub-Antarctic South Georgia provides a protocol for underpinning large-scale marine protected areas. Scientific Reports 6(33163):15pp doi:10.1038/srep33163

[4]Ismail et al. (2015) Objective automated classification technique for marine landscape mapping in submarine canyons. Marine Geology 362:17-32 doi:10.1016/j.margeo.2015.01.006

[5]Lucieer V, Lamarche G (2011) Unsupervised fuzzy classification and object-based image analysis of multibeam data to map deep water substrates, Cook Strait, New Zealand. Cont Shelf R 31:1236-1247 doi:10.1016/j.csr.2011.04.016

[6]Verfaillie et al. (2009) A protocol for classifying ecologically relevant marine zones, a statistical approach. Estuar Coast Shelf Sci 83(2):175-185 doi:10.1016/j.ecss.2009.03.003

[7]Wilson et al. (2007) Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Mar Geod 30(1-2):3-35 doi:10.1080/01490410701295962

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