Using landscape indices to explain biological patterns

CODEMAP Protocol Factsheet 4

Aim Improving the understanding and prediction of spatial patterns in megabenthic species assemblages through the quantification of fine-scale habitat patch characteristics as explanatory variables

Input Full coverage thematic (i.e. classified) seafloor maps of habitat type (see CODEMAP Factsheets 1 & 2 for suggested classification techniques), together with point-based information on megabenthic community composition (species counts converted into assemblages and diversity measures).

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

- Within neighbourhoods of varying size around each biological observation point: calculation of class and landscape indices. Class metrics describe the patch properties of a single class, while landscape metrics consider all patches in the landscape[1,3] (*SDM-Tools in R*)
- Correlation between observed species/diversity and environmental variables using ordination/linear regression techniques with forward selection. Apart from the landscape indices, conventional, single-location environmental descriptors (e.g. depth, slope, Benthic Positioning Index) can be added in the analysis (*R packages vegan, labdsv, gstat*)
- Identification of the amount of variation explained by landscape indices in addition to that explained by conventional environmental descriptors, through variation partitioning (*R package vegan*)

List of Class and Landscape metrics that can be calculated from thematic maps (after McGarigal et al., 2012 and Robert et al., 2014)

Class Metrics		Landscape Metrics	
Area-Edge Metrics	*Core Area Metrics*	*Area-Edge Metrics*	*Contagion-Interspersion Metrics*
Patch Number	Total Core Area	Patch Number	Proportion of Like Adjacencies
Total Area	Mean Core Area	Patch Density	Aggregation Index
Patch Density	Smallest Core Area	Edge Length	Landscape Division Index
Edge Length	Largest Core Area	Mean Patch Area	Splitting Index
Edge Density	*Contagion-Interspersion Metrics*	Smallest Patch Area	Effective Mesh Size
Mean Patch Area	Proportion of Like Adjacencies	Largest Patch Area	*Connectivity Metrics*
Smallest Patch Area	Aggregation Index	*Shape Metrics*	Patch Cohesion Index
Largest Patch Area	Landscape Division Index	Landscape Shape Index	*Diversity Metrics*
Shape Metrics	Splitting Index	Largest Patch Index	Patch Richness
Landscape Shape Index	Effective Mesh Size	Mean Shape Index	
Largest Patch Index	*Connectivity Metrics*	Minimum Shape Index	
Perimeter Area Fractal Dimension	Patch Cohesion Index	Maximum Shape Index	
Mean Perimeter Area Ratio		*Core Area Metrics*	
Minimum Perimeter Area Ratio		Total Core Area	
Maximum Perimeter Area Ratio		Mean Core Area	
Mean Shape Index		Smallest Core Area	
Minimum Shape Index		Largest Core Area	
Maximum Shape Index		Mean Core Area Index	

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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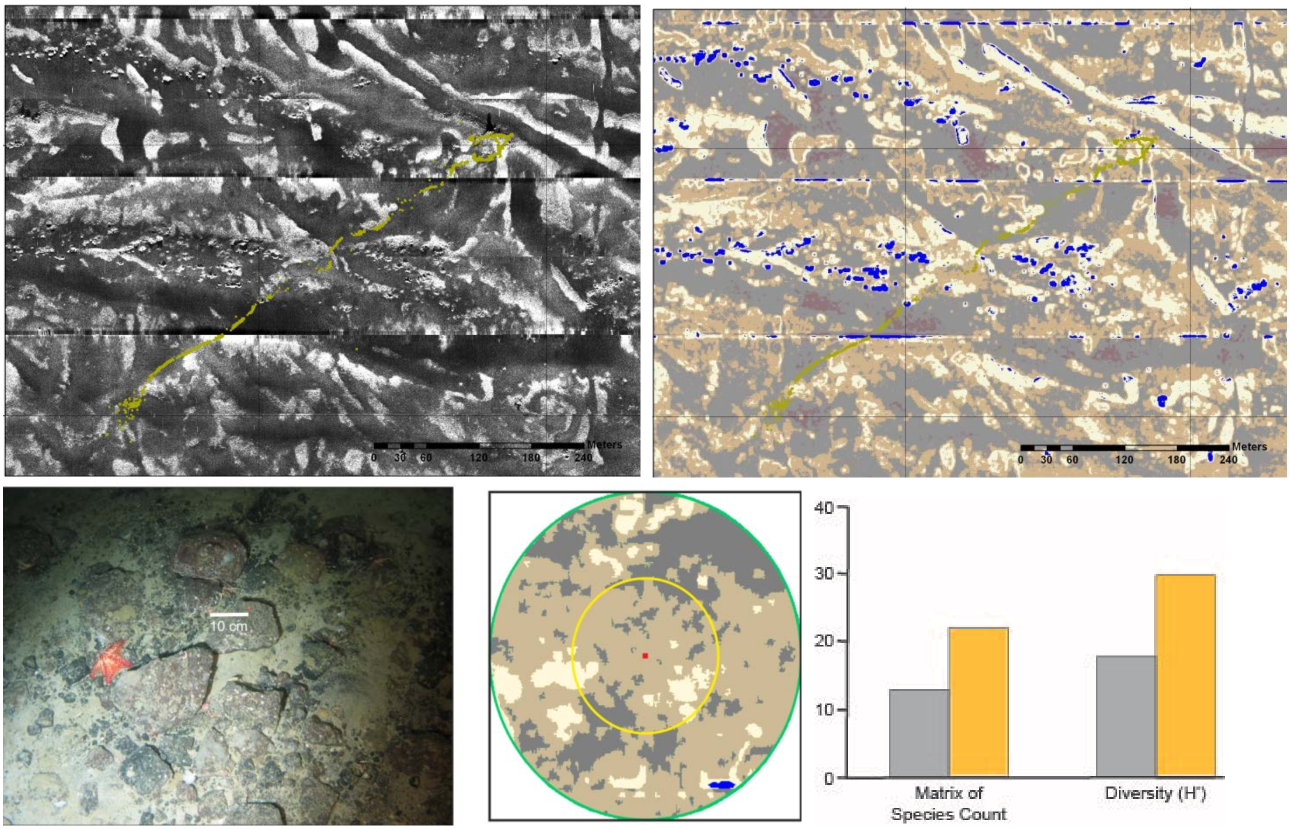

Sidescan sonar mosaic (upper left) and classified seafloor substrate map (upper right) of ice-berg ploughmark terrain on Rockall Bank, NE Atlantic, partly colonised by cold-water corals (classified in blue). Example picture of gravels and boulders on the ploughmark ridges (bottom left). Example of 30m and 75m search radius around the picture location for calculation of landscape metrics (bottom middle). Percentage variation in species composition and diversity explained with (orange) and without (grey) inclusion of landscape indices. After Robert et al. (2014).

Background The spatial distribution of benthic species is driven by a combination of biological factors (interactions between organisms) and environmental drivers. However, it is not only the absolute levels of environmental characteristics that are important: their spatial organisation also plays an important role (e.g. size of homogeneous patches, connectivity between patches, juxtaposition …).[3]

Landscape ecology is the discipline that studies the influence of landscape pattern and structure on organism abundance and ecological processes. It is commonly applied in terrestrial ecology, but is seldom used in the marine environment[4].

Landscape ecology offers several metrics to quantify the heterogeneity and morphological characteristics of a terrain, which can help to explain up to 12% of the variance in community composition, and up to 17% in biodiversity in highly complex terrains[2]. Although the application of landscape metrics certainly has limitations, their addition as explanatory variables when studying species distributions and the spatial variability of biodiversity can improve model performance without requiring additional samples[3].

Further reading

[1]McGarigal K et al. (2012) FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps. University of Massachusetts, Amherst http://www.umass.edu/landeco/research/fragstats/fragstats.html

[2]Robert K et al. (2014) Megafaunal distribution and biodiversity in a heterogeneous landscape: the iceberg-scoured Rockall Bank, NE Atlantic. Marine Ecology Progress Series 501: 67-88 doi: 10.3354/meps10677

[3]Turner MG (2005) Landscape ecology: What is the state of the science? Annu Rev Ecol Evol Syst 36:319-344 doi:10.1146/annurev.ecolsys.36.102003.152614

[4]Wedding LM et al. (2011) Quantifying seascape structure: extending terrestrial spatial pattern metrics to the marine realm. Marine Ecology Progress Series 427:219-232 doi:10.3354/meps09119