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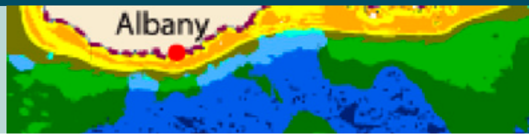
CLASSIFYING *Australia's seascapes for marine conservation*

Geoscience data predicts seabed biodiversity



Andrew Heap

We know very little about the biodiversity of the seabed. Much of it, especially the deep seabed, is poorly known and unexplored. While evolutionary history and local conditions can be used to reliably predict the distribution of species on land to underpin landscape management, the same cannot be said for the seabed.

Geoscience Australia is leading research to develop methodologies to predict marine biodiversity using geoscience information. A crucial first step is to characterise seabed habitats accurately from geological and oceanographical data. The procedure adopted is inspired by the shelf classification applied in eastern Canada by Roff et al (2003), who used physical properties (sediment type, physiography, bed roughness, wave and current regime) to define ecologically meaningful habitats on the Scotian Shelf.

This approach is based on the premise that community types exploit the availability of any given habitat (Day & Roff 2000). Although the species occupying each habitat may be different because of environmental and biological factors (e.g. competition, predator–prey relationships), the overall community types are recognisable and can be predicted from physical properties.

Predicting marine biodiversity is confounded because many marine ecosystems have been altered by human activities, but the degree to which they have been altered is poorly known.

Australia's seascapes

The oceans cover 71% of the Earth's surface, or nearly 350 million square kilometres. Australia's marine region accounts for 4% of this area—about 14 million square kilometres, nearly twice Australia's land area. While land plants and animals can be observed directly, most of Australia's marine plants and animals are not easily accessible or observable. With current technologies, it is impossible to observe all of Australia's marine biodiversity, and it is impractical to classify and count every organism in the ocean.

To make informed decisions about the conservation and sustainable use of Australia's marine resources would require high-quality biological data across the nation's entire marine region, but such data do not exist. To make decisions now, managers must use what is available. Currently, only physical datasets such as those collected by Geoscience Australia are detailed enough to be extrapolated over Australia's entire marine region. Individually, physical data are not always informative, but when combined with other physical datasets to produce 'seascapes' they can effectively represent the spatial distribution of marine biodiversity.

The approach of developing seascapes from physical datasets leads to a series of universal research questions being addressed by Geoscience Australia and the international scientific community:

- What physical variables are the most useful for predicting marine diversity?
- How can the individual physical data layers be integrated into a single seascape?
- How can seascapes help design a national system of representative marine protected areas?

Table 1. Datasets used in the construction of the seascapes in Australia's marine region

Dataset		Data type	Product
Bathymetry (m)	»	Continuous interpolated data	Seascapes
Gravel (>2 mm) content (%)	»		
Mud (<0.63 μm) content (%)	»		
Seabed disturbance ((Nm–^{2})$^{1.5}$)	»		
Slope (°)	»		
Seabed temperature (°C)	»		
Primary productivity (g Carbon m^{-2} a^{-1})	»		
Geomorphology	»	Categorical data	Focal variety analysis

Physical surrogates

The assumption that physical properties can be used as surrogates to represent marine biodiversity is central to the seascapes approach. While linkages between the physical environment and biota seem intuitive, understanding how the biota relates to physical properties is only half the story. It is equally essential to identify which physical properties are relevant. To date, physical properties that show the strongest relationship with the biota (as defined by some measure of goodness of fit) are considered to be most relevant as surrogates for biodiversity.

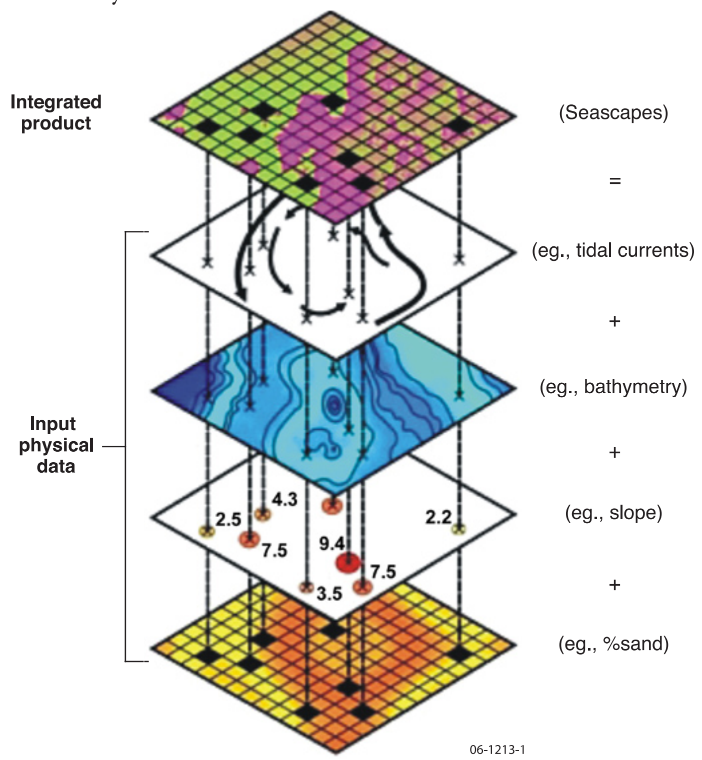


Figure 1. Seascapes represent a combination of different physical data that have an identifiable and consistent relationship with marine biota.

The influence of physical properties on seabed communities is clear and well documented. Relationships between physical properties and biota have been shown to exist in many studies of the marine environment (e.g. Thouzeau et al 1991, Snelgrove & Butman 1994, Williams & Bax 2001, Ramey & Snelgrove 2003). These studies show that, broadly, seabed biota have measurable and consistent relationships with many easily measured physical properties (table 1).

A Geoscience Australia study of associations between sediment properties and benthic biota in the southern Gulf of Carpentaria (Post et al 2006) shows that spatial changes in seabed biota are strongly related to mud and gravel content, seabed disturbance from waves and currents, water depth, and geomorphology.

Defining seascapes

While surrogacy studies provide important clues to how the biota are related to physical properties and which physical properties are most relevant, those studies are at a spatial scale that is too small to help managers make informed decisions about the conservation and sustainable use of Australia's entire marine region. We must take the results of these studies and extrapolate them over larger distances by creating seascapes.

Seascapes describe a layer of ecologically meaningful physical properties to spatially represent potential seabed habitats (figure 1). Each area of a seascape corresponds to an area of similar physical properties and, by association, habitats and communities. Geoscience Australia has used physical properties that have consistent relationships with the biota (table 1) and are known in sufficient detail across Australia's entire marine region (figure 2) to create seascapes for the region (figure 3).

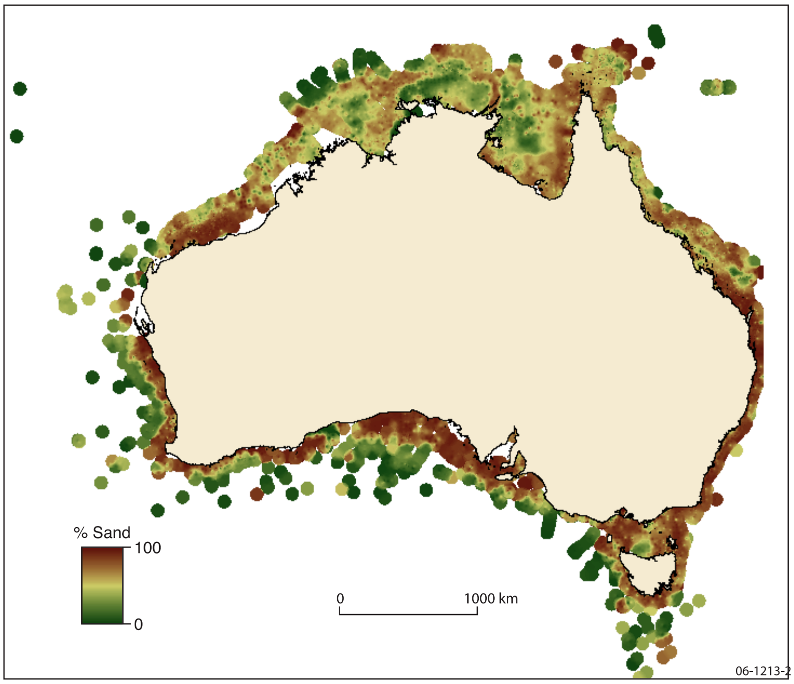


Figure 2. Physical data such as % sand can be extrapolated across vast areas of Australia's marine region.

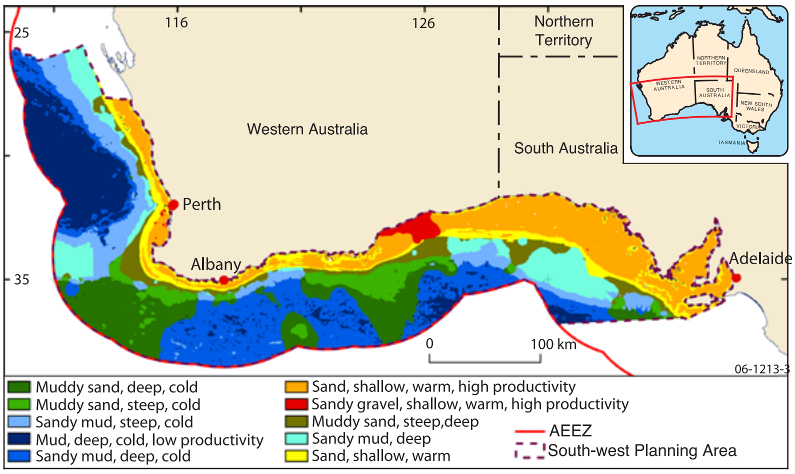


Figure 3. Each of the 10 seascapes derived for the South West Planning Region are defined by a diagnostic combination of physical properties.

The integration of these data to create seascape maps has been accomplished through an unsupervised classification, whereby all the data are combined with no prior assumptions about how each of the variables influences the biota. The process iteratively classifies the data into separate classes—based on statistical relationships—and continues until 100% of the classes are unchanged between iterations. The result is a number of mutually exclusive seascapes (figure 3).

Using this approach, the South West Planning Region contains a total of 10 separate seascapes, each defined by a diagnostic combination of physical properties. For example, the 'muddy sand steep deep' seascape is characterised by at least 50% sand and 20% mud, with relatively rugose and deep seabed topography. Interestingly, this seascape characterises those areas where numerous submarine canyons have incised the margin.

A major factor in defining seascapes is the method by which underlying physical property data are interpolated across Australia's marine region. Evaluation of two of the most diagnostic physical properties (gravel and mud percentage) using different interpolation techniques reveals that, while the overall fit of the interpolated surface across Australia's entire marine region is moderate (about 60%), the differences in

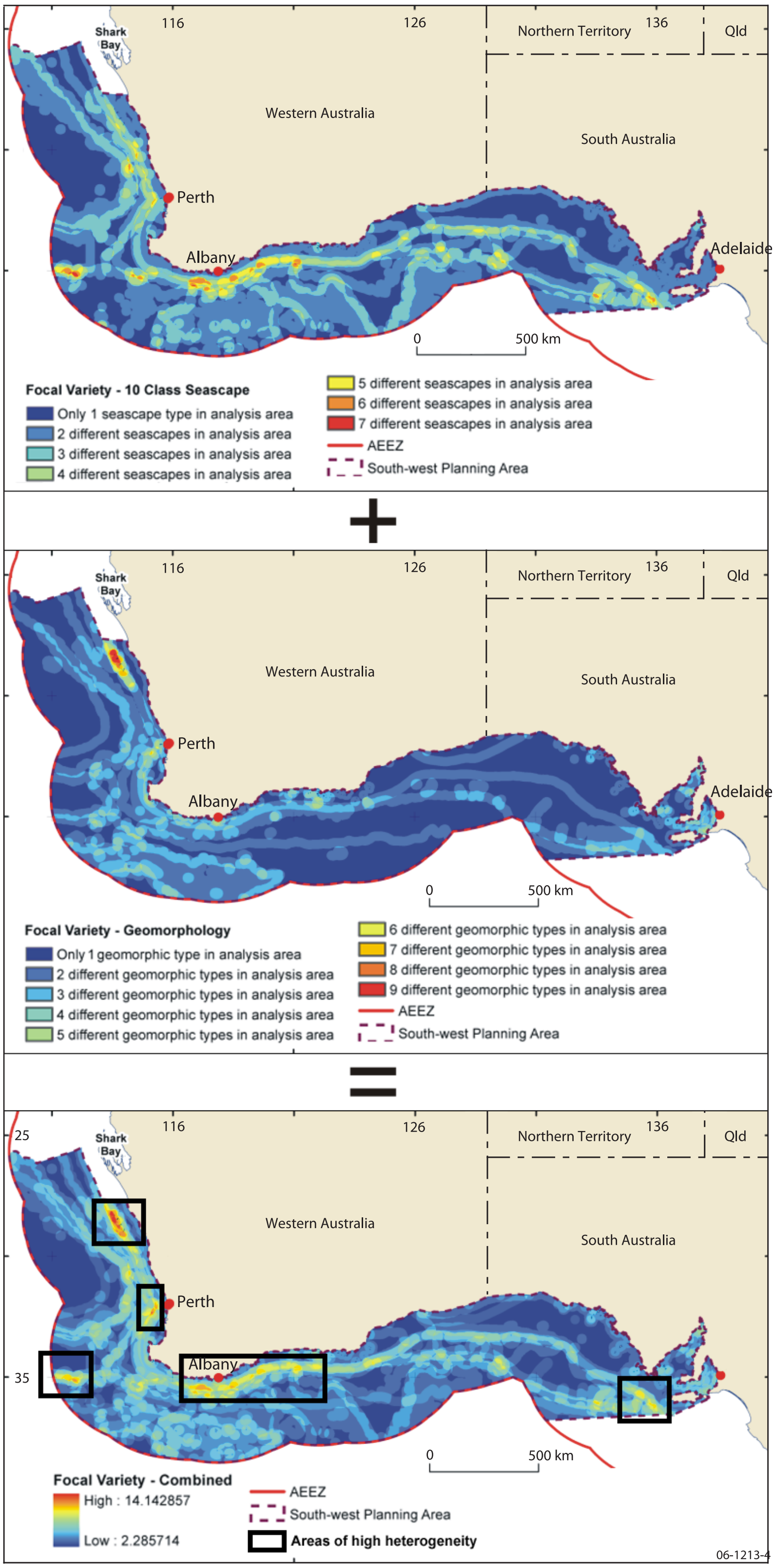


Figure 4. The selection of marine protected areas can be aided by a focal variety analysis of the seascapes and geomorphology to produce a map showing where the greatest seabed diversity occurs.

the underlying data produced by different interpolation methods are very small (less than 3%). Also, the effects of using different interpolation methods on the shape, distribution and area of the final seascapes are not significant. These results mean that the approach is relatively robust.

Geoscience Australia, together with Australia's marine biological research community, is currently working to correlate the seascapes with available biological information. The outcome will be ecologically meaningful seascapes that estimate the marine biodiversity over the scales required for marine management.

National system of marine protected areas

The seascapes can be used to help managers make decisions about where to place a system of representative marine protected areas. Ideally, such a system will maximise the biodiversity it protects while covering the smallest area. Maximum biodiversity is assumed to coincide with maximum habitat heterogeneity on the seabed, and thus with areas in which the most seascapes occur.

One way to define these regions using seascapes is to conduct a focal variety analysis in a geographic information system (GIS). This procedure counts seascape types within a specified distance (in this case 20 kilometres; figure 4). The focal variety analysis for the southern margin of Australia shows areas containing the most seascape boundaries (and thus highest seabed habitat diversity) in red, and areas of relative habitat homogeneity

> " The seascapes can be used to help managers make decisions about where to place a system of representative marine protected areas"

in blue. Geomorphology is a categorical variable and so is treated separately, and a separate focal variety analysis is completed on this dataset. The red areas show where geomorphology is most heterogeneous and blue areas where it is most homogeneous. The results are combined to provide a map showing seabed habitat diversity and denoting regions where marine protected areas could maximise biodiversity coverage.

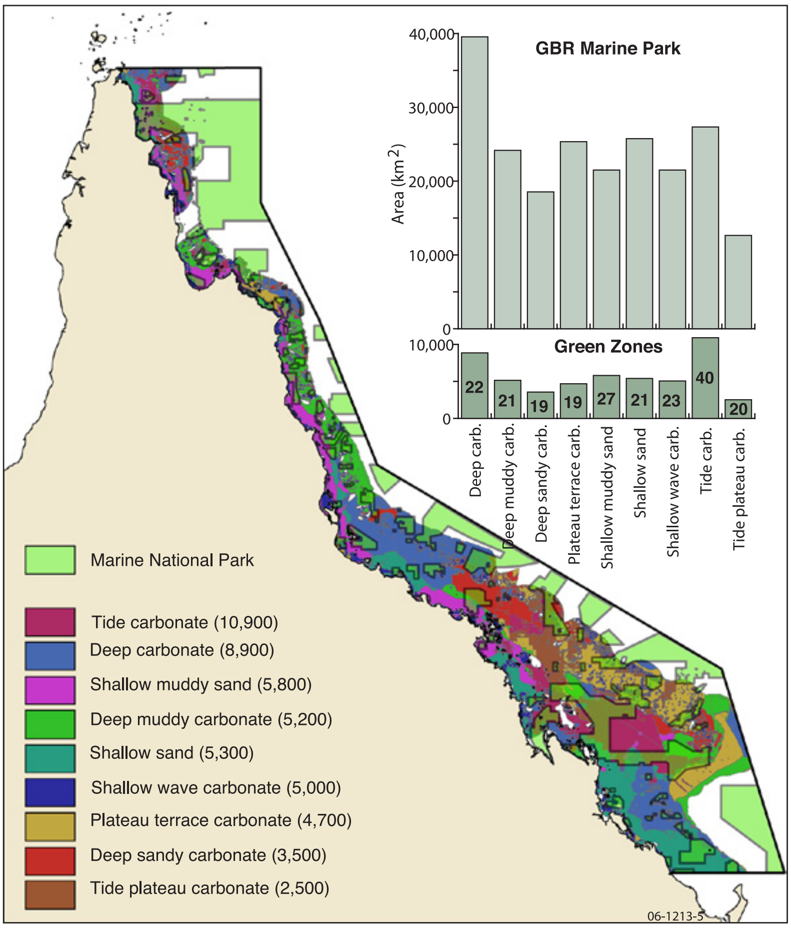


Figure 5. Simple spatial analysis provides an indication of whether the marine protected area system is comprehensive, adequate and representative. Numbers in blue are percentage of each seascape covered by Marine National Park zones (green zones).

Seascapes can also be used to test the efficacy of the marine protected area system using simple spatial analysis in a GIS. An effective system will be comprehensive, adequate and representative. In a comprehensive system, the habitats in the marine protected areas are proportional to their coverage across the entire planning area, for example the Great Barrier Reef (GBR) Marine Park. In an adequate system, enough of the habitat is protected to be self-sufficient (20% is considered appropriate). In a representative system, all the seascapes in the planning area are represented in the marine protected areas.

Geoscience Australia has analysed the seascapes contained in the green zones (Marine National Park zones) of the GBR Marine Park (figure 5). This analysis shows that the green zones are relatively comprehensive, with a slight over-representation of the tide carbonate seascape. The green zones are adequate, as only two of the nine seascapes have less than 20% of their total area covered, and they are representative because they contain all the seascapes that occur in the marine park.

Environmental significance

The mandate for undertaking this work comes directly from the United Nations Convention on Biological Diversity (CBD), which Australia ratified in 1994. The CBD requires each country to set up a system of marine protected areas for the conservation and sustainable use of threatened species, habitats and living marine resources and ecological processes (de Fontaubert et al 1996). To meet Australia's obligations under the CBD, the Australian Government and state governments are creating a national system of representative marine protected areas under the national oceans policy (ANZECC 1999) and the *Environment Protection and Biodiversity Conservation Act 1999*.

By creating seascapes from fundamental geoscience data on the nature of the seabed and by testing how far physical properties can be used as surrogates for biodiversity, Geoscience Australia is playing a crucial role in the development of the nation's system of marine protected areas.

Using seascapes for marine conservation is a new endeavour, and Australia is at the forefront of this work. We are among the first nations to tackle the problem of predicting marine biodiversity at the scales needed to manage our vast jurisdiction effectively. Geoscience Australia will continue to conduct marine environmental surveys to improve surrogacy and seascape research, providing scientific information to manage Australia's marine environment for conservation and sustainable resource use.

Geoscience data is the only spatially comprehensive data that is currently available to predict biodiversity over Australia's entire marine region. Geoscience Australia continues to work in collaboration with Australia's marine biologists and ecologists in the formation of seascapes for marine biodiversity prediction, including undertaking targeted marine surveys to collect further physical and biological data and building combined databases that permit direct correlation of data.

This research will improve the accuracy and precision with which we can predict Australia's marine biodiversity and thus strengthen confidence in decisions about the conservation and sustainable use of Australia's marine resources.

For more information

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