Australian Government
Geoscience Australia

AUSGEO news
ISSUE 84 Dec 2006

Mapping *marine diversity*

Habitats are keys to conservation management

Alix Post, Ted Wassenberg (CSIRO Marine and Atmospheric Research), Vicki Passlow

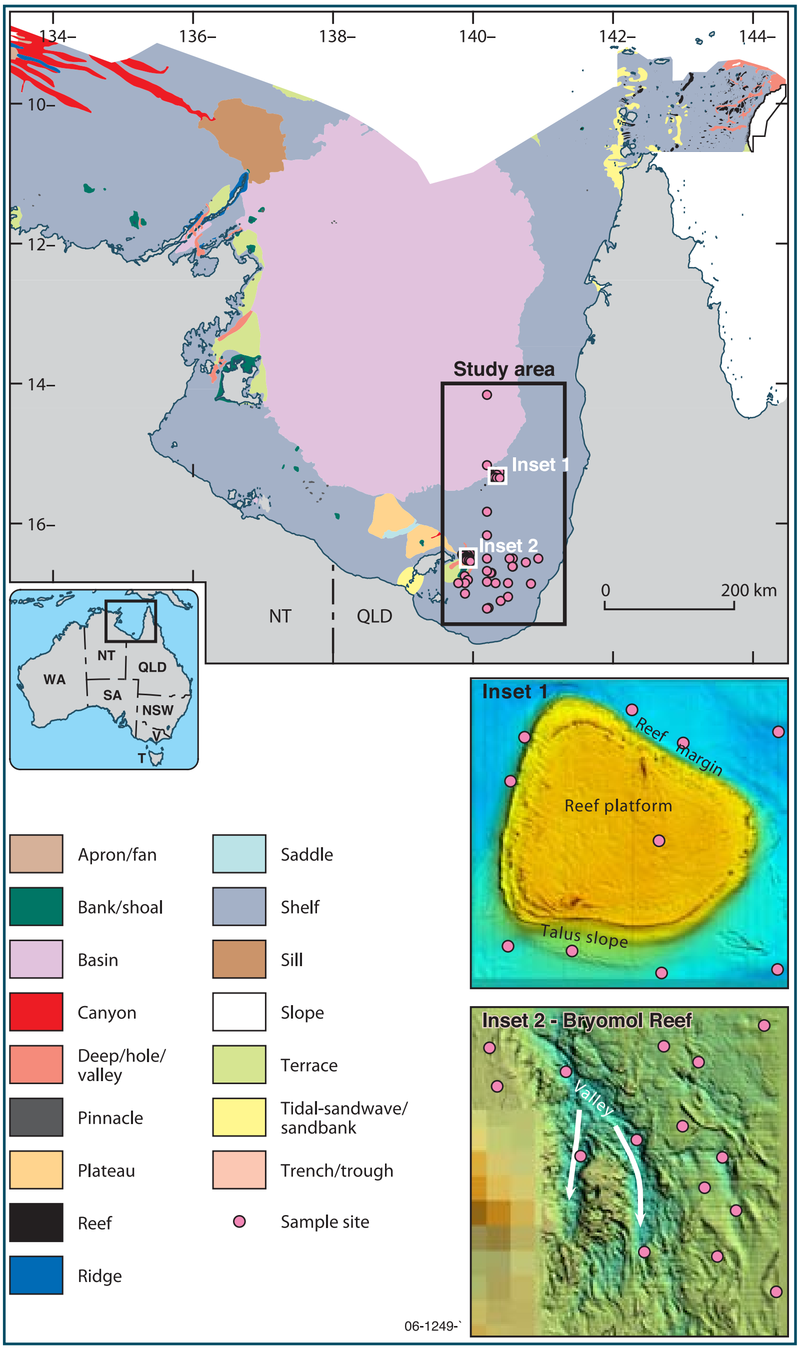

Figure 1. Geomorphic features across the Northern Planning Region, and within the study area, with sample areas shown by the pink dots. The insets show multibeam bathymetry images and detailed geomorphic features intersected by the sample sites.

Australia's Exclusive Economic Zone covers over ten million square kilometres, significantly more than the area of its land surface. The Australian Government has made a commitment to assign a proportion of this as marine protected areas (MPAs). The MPAs are to be designed to protect and preserve representative samples of marine biodiversity.

However, our knowledge of marine diversity and the distribution of marine biota is extremely patchy. Biological surveys are continually discovering species that are new to science. Recent expeditions in the deep ocean have found that, among samples collected at depths of more than 3000 metres, about half the specimens belong to new species (Schrope 2005).

Even within Australia's existing MPAs, our knowledge of the distribution, abundance and diversity of marine organisms remains sparse (e.g. southeast region MPAs; Harris, in press). The lack of biological data is a serious impediment to the aim of selecting for protection sites that are representative of the total marine biodiversity.

Defining habitats

An alternative to the species-based approach to conservation is the protection of marine habitats (e.g. Zacharias and Roff 2000). Marine habitats can be defined on the basis of physical datasets, such as the morphology of the seabed, the water depth and the sediment properties. This approach is similar to the way in which forest types (or biomes) on land are mapped based on knowledge of the slope, aspect, climate and soil types.

> "Physical parameters can be measured much more quickly... providing a rapid assessment of marine ecosystems"

Physical parameters can be measured much more quickly and across wider areas than biological information, providing a rapid assessment of marine ecosystems that can contribute significantly to the selection and ongoing monitoring of MPAs. This habitat approach is being increasingly employed in the management of marine areas in Canada, New Zealand, South Africa and the United States, as well as in Australia.

The successful use of physical parameters as a surrogate for species diversity and distributions depends on the selection of relevant physical datasets. Although an increasing number of studies test the relationships between biological and physical datasets, broader environmental associations are still poorly established. The

Table 1. Characteristics of different benthic habitats and associated faunas

Morphology	Average depth (m)	Seabed exposure	Grain Size	Dominant fauna
Shelf	14–35	Mod	Sandy	Prawns
				Sea Urchins
Valley	37–43	Max	Sandy gravel	Bryozoans
				Brittlestars
				Crinoids
Bryomol Reef	27–36	Max	Sandy gravel	Brittlestars
				Hydrozoans
				Bryozoans
Talus slope	38–43	Mod–High	Sandy	Anenomes
Reef platform	27	Mod–High	Sandy gravel	Ascidians
				Octocorals
Reef margin	48–49	Mod–High	Sandy mud	Crinoids
				Sponges
Basin	51–65	Low–Mod	Sandy mud	Polychaetes

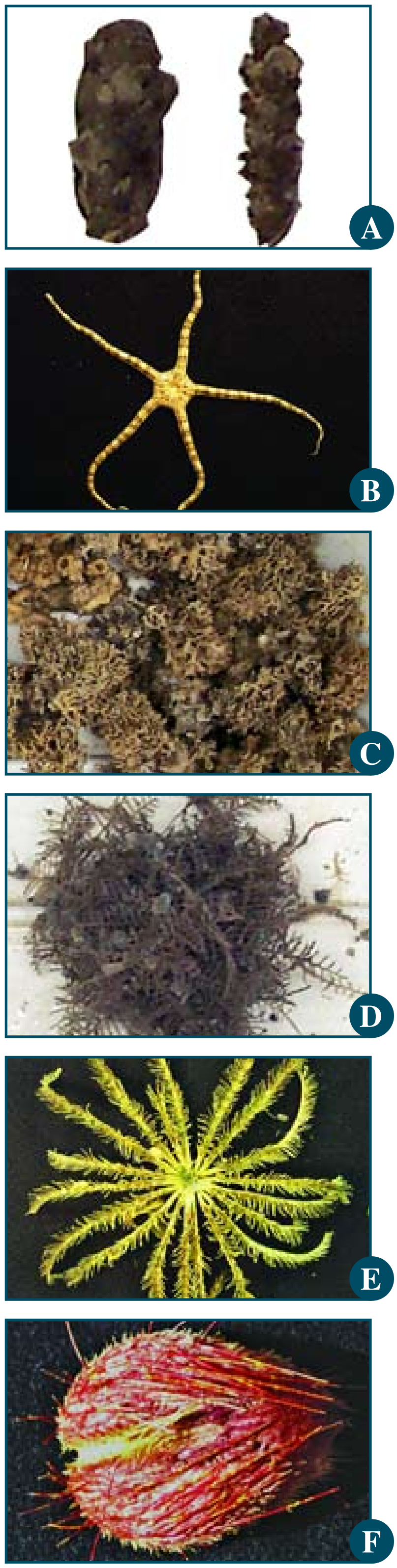

Figure 2. The six taxa with the highest abundance across the study area: A) polychaete tubes; B) brittlestars; C) a species of bryozoan; D) a species of hydroid; E) crinoids; and F) a species of heart urchin. Photos courtesy of T Wassenburg.

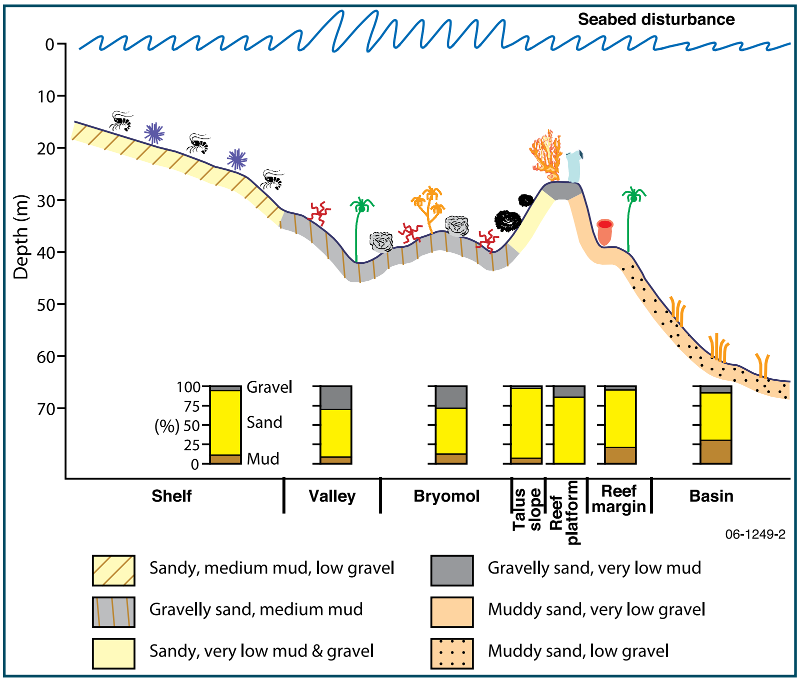

Figure 3. Relationship between physical properties and benthic biota in the southern Gulf of Carpentaria. For a full description of the key benthic biota and explanation of symbols, refer to table 1.

environmental associations studied to date vary greatly between regions, organisms, scales and approaches (e.g. Thouzeau et al 1991, Kostylev et al 2001, Ramey & Snelgrove 2003). Detailed testing within the Australian region is helping to reveal which physical datasets best describe the distribution of seabed biota in different settings around the Australian margin.

“Recent research in the Gulf of Carpentaria, northern Australia, has provided detailed physical and biological datasets”

Mapping biota in the Gulf of Carpentaria

Recent research in the Gulf of Carpentaria, northern Australia, has provided detailed physical and biological datasets, which we have used to test the relationships between physical habitats and the distribution of seabed communities. Sampling and detailed bathymetry mapping have revealed a range of physical habitat types, including reefs, plateaus, valleys and shelf environments (Heap et al 2006; figure 1 and table 1), along with distinctive seafloor biota associated with these different features.

A total of 569 species were collected on the research voyage. The six taxa with the highest abundance across the study area are polychaetes (tube worms), brittlestars, a species of bryozoan, a species of hydroid, crinoids, and a species of heart urchin (figure 2). Of these, the heart urchin species has the highest total abundance, while the species of bryozoan and hydroid have the broadest distributions.

A range of physical variables were tested against the species data to determine whether statistically meaningful relationships could be established, which could allow better prediction of species distributions (see Post et al 2006). This analysis revealed that the distribution of the seabed biota can be best predicted in this region based on a combination of physical variables, including the sediment composition (mud and gravel content), sediment disturbance, the seabed morphology and water depth. The relationship between these variables and the seabed biota is illustrated in figure 3 across the seven main geomorphic zones: shelf, a relict bryozoan–mollusc built reef (bryomol reef), valley, talus slope, reef platform, reef margin and basin.

The shelf zone within the southeastern part of the Gulf is characterised by shallow depths (15 to 30 metres) with moderate seabed disturbance and sandy low carbonate sediments (figure 3). The fauna in this shelf zone is dominated by mobile organisms with relatively low diversity, with prawns and sea

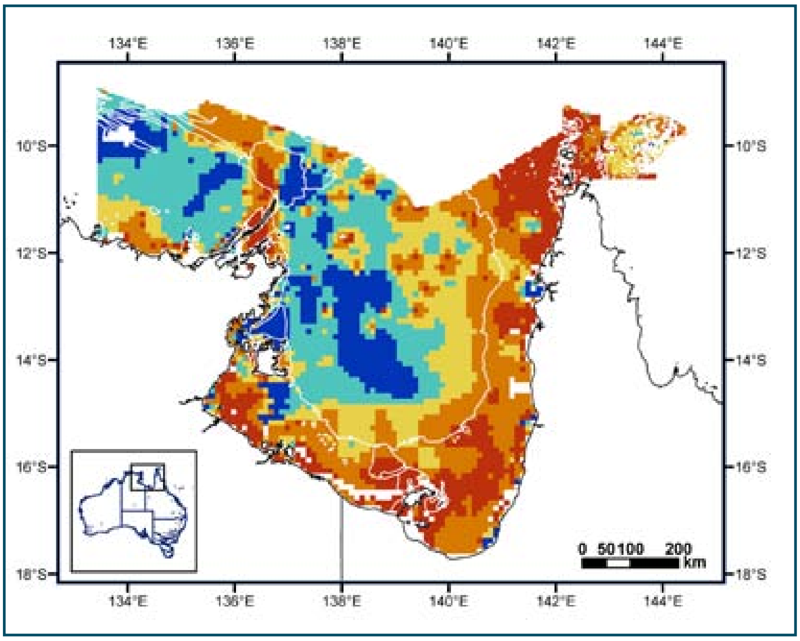

Figure 4. Distribution of five habitat clusters derived from the percentage of gravel and mud, the water depth and the seabed exposure for part of the Northern Planning Area, with geomorphic units shown by the grey outlines. The southeastern and eastern parts of the Gulf and Torres Strait are part of clusters 1, 2 and 3, while the central and western Gulf and the western Arafura Sea are characterised by clusters 4 and 5. Substrate clusters occur within different geomorphic features, illustrating the importance of combining these datasets.

urchins more abundant. The basin environment is also dominated by mobile fauna (predominantly polychaetes) with medium diversity and, because the water is deeper, has low to moderate seabed disturbance with muddy sand sediments. The bryomol reef and valley environments lie at depths intermediate between the shelf and basin zones (25 to 39 metres and 37 to 42 metres, respectively), with very high seabed disturbance (maximum values), particularly across the valley area, and a gravelly sand seafloor. The faunas associated with these two zones are composed of equal abundances of attaching and mobile organisms, with the bryomol reef dominated by brittlestars, hydrozoans and bryozoans, and the valley faunas by bryozoans, crinoids and brittlestars.

> "The modern reef environment is divided into three distinct zones, each with a moderate to high seabed disturbance"

The modern reef environment is divided into three distinct zones, each with a moderate to high seabed disturbance (figure 3). The talus slope is sandy with high carbonate content, and the presence of ripples indicates strong bottom currents. These characteristics are associated with low faunal diversity dominated by solitary anemones.

The reef margin, by contrast, is composed of muddy sand sediments, reflecting the lower energy of this area. These features have produced high faunal diversity, with crinoids and sponges dominating the community. The reef platform is distinct from these other two zones in its higher energy and harder substrates, with relatively high gravel content. Faunas on the reef platform show high diversity, with an abundance of ascidians and octocorals.

How are species related to physical factors?

By various mechanisms, the physical factors identified in this study can be associated with the types of organisms present. The seafloor properties are clearly associated with the habitat modes of the organisms. The areas with a sandy seafloor, such as the shelf and basin areas, are dominated by mobile deposit feeders and infauna, since those organisms require a soft seafloor in which they can burrow and forage for food (Jumars 1993). Gravelly areas, such as on the reef and bryomol reef areas, contain high proportions of suspension feeders, which attach to the strong anchor points available in these environments.

Seabed disturbance is a measure of the stability of the seabed environment. In areas with a low frequency and magnitude of disturbance, competition between organisms is greater, which tends to suppress diversity (Connell 1978). The relatively low seabed disturbance of the shelf and basin environments (low to moderate) in this study is most likely associated with the lower overall species diversity in those environments. In areas of very high frequency and magnitude of disturbance, diversity is also suppressed due to the high variability of the environment, which reduces reproductive success and the ability of the community to mature or be recolonised before the next disturbance event (Connell 1978).

An area of very high disturbance in this study occurs on the talus slope adjacent to the main patch reef. The species diversity on the slope, which is characterised by active sedimentation, is substantially lower than at the surrounding reef sites, where sediment input is much lower. This comparison suggests that areas of lower sediment input and lower disturbance (such as on the reefs) support a larger variety of faunas compared to highly variable areas (such as the talus slope) where species diversity is suppressed. Some degree of disturbance also reflects current flows; these can bring in nutrients and other food sources, which are particularly important for suspension feeders.

"This study demonstrates that selected physical datasets are well correlated to the distribution of the seabed biota in this region"

In summary, this study reveals an association between the sediment composition and the types of macroorganisms present, and particularly their habitat modes. Mobile and infaunal species are more prevalent on softer substrates, while suspension feeders dominate areas with higher gravel content and harder substrates. The seabed disturbance may reflect the supply of food via currents to suspension feeders in areas of moderate disturbance, while low disturbance leads to reduced diversity, which could be due to higher levels of competition. The high seabed disturbance on the sandy substrate of the talus slope is also associated with a low diversity of mobile organisms, reflecting the stress to organisms in high-energy environments where anchor points are not available (e.g. Connell 1978). The water depth primarily reflects changes in light intensity, temperature, oxygen, salinity and energy (Murray 1991), and is associated with the distinct communities that occur between the shelf and basin environments in this study.

Applying physical relationships for marine planning

The biophysical relationships established from this study can be used to predict the diversity and distribution of marine benthic organisms across the broader region of the Northern Planning Area. The four physical parameters that show the strongest relationship to the seabed biota (mud content, gravel content, seabed disturbance and water depth) were combined using existing datasets across the broader region with an unsupervised classification. Five classes are formed from this classification, and their distribution can be used to interpret the distribution of potential seabed habitats (figure 4). We obtain further information about habitat variability by overlaying the geomorphic features. Through the production of habitat maps such as these, marine managers can take a more rigorous approach in the selection of marine reserves.

Conclusions

Determining representative areas within the Northern Planning Area for protection as part of a network of MPAs is not currently possible based on the sparsely distributed biological data currently available for this region. Physical datasets, however, can provide information about the variations in the physical environment, and hence the variations in the seabed habitats. This study demonstrates that selected physical datasets are well correlated to the distribution of the seabed biota in this region. By combining these broadly distributed physical datasets, we can produce maps that show the distribution of distinct marine habitats in the region and provide marine managers with information about the predicted distribution of seabed communities.

This information will provide a more rigorous basis for the selection of representative areas for protection within a network of MPAs. At Geoscience Australia, continuing research ensures that habitat maps will be based on rigorously tested parameters. Those parameters will need to be good predictors of seabed biota for the regions that they are applied to. Current research is focusing on a number of regions in Australia's marine jurisdiction, including the northwest and southwest regions.

References

Connell JH. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302–1310.

Harris PT. In press. Applications of geophysical information to the design of a representative system of marine protected areas in southeastern Australia. In: Todd BJ & Greene G (eds), Marine Benthic Habitat Mapping, Geological Association of Canada and GEOHAB.

Heap A, Harris P, Passlow V, Wassenberg T, Hughes M, Sbaffi L, Mathews E, Fellows M, Fountain L, Porter-Smith R, Daniell J, Buchanan C & Robertson L. 2006. Sources and sinks of terrigenous sediments in the Southern Gulf of Carpentaria. Geoscience Australia Record 2006/11.

Jumars PA. 1993. Concepts in Biological Oceanography: An interdisciplinary primer. Oxford University Press, New York.

Kostylev VE, Todd BJ, Fader GBJ, Courtney RC, Cameron GDM & Pickrill RA. 2001. Benthic habitat mapping on the Scotian Shelf based on multibeam bathymetry, surficial geology and sea floor photographs. Marine Ecology Progress Series 219:121–137.

Murray JW. 1991. Ecology and Palaeoecology of Benthic Foraminifera. Longman Scientific and Technical, Harlow, UK, 39.

Ramey PA & Snelgrove PVR. 2003. Spatial patterns in sedimentary macrofaunal communities on the south coast of Newfoundland in relation to surface oceanography and sediment characteristics. Marine Ecology Progress Series 262:215–227.

Post AL, Wassenberg TJ & Passlow V. 2006. Physical surrogates for macrofaunal distributions and abundance in a tropical gulf. Marine and Freshwater Research 57:469–483.

Schrope M. 2005. Deep sea special: The undiscovered oceans. New Scientist 2525:38–43.

Thouzeau G, Robert G & Ugarte R. 1991. Faunal assemblages of benthic megainvertebrates inhabiting sea scallop grounds from eastern Georges Bank, in relation to environmental factors. Marine Ecology Progress Series 74:61–82.

Zacharias MA & Roff JC. 2000. A hierarchical ecological approach to conserving marine biodiversity. Conservation Biology 14:1327–1334.

For more information

phone Alix Post on +61 2 6249 9023
email alix.post@ga.gov.au