The application of multibeam mapping to scientific exploration of the Great Barrier Reef

The development of multibeam mapping, or swath mapping, has been one of the most significant technological advances in the tools used by marine scientists for the past 15 years. Traditionally, hydrographic surveys were carried out with singlebeam echosounders following a grid of tracks, which can only receive single incidence reflections from the seabed directly beneath the vessel. Missing data was simply interpolated between the tracks. Multibeam systems can now simultaneously collect data using a broad swath of sound with multiple received beams reflected off the seabed. The results of swath mapping are high-resolution digital terrain models (DTMs) of the seabed that are equivalent to aerial or satellite imagery on land.

Artist's impression of a multibeam survey using a wide swath to measure multiple depth points across the seabed surface. Image courtesy of Atlas™ Hydrographic.

Multibeam at James Cook University

Through collaborations between Geoscience Australia, Australian Institute of Marine Science, Royal Australian Navy and industry, marine scientists at James Cook University (JCU) have become leaders in the application of multibeam systems in the Great Barrier Reef (GBR). At JCU, multibeam data have revolutionised geological mapping on the northeast Australian continental shelf and our understanding of coral reef development and modern seabed processes. Multibeam has assisted in locating and identifying the remains of fossil barrier reefs which stretch along the entire outer GBR in depths of about 40 to 70 m. The deeper parts of modern coral reefs have also been mapped, which reveal the multiple layers of ancient reefs built up to result in the reefs we know of today.

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Beyond the application of multibeam data to our knowledge of the evolution of the GBR, multibeam has assisted in discovering small holes close to the coast that vent freshwater seaps in the seabed. Ancient river channels have been mapped which provide an understanding of the development of the shelf when sea-levels were much lower. Offshore of the northern GBR, multibeam has been used to reveal rugged submarine canyons that plunge for over 1000 m to the deep abyss and which drain vast undersea landslides. As our exploration turns to the inter-reefal and offshore areas of the GBR, multibeam surveys will be critical in providing the baseline maps and identifying groundtruth sampling sites to better understand seabed ecosystems.

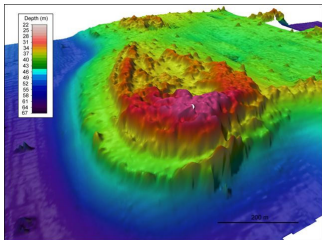
What is a multibeam system?

Compared to a singlebeam echosounder, a multibeam system is a much more complicated beast. A multibeam uses a multi-element array to transmit a wide angular swath of acoustic energy which can be up to 12 times the water depth. For example, in 50 m of water a swath width can theoretically be up to 600 m wide. The receive array measures soundings of the water depth across the swath and also the echo strength of the returns, which is called backscatter. The number of depth measurements across the swath varies between instruments but modern multibeam systems can record over 100,000 soundings per second. The multibeam system tracks the precise navigation of the vessel, gyro heading, and vessel motion data, such as heave, pitch and roll, to assign an accurate depth and position for each individual sounding. Survey lines are typically placed to have some overlap of swath coverage, which results in 100% of the seafloor surveyed and revealing high-resolution details of the seabed morphology.

The JCU research vessel *RV James Kirby* at Townsville, installed with the Reson™ 8101 multibeam system. Note the raised multibeam transducer on a side pole mount.

How is multibeam data is used?

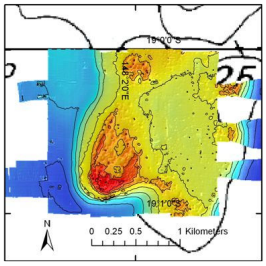
At JCU, a Reson™ Seabat 8101 multibeam system is mounted on our research vessel *RV James Kirby*, which is capable of mapping the seabed from 3 to 250 m depth. Bathymetry and backscatter data are collected at the first stage of any geophysical investigation of the seabed. The bathymetric data are used to generate sun-shaded relief images that reveal highly detailed seafloor morphology. These images are used to detect and interpret features such as coral outcrops, channels, sandwaves and other small objects. Backscatter is generated from the variations in acoustic energy reflected by the seabed, and generally, harder objects reflect greater backscatter energy than softer seafloor. Thus it is possible to discriminate variations in sediment type and hardness based on the backscatter image. When the bathymetry maps and backscatter images are combined, they form the basis for interpreting geological processes and features on the seabed, or are used to plan for targeted groundtruth sampling, such as underwater video or sediment grabs and cores.



Shrimp Reef on the central GBR. Note the ancient deeper terraces around the modern shallow reef. IVS3D™ Fledermaus visualisation software used to create an interactive DTM gridded at 5 m resolution.

Multibeam data visualisation

Bathymetry data can be combined with and overlain on other datasets, such as marine charts or satellite imagery, to show the relationships between other geographic features. The image of Shrimp Reef was collected by multibeam and the data converted into an interactive 3D DTM gridded at 5 m horizontal resolution using IVS3D™ Fledermaus software. The DTM was exported as an ESRI™ grid file for input to ArcGIS, and then overlain with a marine chart and computer-generated depth contours. A geotiff of the DTM was also converted into a kmz file for import as an image overlay in Google™ Earth. These examples of data visualisation are easily transferred as files for the public and available for viewing using freeware visualisation software.



ESRI™ ArcGIS used to create a map of Shrimp Reef using a DTM overlaid with depth contours and a marine chart geotiff in the background.

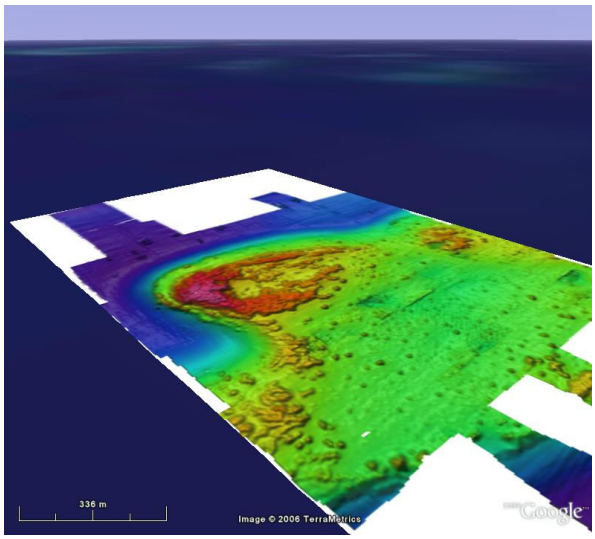


Figure 5. Google™ Earth view of Shrimp Reef, mapped as a kmz file and overlaid on true colour Landsat imagery of the GBR.

"...multibeam surveys will be critical in providing the baseline maps and identifying groundtruth sampling sites to better understand seabed ecosystems".

Biography and contact information

Dr Robin Beaman completed his PhD at University of Tasmania in 2005, and has since pursued postdoctoral research at JCU in Cairns. He is generally interested in marine geology, and his research is aimed at studying: the evolution of drowned shelf edge reefs; continental slope ecosystems; palaeochannels as marine wildlife corridors; and deep reef and shoal habitats on the GBR. Dr Beaman is an expert in the use of multibeam systems and his research using these tools has taken him to Antarctica, across the Pacific and the waters around Australia. For further details, contact him via email: robin.beaman@jcu.edu.au.