Acoustical Methods for Marine Habitat Surveys

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The mapping and management of marine special areas of conservation (marine SACs) is one part of the 1992 European Community Habitats Directive, which aims to ensure the long-term health and sustainable use of key European critical habitat areas. In 1995, the combined conservation organisations in the UK undertook a programme of research and evaluation of methodologies for addressing the requirements of the Habitats Directive. An important element of this programme was the testing of acoustic based survey techniques for mapping the habitats that currently exist at SACs and the testing of these techniques for long term monitoring of habitat change on the SACs. Mapping a near-shore SAC in the detail required to monitor habitat change necessitates full coverage bathymetric charts with positional accuracies of 1m or better, object identification at sub-metre scale and habitat identification on 1-2m grids. Methodologies for accomplishing these requirements are reviewed with examples from Norway and the west coast of Scotland.

Key issues that need to be addressed on each SAC are: 'What is contains now and what state is it in?' and, 'What part of the environment might indicate future changes to the health of the area?'. These issues can only be addressed fully using survey methods and equipment with high spatial fidelity and full 3D coverage.

Survey Methodology for marine SACs

Historically, finding the position of features using echosounders and sidescan sonar has been subject to large errors cumulating from survey equipment errors and navigation errors. Today, through the increased accuracy of differential GPS and the combined use of digital sidescan, bathymetric sidescan and multibeam sonar, it has become possible to measure habitats and habitat change in great detail. Equipment related factors that influence the outcome of a habitat survey include the resolution of the survey instruments, or the smallest feature that can be recognised with the instrument, the 3D spatial coverage and the fidelity with which the proposed survey method can record the boundaries of different habitat units. A further issue is the repeatability of the methods that are used, which has two aspects: the equipment must produce a repeatable signature between surveys over unchanging seafloor conditions; and the equipment must be able to record the minimum change in seafloor conditions when a critical change in health is experienced between surveys.

Single beam sonar

The echo-sounder or single beam sonar has been used for a number of decades to measure bathymetry. More recently it has been used to measure the acoustic amplitude variations of the reflected pulse from the seafloor for seafloor classification where the intensity of reflection is a measure of the roughness and hardness of the seafloor. With the increase in positional accuracy through the use of DGPS, this method has found widespread acceptance as a method of remote acoustic mapping of marine habitats. Figure 1. shows an example of this for a small fjord in Norway. The echosounder data recorded with an *ECHOplus* system has been colour coded to indicate different seafloor types. The resolution of the echo-sounder is controlled by the sonar frequency, the beam pattern and the precision with which time can be measured for the acoustic pulse. However, the water depth and velocity of the acoustic pulse in the water column will determine the number of samples or pings per second on the seafloor. Thus the fidelity of recording changes in seafloor type is determined by the ping rate with respect to the speed of boat over the seafloor and the accuracy in positioning the survey vessel.

Sidescan sonar

The sidescan sonar has established itself as the predominant tool for imaging the seafloor because of its good object detection and seafloor character discrimination when deployed with the transducers mounted on a tow fish close to the seafloor. For high-resolution surveying, transducer frequencies typically range between 100kHz and 700kHz and modern multi-beam systems are capable of resolving objects of 10cm or less. However, apart from the most advanced sidescan systems, there is a large absolute error in the position of the object on the seafloor due to the fact that the position and orientation of the sonar fish in the water column behind the boat is poorly known. The absolute error in position can be improved with these systems through the use of ground control points either from known, precisely located, objects on the seafloor or through the use of amplitude data from other acoustic methods such as bathymetric sidescan and multibeam. An important issue for many marine SACs is the decimation of biogenic reefs by fishing activity such as trawling. Such impacts have been recorded using high-resolution sidescan, and with the position fixing now available the possibility of monitoring this type of activity on a long-term basis is a realistic task.

Bathymetric Sidescan

The bathymetric sidescan is an extension of high-resolution digital sidescan that not only enables a picture of the seafloor to be produced across a swath sampled by the transducers along the boat track, but also measures the bathymetry across the swath through the use of multiple transducers. The method has found widespread application for mapping large swaths of gently undulating seafloor as the width of survey is approximately 7 times the depth of water to the transducers. The transducers are usually hull mounted and thus with the addition of a motion reference unit and DGPS it is possible to locate features on the seafloor with a high degree of certainty. This is of particular relevance for habitat mapping and long term monitoring. A further advantage of the technique is that the amplitudes of reflection strength, or "sidescan-like" image, can be measured coincidently to the bathymetric data points. The amplitude data can then be used as an overlay to the bathymetry to map the position and spatial distribution of habitat types. An example of this is given in Figure 2a showing the sidescan overlay to bathymetry collected with a Submetrix System 2000. Figure 2b shows the same area classed by seafloor type, based on ground truth data from video, diver observations and grabs. The amplitude and bathymetric data can also be used to provide ground truth locations and thus anchor points for stretching or warping higher resolution sidescan images. Together with multibeam sonars, these systems represent the state of the art in acoustic seafloor mapping, where near 100% seafloor coverage is required with footprint sizes of less than 25cm.

Multibeam

Multibeam sonar uses a combination of hardware and software control of multiple transducers to produce a number of sonar signals or beams that propagate from the sonar head in a fan and return a bathymetric and amplitude measure of the seafloor along the swath covered by the boat track. The method, like the bathymetric sidescan, produces a bathymetric map of the seafloor, which can be mosaiced into a full 3D chart, while the amplitudes can be used for seafloor discrimination. Most multibeam systems are hull mounted and with high-resolution systems using frequencies of up to 300kHz can discriminate objects of 10cm. As with the bathymetric sidescan, because the multibeam is hull mounted, the beam angles result in amplitude maps that lack the dynamic range of the true sidescan images. However, they also have the advantage that the amplitudes are co-located with the bathymetry.

Summary

Advances in acoustics and positioning systems over the last five years has give the marine community the opportunity to map and monitor near-shore habitats in detail hitherto unobtainable. This detailed mapping is critical to efforts for mapping and monitoring the health of these areas under the EC Habitats Directive. Furthermore, the work is leading to new insights to these areas and will hopefully not only result in the long-term protection of their health but also to the sustainable use for future generations.

Acknowledgements

Part of this work was funded by the European Access to Infrastructure fund at the University of Trondheim and part funded by Scottish Natural Heritage.

Biography

Subsequent to positions in geophysical contracting companies in the U.S., Richard Bates is currently a lecturer at the University of St. Andrews. His research interests include the use of marine and land high-resolution geophysical methods for biological habitat surveying, engineering, archaeology and palaeo-environmental reconstruction.

Dr. Colin Moore

Following research appointments at the universities of Paris and Liverpool, Colin Moore is currently senior lecturer and head of the Marine Ecology Research Group in the Department of Biological Sciences, Heriot-Watt University, where his research team focus on seabed ecology in relation to pollution and conservation.

Figures

Figure 1. Bathymetric chart of Hopavågen with overlay of classed Line track data from ECHOplus acoustic ground discrimination system

Figure 2a. View looking into outer Loch Laxford showing sidescan image geo-referenced to bathymetric chart from Submetrix System 2000

Figure 2b. View looking into outer Loch Laxford showing overlay of habitat classification on bathymetric chart and sidescan geo-referenced image

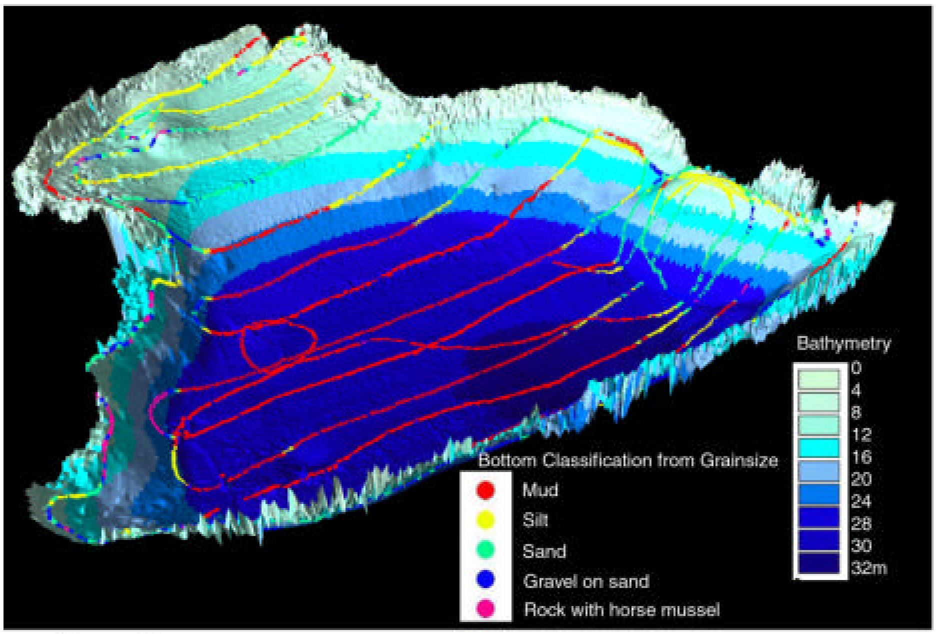

Figure 1

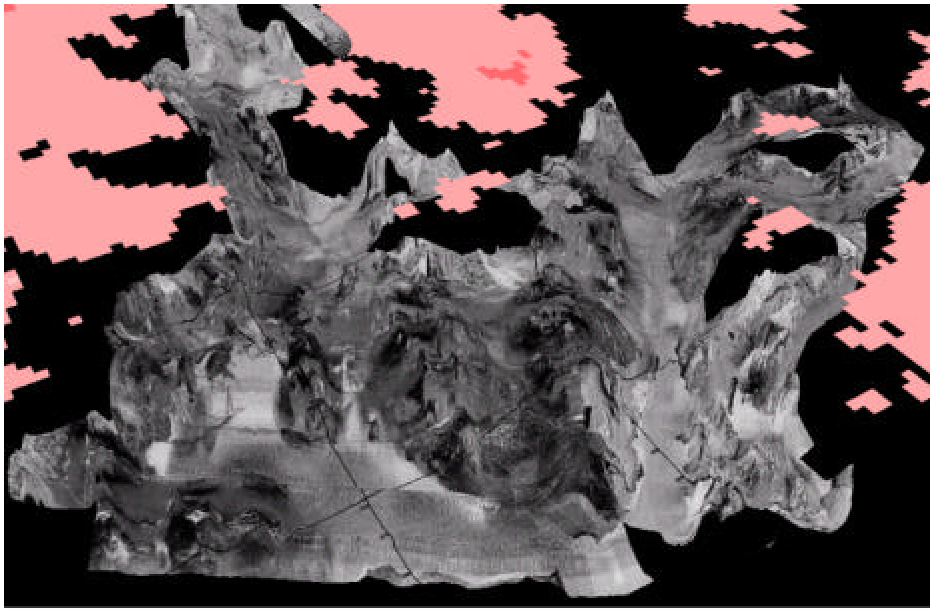

Figure 2a

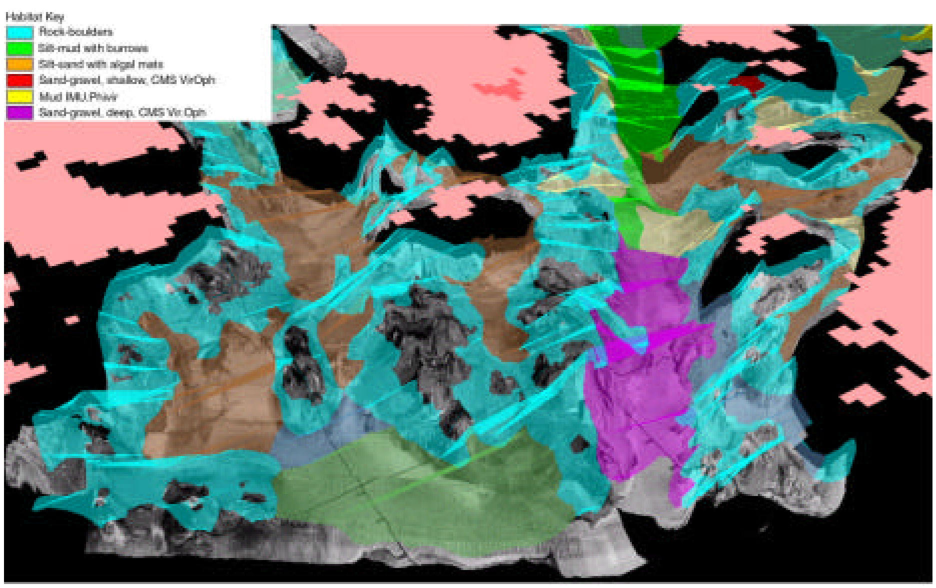

Figure 2b