Theme Session on the Acoustic Seabed Classification – Applications in Fisheries Science and Ecosystem Studies (T)

ICES CM 2004/T:01

Diel variations in acoustical scattering from a sandy seabed

D. V. Holliday, Charles F. Greenlaw, Jan E. B. Rines, and David Thistle

Understanding sources of variability in scattering from the seabed is increasingly important since new acoustical methods are being actively developed to classify and map seabed habitats. Gas bubbles, even in small numbers, strongly modify the propagation and scattering of sound. Shallow water littoral environments are often sufficiently well lit by sunlight to support diverse populations of benthic and epibenthic marine microalgae. Photosynthesis in marine algae produces oxygen. Oxygen saturation levels as high as 600% have been measured in the pore water of a sand sediment at 1 mm below the seabed-water interface, decreasing to 100% saturation at 4.5 mm. While light is rapidly attenuated with depth in sand, measurements on sand from eight beaches indicate that sufficient light is often available for photosynthesis at depths of several mm into the bottom. Our laboratory measurements reveal large diel changes in acoustical scattering over a wide range of acoustic frequencies that appear to be due to the cyclical growth and dissolution of surficial and interstitial bubbles. These changes appear to be synchronized with natural light cycles. We suggest several physical and biological mechanisms that can produce gas bubbles in oxygen saturated pore water. (Work supported by ONR.)

Keywords: acoustical scattering, seabed, bubbles, photosynthesis.

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ICES CM 2004/T:02

Mapping sediment biotopes as continuous distributions rather than discrete entities with hard boundaries

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Seabed biotopes can be mapped and classified using a combination of acoustic systems and biological sampling. Biotopes classified in this way are described in terms of their key physical and biological characteristics and are visually presented as defined regions with distinct boundaries. This approach to seabed mapping is most suited to epi-benthic environments where relatively clear demarcations between biotopes are encountered, such as between reefs, seagrass beds, and mobile sediments. Where the benthic environment consists largely of sediment populated mostly by infaunal communities, changes in the physical structure of the seabed will be more gradual and result in a progressive shift in the structure of the biological assemblages. We present an approach to habitat mapping for sediment communities where boundaries between biotopes are indistinct. The approach combines multivariate classification, Bayesian statistics, and geostatistics to arrive at a series of continuous representations of the distribution of each biological community. Acoustic data (100% sidescan coverage) and biological data (from ground-truth sampling) collected from an area of seabed in the coastal waters of south-east England were used to assess the validity of the approach and demonstrate its application. A biotope map for the study area was produced showing the maximum likelihood of encountering a particular assemblage at each geographic location. We also compared output maps developed using a purely objective classification of the biological data with one developed from a supervised classification where the grab samples were assigned to one of eight acoustically distinct regions of the seabed. The latter approach arrived at a set of biotopes that were more clearly defined in terms of their spatial distribution and characterising species.

Keywords: seabed biotopes, seabed mapping, ultivariate classification, Bayesian statistics, geostatistics.

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ICES CM 2004/T:03

Integration of ground-truthing approaches to characterise an area licensed for dredge material disposal off the Northeast coast of the UK

Silvana N. R. Birchenough, Siân, E. Boyd, Roger A. Coggan, David S. Limpenny, William J. Meadows, and Robert Foster-Smith

Traditional sampling methods were combined with acoustic techniques, video images and Sediment Profile Imagery (SPI) to assess spatial and temporal changes in macrobenthic communities at a dredged material disposal site off the North East Coast of the UK. Annually over 150,000 tonnes of maintenance dredgings from the Tyne Estuary are disposed of at a designated licensed site. It has been recognised that the disposal of these materials at sea can produce long-term environmental impacts with repercussions for the biota and sediments. Therefore, monitoring is required to determine whether unacceptable impacts are occurring or if conditions that could lead such impacts are developing. The site of approximately 3.5 x 8.7 km was surveyed with a high-resolution sidescan sonar system producing a mosaic with 100% coverage of the survey area, which revealed a clear footprint of the disposal operations in the centre of the licensed area. Benthic communities and sediments were ground-truthed using a Hamon grab fitted with a video camera. Results of the pilot survey and first year of the study indicated a reduction in species richness and total abundance and biomass of organisms in the vicinity of the disposal site. The use of SPI provided additional ground-truth information on the status of the sediments and biogenic activities. This study demonstrates the advantages of combining conventional methods, acoustic techniques and optical imaging devices when assessing anthropogenic effects. Their collective contribution has allowed a thorough ecological assessment following anthropogenic activities at the seabed, which is a significant improvement over individual approaches.

Keywords: Dredged material disposal, ground-truthing, acoustic techniques.

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ICES CM 2004/T:04

Developing a strategy for seabed mapping at different spatial scales and resolutions: case study of seabed characterisation in an area of the eastern English Channel

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As part of a larger study of the role of seabed mapping techniques in environmental monitoring and management, acoustic surveys were made at a study site in the eastern English Channel with the aim of developing a strategy for mapping at different spatial scales. The site comprised a broad scale area (40 x 15 km) between Dungeness and Hastings, within which was nested a smaller study box (4 x 12 km), containing an area licensed for aggregate extraction. During a previous investigation, a basic (low resolution) interpretation was made of 100% sidescan coverage of the smaller study box, recognising four acoustically distinct areas, which were ground-truthed and classified as four distinct biotopes. The present study made a more detailed (high resolution) interpretation of the same sidescan mosaic, recognising nine different seabed facies and mapping the area into ~20 regions. Each of the original acoustically distinct areas contained multiple seabed facies, accounting for the high variability between replicate ground-truth samples noted during the initial study. Consequently, the site was re-visited to ground-truth the seabed facies map. Results of that ground-truthing are presented, and comparisons made between the low- and high- resolution characterisations of the seabed. Within the broad scale study area, a foundation pattern of sidescan lines spaced at 2 km intervals has gradually been augmented with additional 'in-fill' lines to achieve progressively greater density of sidescan coverage. The relationship between density of acoustic coverage and confidence in interpreting broad scale patterns and features is explored. Strategies for mapping at different spatial scales are discussed.

Keywords: Seabed mapping, ground-truthing, broad scale, aggregate extraction

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ICES CM 2004/T:05

Case studies for the evaluation of Submersed Aquatic Vegetation (SAV) using hydroacoustics as a dedicated assessment tool

Patrick Schneider, J. Burczynski, and B. Sabol

Although the recognition of certain features in the bottom signal has been used in some applications for obtaining an indication of the presence of a plant layer, this has basically remained a marginal application in hydroacoustics. In recent years, specific algorithms have been developed that allow to detect the real bottom signal within plant layers in a more reliable fashion. Originally called SAVEWS (Submersed Aquatic Vegetation Early Warning System), a patented processing technique, developed by a team under the direction of Bruce Sabol, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, has been adapted to the Windows® environment through BioSonics Inc., Seattle, under the name EcoSAV®. This commercially available software allows to convert a digital echosounder into a dedicated tool for assessing submerged aquatic vegetation (SAV). Taking into account other already established applications, hydroacoustics is now a paramount tool for assessing many different aspects of aquatic ecosystems. Case studies of this new method are presented.

Keywords: Submersed aquatic vegetation, seagrass beds, hydroacoustic assessment, vegetation coverage, habitat mapping, ecosystem management

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ICES CM 2004/T:06

Assessment of sandeel distribution and abundance: a seabed discrimination approach

Jeroen van der Kooij, Steven Mackinson, Adam Nicholls, and David Righton

The lesser sandeel (*Ammodytes marinus*) is an important forage and industrial fish species found in large numbers across the central and southern North Sea. Mapping their distribution and estimating abundance is difficult because they remain buried in the sediment for a large part of the year. We used the Questar Tangent Seaview (QTC) acoustic ground discrimination system to identify the acoustic characteristics of buried sandeels at fishing grounds on the Dogger Bank. This signature was subsequently used to identify the night-time distribution of sandeels within a 27 nm by 30 nm area in four successive years. The 'acoustic distributions' are compared with the distribution of different seabed types to show how the occupancy of habitat by sandeels changed over time. The results are compared to sandeel distribution data collected using standard fisheries acoustics and dredge fishing methods. We discuss how the various sources of information may lead to integrated method for the assessment of sandeel abundance.

Keywords: QTC, sandeel, acoustic ground discrimination

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ICES CM 2004/T:07

Longline Fishing Activity and Bathymetry in the South Georgia Region

R. C. Wakeford, M. Belchier, and P. Morris

The Patagonian toothfish (*Dissostichus eleginoides*) is a large, predatory, nototheniid fish that is found around sub-antarctic islands and seamounts and in the cold temperate waters off Patagonia. Adult fish are usually found living close to the seabed at depths of 500 to 2,000 m whilst younger fish inhabit shallower waters. The fish, which can attain lengths in excess of 2 metres and weigh over 70 kg, are slow growing, taking between 6–10 years to reach sexual maturity and may live for more than 50 years. A longline fishery for toothfish has operated around the island of South Georgia since the early 1990's. Between 10 and 18 vessels are licensed to fish within the South Georgia maritime zone each year. Longlines of baited hooks are usually set in water depths of 1,000 m around the South Georgia shelf edge. However, fishing effort around the island is not uniform, as fishermen have established which areas are the most productive. The available charts of the region are very incomplete and only give a poor idea of the form of the continental margin. In the past this made it difficult to establish any link between fishing success and the nature of the seafloor. Recent swath bathymetry surveys, however, now reveal the detailed bathymetry of the slope and allow us to relate the areas of greatest fishing activity to the nature of the seabed. This, in addition to preliminary analysis of the benthos, provides valuable insights into the preferred toothfish habitats, and the potential impact of the fishery on the ecosystem. Combined, this information will influence future strategies for fishery management and conservation.

Keywords: Bathymetry, longline fishery, benthic mapping, South Georgia.

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ICES CM 2004/:T:09

Classifying marine habitats using geophysical parameters

Katrina Baxter, A. Bickers, and G. Kendrick

Identifying the type and distribution of marine habitats and the communities they contain is fundamental to being able to protect biodiversity and manage fisheries resources on a regional basis. However, classification methods that rely heavily on species groupings to define habitat types have limited use when attempting to map large areas. Similarly, where little broad-scale habitat data exists, it is difficult to identify the range of habitat conditions suited to particular species or communities that may need protection.

In the absence of detailed species data, we illustrate the use of geophysical factors to classify benthic habitats within the Recherché Archipelago, Western Australia, using a combination of sidescan sonar and video. A consistent geophysical classification scheme was adopted to provide workable definitions of habitat that link the different methods of data collection but also provides for the future addition of species data.

Substrate (sediment or rock types) and textural attributes of the seafloor were identified from sidescan sonar records. Substrates boundaries were validated and the related benthic biota determined from towed video footage. The spatial extents of habitats were delineated within a Geographic Information Systems (GIS) and final habitat and substrate maps were compiled for 1200 square kilometres of the Archipelago.

With further geophysical factors such as depth and exposure, spatial models can be developed that use combinations of factors as predictors of habitat type. These combinations may explain possible reasons for habitat formation and, with the future addition of species data, why certain species occupy particular habitat types.

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ICES CM 2004/T:10

Seabed sediment classification using side-scan sonar and multibeam technology

Dennis Anthony

The Royal Danish Administration of Navigation and Hydrography (RDANH) have the responsibility of surveying Danish waters and establishing the bathymetrical datasets for producing high-standard navigational charts. The bathymetric surveys are carried out using multibeam echosounding, and additional side-scan sonar data are used to validate critical bathymetric data. As a by-product of the bathymetric surveys, these high-resolution data reveals information of the seabed sediment character, and with additional processing, it is possible to perform a semi-automatic seabed sediment classification.

The multibeam backscatter strength is very well suited as indicator of seabed sediment type. However, beam angle correction is not quite straight-forward, as angular response from the seabed is dependant of seabed type. A towed side-scan sonar is still the ultimate tool for high resolution seabed mapping, and has the advantage of being able to identify even small scale bedforms, single stones and other seabed structures. Side-scan data are very good for visual interpretation by a trained operator, but is less suited for automatic processing for seabed classification purposes. When high-resolution side-scan sonar data is used in conjunction with detailed bathymetry, unique seabed areas can be depicted.

By combining multibeam and side-scan sonar data from hydrographic surveying, it is possible to produce detailed seabed sediment maps in general classes from pure acoustic sampling. The sediment maps reflect the various hydrodynamic and geological settings of the surveyed area.

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ICES 2004/T:11

Seabed terrains and fauna associations based on acoustic sampling

Rudy Kloser, Alan Williams, Franzis Althaus, and Alan Butler

Mapping the form and nature of the seabed is a necessary requirement for understanding its ecological role for biological communities. We are developing a surrogate-based methodology to do this in response to the need to manage Australia's deep offshore (>50 m) seabed under Australia's Oceans Policy. Remote sensing surrogates of seafloor biotopes using visual and acoustic devices is attractive due to their collective properties: large sampling coverage per unit cost, non-destructive sampling and high spatial resolution. The necessary targeted physical sampling varies in quantity and quality depending on the taxonomic resolution required. A hierarchical classification framework can guide the sampling resolution needed at different spatial scales in relation to management needs. We outline our progress with the development of methods to relate the broad scale acoustic data to the fine scale physical and visual sampling. A Simrad EM1002 multibeam sonar provided measures of seafloor morphology and substratum variability at 62 reference

sites, a towed video camera provided measures of benthic biota and their multi-scale spatial relationships with seabed structure, and a simple epi-benthic sled provided measures of benthic invertebrate biodiversity based on taxonomic and functional types, and samples of substrata. Four ecologically distinct terrain types were chosen that showed a high degree of fine scale variability. The presence/absence of seabed fauna groups to the four terrain types was not distinct but improved when abundance or percentage cover was included. The ability of the multibeam sonar bathymetric and seabed backscatter data to correctly classify the four terrain types at fine scale (10's m) is discussed.

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Considerations in large-scale acoustic seabed characterization for mapping benthic habitats

J. M. Preston, A. C. Christney, W. T. Collins, R. A. McConnaughey, and S. Syrjala

In 1999, NMFS Alaska and QTC collected about 18,000 line miles of seabed acoustic data at 38 and 120 kHz from the eastern Bering Sea. With four million echoes at each frequency, this data set permitted thorough explorations of some practical considerations that influence every acoustic seabed classification. Our unsupervised classification involved an objective determination of the optimal number of classes for each of the pre-classification methods we explored, allowing useful comparisons among methods. Stacking, one of the pre-classification steps, is the process of averaging sequential echoes to allow sediment information to express itself in spite of ping-to-ping variability. With stacks of fifty pings, feature spaces had more detail and better defined clusters, thus more classes in unsupervised classification, compared to stacks of five pings. Classification by echo shape requires resampling to compensate for depth changes. While effective, resampling changes the apparent roughness and the amount of detail submitted to the feature-generating algorithms. Depth and stack size affect spatial resolution; the scale of the survey and the sharpness of sediment boundaries guide the surveyor's choice of spatial resolution. Even such a huge data set is a sampling of the sea bottom, and further sub-sampling simplified feature spaces further, reducing the optimal number of classes. The two frequencies differed in beam width and sediment penetration, thus gave complimentary information. The influences of each of these pre-classification methods and other considerations will be presented, as maps of acoustic diversity and with statistical comparisons, accompanied by preliminary correlations with fish census data.

Keywords: acoustic seabed classification, seabed characterization, benthic habitat, hydro-acoustic remote sensing

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ICES CM 2004/T:15

Mapping, understanding and managing fishery habitat: a case study of the commercial pink ling (*Genypterus blacodes*: Ophidiidae) off SE Australia

Alan Williams, Rudy Kloser, and Bruce Barker

Benthic habitats of the upper continental slope seabed (~200-700 m depth) off SE Australia are being surveyed for the first time using multi-beam acoustics, video cameras and physical samplers. Research is presently focussed on developing multi-scale mapping methods to support the needs of regional, ecosystem-based, marine management plans being developed under Australia's Oceans Policy. Early survey results show immediate application to one aspect of this integrated planning structure: the understanding and management of 'fishery habitat'. A survey of the Big Horseshoe submarine canyon - one of the region's prime fishing grounds - demonstrated the multi-scale association of the commercial pink ling with benthic habitats. In this paper we provide a visualisation of these associations using terrain maps generated by multibeam acoustics, together with video images and physical samples, and set in the context of a hierarchical habitat classification framework. Within this framework, benthic habitats are discussed in relation to their ecological role for pink ling, their use by commercial fishers as 'trawl' and 'non-trawl' fishing grounds, the impacts resulting from fishing, and the integration and interpretation of this information for spatial management of fishing effort.

Keywords: continental slope/submarine canyon/Australia/fishery habitat/ fishing grounds/ multibeam/ground-truthing/video/pink ling/spatial management

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ICES CM 2004/T:16 Poster

Mapping deep-water benthic habitats around South Georgia

R. C. Wakeford, J. M. Clark, M. Belchier, and P. Morris

South Georgia lies on a small continental shelf with water depths of a few hundred meters. At the margins of this, the seabed rapidly declines to the ocean floor at depths between 3-4000 m. The continental shelf supports numerous fish species within a complex ecosystem that has attracted much interest from commercial fishing. A significant longline fishery exists for toothfish (*Dissostichus eleginoides*), whereas both demersal and pelagic trawling has been used to target mackerel icefish (*Champsocephalus gunnari*). Although these species are managed sustainably within precautionary limits, the impact of these fisheries on the benthos is relatively unknown. Benthic species data now available from recent research cruises and fisheries observers have been analysed to map the location and relative abundance of different species around South Georgia.This has enabled areas of high diversity and biologically important species, such as deep-water corals, to be identified. Recent advances in charting the bathymetry around South Georgia using acoustic surveys now reveal the detailed topography of the slope and allow us to characterise species to specific features of the seabed. With additional knowledge of the behaviour and specific location of fishing activities, areas of potential impact can be identified for fisheries management and species conservation purposes.

Keywords: bathymetry, benthic mapping, South Georgia

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ICES CM 2004/T:17 Poster

Forum Skagerrak II. Seabed mapping and biological groundtruthing of habitats on the Swedish west coast

Mattias Sköld, Tomas Lundälv, and Per Nilsson

One difficulty in managing the offshore marine environment is lack of inventories of habitats and species of large areas. Using advanced techniques such as multibeam swath bathymetry and side scan sonar, it is now possible to efficiently and in detail survey the seabed topography and structure. With biological groundtruthing and geological and biological interpretation of datasets, habitat maps can be developed. Fish habitats are often controlled by the nature of the seabed, and fishery interests seek information that makes fishing more economical and safe. Environmental managers seek information on the spatial extent of sensitive habitats to minimise environmental impacts of human activities, such as bottom trawling. As a test case, an area situated in the Swedish economic zone has been chosen due to indications of high biological values (valuable fishing ground for both commercial and recreational fisheries and reports that deep-water coral habitats are present in the area). The fishery in the area is under EU regulation and thus provides an interesting case since interregional interests operate and there are few examples of marine protected areas outside territorial waters. The aim of the project is to

(1) carry out a survey of a selected offshore area and to develop maps of benthic habitats.

(2) develop a dialog with stakeholders i.e. commercial and recreational fishermen, and governmental authorities to use the achieved knowledge. The ultimate aim of the project is to deliver results that can be used to set up a management plan for best fishing practises.

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ICES CM 2004/T:18 Poster

Acoustic detection of a scallop bed from a single-beam echosounder

Estelle Hutin, Y. Simard, and P. Archambault

A dense scallop (*Chlamys islandica*) bed located in the lower St. Lawrence Estuary was surveyed in summers 2002 and 2003 using three different acoustic approaches ground-truthed with photographic, grab and dredge samples. In 2002, a 38 kHz 7º split-beam Simrad EK60 scientific echosounder was connected to a QTC View Series IV acoustic ground discrimination system (AGDS). The raw volume backscattering strength (S_v) of the seabed echo was also collected for every ping along the ship track. In 2003, a 50 kHz, 42º single beam Suzuki ES-2025 echosounder connected to a QTC View Series V AGDS was used. The QTC View data were analysed with QTC Impact following the standard procedures. The Simrad EK60 seabed S_v data were submitted to a principal component analysis (PCA), whose first 10 principal components (77% variance) were submitted to a k-means clustering analysis. A similar treatment was performed on the residuals of the S_v from a linear regression on bottom depth. The same seabed S_v data were submitted to a stepwise discriminant analysis (DA) using the groundtruthed samples as the known groups, using different metrics: the scallop density, the community and biotope types. The DA solution was then generalised to the whole data set. The QTC approaches failed to reveal the scallop bed; the resulting classification mimicked the bathymetry. The PCA-k-means approach presented similar results. The PCA-k-means on the S_v residuals revealed the scallop bed. The DA was the best solution for the scallop density with a success rate of 70%.

Keywords: Acoustic ground discrimination, habitat mapping, benthic biotopes, remote sensing, classification.

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Seabed acoustic characterisation of the bay of La Concha, San Sebastian (North-east of Spain) as a tool for coastal management

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The distribution and coverage of different seabed types of La Concha were determined in order to obtain a geomorphological map that can be used as a management tool for the beaches located in the bay. Acoustic techniques, including the Acoustic Ground Discrimination System RoxAnn and sidescan sonar were used, and grab samples were taken to calibrate the acoustic results. As the study area was very shallow (0-28m depth), aerial images were also used for seabed cartography. All the data were geo-referenced and integrated into a GIS for spatial data analysis. A supervised classification method was used to classify the acoustic data into different seabed types.

A high correlation degree was found between the roughness (or E1) of RoxAnn and the sedimentological parameters such as grain size and sediment composition. The hardness was not correlated with these parameters but gave valuable information on grain size and porosity of the seabed. Sidescan sonar data were used to define seabed topography and seabed texture and to interpret sediment dynamics. As a result, the coverage of different bottom types was quantified and mapped: bedrock, rocks, mixtures of sand and pebbles, different types of sand, gravel and mud.

The acoustic techniques integrated with sampling techniques demonstrated to be valuable methods to illustrate seabed types distribution and changes related to different sea conditions.

Keywords: RoxAnn, Sidescan sonar, seabed acoustic classification.

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