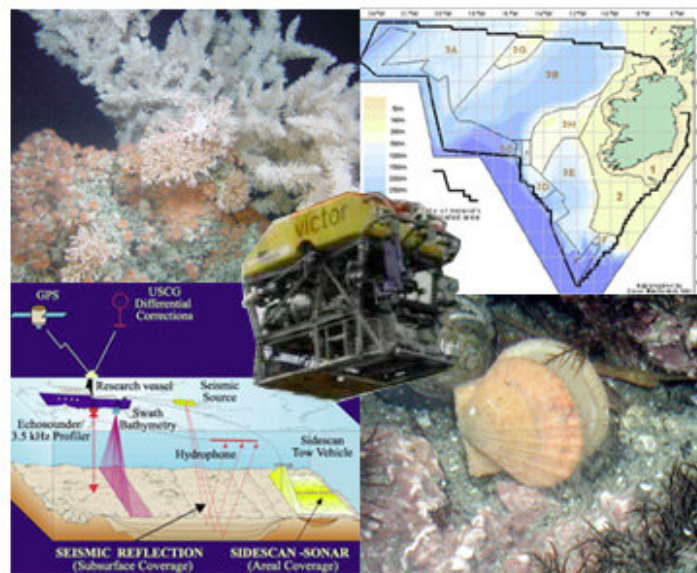




GEOHAB

**Marine Geological and Biological
Habitat Mapping**

Fifth International Symposium *May 5th to 7th, 2004* *Galway, Ireland*



Agenda and Abstracts



Earth and Ocean Sciences Department
NUI, Galway



Marine Institute
Foias na Mara

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GeoHAB 2004

Introduction

On behalf of the Department of Earth and Ocean Sciences, National University of Ireland, Galway, we would like to welcome you to the Fifth International GeoHAB Symposium. GeoHAB is going from strength to strength as is evident from the conference programme which features 40 oral and 24 poster presentations. Scientists from 11 different countries around the globe are participating, representing Australia, Belgium, Canada, Denmark, Ireland, Portugal (Azores), New Zealand, Norway, Sweden, United Kingdom and the United States.

It is timely that GeoHAB has come to the west coast of Ireland. Galway is now considered the gateway to the North-East Atlantic for both Irish and European research efforts and has in recent years increasingly hosted major marine conferences and is a regular port of call for European research vessels. The national Marine Institute has recently relocated to Galway from Dublin and is currently awaiting completion of the construction of a major 'state of the art' research facility on the outskirts of the town. Ireland's first ever ocean capable research vessel, the 65m 'Celtic Explorer' began service just over a year ago and is based here also. The National University of Ireland, in Galway has a long tradition of marine research in Ireland which in recent years has been focused in the purpose built Martin Ryan Marine Science Institute. Major national Higher Education Authority infrastructure funding received in the last two years has enabled the University to again expand its marine research capability. Reflecting this increased focus on marine matters, internal restructuring of the old departments of Geology, Applied Geophysics and Oceanography has given rise to a new single Department of Earth and Ocean Sciences. The combined talents of these old departments together with those of a fresh intake of young staff and post-graduate students is being brought to bear on adding value to the National Seabed Survey effort. As most of you know already, significant

investment by the Irish Government over four years ago now, has enabled Ireland to undertake the single biggest national marine research programme in its history. Indeed, to date, it is the largest multi-beam survey of a national seabed territory undertaken anywhere in the world. We have devoted a special session to the Seabed Survey and ancillary projects.

The other principal themes visited during the course of the three day conference programme are:

- Regional mapping initiatives
- Geohabitat mapping case studies
- Habitat mapping for fisheries management
- Inshore mapping and seabed classification - methods and tools
- Geologic, sediment transport and oceanographic modelling
- Habitat classification and prediction.

We intend to devote most of the final afternoon to open forum discussion of the need to develop a 'universal translator' to facilitate the production of secondary common format maps (from local primary map data), to improve inter-comparability.

Discussions will centre on two specific topics:

- a comparison of existing seabed classification schemes, and
- the need for a common habitat mapping grid.

We hope that you have an enjoyable stay in Galway and find the meeting stimulating and informative.

Anthony Grehan, Margaret Wilson and Janine Guinan

Conference Steering Committee

Anthony Grehan, Department of Earth and Ocean Sciences, NUI, Galway
Margaret Wilson, Department of Earth and Ocean Sciences, NUI, Galway
Janine Guinan, Department of Earth and Ocean Sciences, NUI, Galway
Colin Brown, Department of Earth and Ocean Sciences, NUI, Galway
Brian Todd, Canadian Geological Survey (Atlantic)

Host Conference Committee

Barbara Glynn
Brian O'Connell
Fiona Grant
Gavin Duffy
Klaus Leurer
Padraic MacAodha
Sadhbh Baxter
Shane Rooney

Acknowledgements

We would like to thank all our session chairpersons for acting as moderators.

We would like to express our thanks for support to:

**Department of Earth and Ocean Sciences
NUI, Galway HEA PRTLII Cycle III Marine Science Research Programme,**

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GeoHAB venue

Connemara Coast Hotel, Furbo, Co. Galway Ireland



GeoHAB 2004 - Agenda

Day 1: Wednesday, May 5th, 2004

0800 -0930	Registration & Coffee	
0930 -1000	Hosts welcome	Paul Ryan (Head of Department of Earth and Ocean Sciences, NUIG) Anthony Grehan (Convenor)
SESSION 1: Regional mapping initiatives Chair: H. Gary Greene, Moss Landing Marine Laboratory, USA		
1000-1020	Habitat Mapping for Ocean Management on the Western Canadian Continental Shelf	Kim Conway , Barrie, J.V., Picard, K., Hill, P.R., Yamanaka, L., Sinclair, A.
1020-1040	Marine Mining and Habitat: Issues for Western Canada	J. Vaughn Barrie , Good, T.M., Conway, K.W.
1040-1100	Development of a Regional Seafloor Surficial Geologic (Habitat) Map for the Continental Margins of Oregon and Washington, USA	Chris Romsos , Goldfinger, C., Robison, R., Milstein, R., Wakefield, W.
1100-1140	Coffee	

1140-1200	A National Marine Sediment Database for Australia- a vital step in marine bioregionalisation.	Vicki Passlow , Hemer, M., Glenn, K., Rogis, J., Hancock, A.
1200-1220	Mapping of coastal seabed habitats in Tasmania: development and integration of remote sensing techniques within a hierarchical framework	Alan Jordan , Halley, V., Lawler, M., Mount, R.
1220-1240	A strategy for regional scale habitat mapping - an example from the outer Bristol Channel, South Wales	Ceri James , Philpott, S., Jenkins, G., Mackie, A., Derbyshire, T., Rees, I.
1240-1300	Development of a Framework for Mapping European Seabed Habitats (MESH)	Connor, D., Roger Coggan
1300-1420	Lunch	
SESSION 2: The Irish National Seabed Survey Chair: Brian Todd, Geological Survey of Canada		
1420-1440	Overview and status report on Seabed Survey together with spin-offs in terms of industry/research collaborations	Eibhlín Doyle
1440-1500	Seabed data management in the GSI	Archie Donovan

1500-1520	Grid Enabled Data Mining on the Irish National Seabed Survey	Martin Kenirons , Shearer, A., Holland-Ryan, J., Ryan, P., Riordan, C.O.
1520-1540	Marine Geographic Information Systems and High-Performance Computing Network	Declan Dunne
1540-1620	Coffee	
1620-1640	The Irish National Seabed Survey developing marine R&D capacity	Fiona Fitzpatrick
1640-1700	Shallow marine and freshwater surveys around Clew Bay, Ireland	Shane Rooney , Glynn, B., Brown, C.
1700-1720	A biogeological view of the Belgica Mounds (Porcupine Seabight): Synthesis of video surveying TOBI sidescan sonar imagery and microbathymetric mapping	Anneleen Foubert , Beck, T., Huvenne, V.A.i., Wheeler, A.J., Grehan, A., Opderdecke, J., de Haas, H., Henriët, J.P., and Thiede, J.
1720-1740	Multibeam seabed classification on the West Porcupine Bank, Irish margin	Xavier Monteys
1740-1800	Assemble posters	
1800-1930	Icebreaker & media reception	

Day 2: Thursday, May 6th, 2004

SESSION 3: Geohabitat mapping case studies		
Chair: Kathy Scanlon, US Geological Survey		
0900 -0920	Mapping Benthic Sublittoral Biotopes on the shelf of Faial island and neighbouring island (Azores, Portugal)	Fernando Tempera , Bates, R., Santos, R.S.
0920 -0940	Marine geology and benthic habitat of German Bank, Scotian Shelf, Atlantic Canada	Brian Todd , Kostylev, V.E., Valentine, P.C., Longva, O.
0940-1000	Benthic habitat mapping on Scotian Shelf	Vladimir Kostylev
1000-1020	The MINCH project – the use of multibeam sonar and visual survey techniques to map cold water coral habitats in Scottish waters	Craig Brown , Roberts, M., Bates, R., Mitchell, A., Long, D., Service, M., Harper, C., Hancock, J.
1020-1040	Developing geological understanding from multi-disciplinary surveys: examples from west of Scotland	Dave Long , Wilson, C., Brown, C., Roberts, M., Bates, R., Service, M.
1040-1140	Coffee & Posters	

SESSION 4: Habitat mapping for fisheries management		
Chair: Alan Jordan, Tasmanian Aquaculture and Fisheries Institute, Australia		
1140-1200	High resolution mapping of the Swedish West Coast as a tool for fishery management	Ola Oskarsson , Sköld, M., Nilsson, O., Dahlen, A., Bengtsson, J.
1200-1220	Distribution, abundance and habitat associations of demersal fishes determined from ROV video observations on Heceta Bank, Oregon, USA	Julia Clemons , Wakefield, W.W., Embley, R.W., Tissot, B.N., Yoklavich, M.M., Hart, T.D., Merle, S.G., Whitmire, C.E., Barss, W.H.
1220-1240	Spatial Utilization of Benthic Habitat by Demersal Fish on the Continental Shelf off Nova Scotia, Canada	Donald Gordon , Anderson, J., Fader, G.
1240-1300	Multibeam Sonar mapping and Scallop Stock Assessment: GIS Data Integration in Support of Sustainable Fisheries Management	Gerry Sutton , Tully, O., Hervas, A., Hickey, J., Monteys, X.
1300-1420	Lunch	

SESSION 5: Inshore mapping and seabed classification - methods and tools		
Chair: Colin Brown, Department of Earth and Ocean Sciences, NUI Galway		
1420-1440	Nearshore habitat mapping using Lidar bathymetry	Bill Gilmour, Tuell, G.
1440-1500	Coastal habitat mapping in Norway, with examples of interferometric sonar applications	Terje Thorsnes, Longva, O., Christensen, O., Andresen, K., Sandberg, J.H.
1500-1520	Mapping seabed habitats in the Firth of Lorn, west coast of Scotland: Evaluation and comparison of biotope maps produced using the acoustic ground discrimination system, RoxAnn, and sidescan sonar	Craig Brown, Mitchell, A., Limpenny, D., Robertson, M., Service, M., Golding, N.
1520-1540	Marine habitat mapping and classification using sidescan sonar: examples of mapping shallow water marine habitats in Australia	Andrew Bickers, Baxter, K.
1540-1620	Coffee & Posters	

1620-1640	Acoustic classification of nearshore seabed habitats based on echo-integration and visualisation	Miles Lawler , Jordan, A., Halley, V.
1640-1700	The Hudson River Benthic Mapping Project – An example of process related classification of sedimentary environments	Frank Nitsche , Bell, R., Ryan, W.F., Carbotte, S.
1700-1720	Towards quantitative seabed characterisation using extended Biot theory	Klaus Leurer , Brown, C.
1720-1740	Improving seafloor data acquisition, integration and visualisation: the AMASON (Advanced MAPPING with SONar and Video) project	Yvan Petillot , Katia Lebart , Capus, C., Coiras, E., Lane, D., TenaRuiz, I., Banks, A., Smith, C., Grehan, A., Canals, M., Urgeles, R., Cardew, M., Jaffray, B., Wallace, J., Allais, A-G., Rigaud, V.
1740-1830	GeoHAB Steering Committee Meeting	Steering Committee members
1900	Conference Dinner	
2100	Traditional Irish music and Ceilí	

Day 3: Friday, May 7th, 2004

SESSION 6: Geologic, sediment transport and oceanographic modelling		
Chair: Terje Thorsnes, Norwegian Geological Survey		
0920 -0940	The evolution of a post transgression littoral terrain – A case study from the Bunurong Marine National Park, South East Australia	Joseph Leach
0940-1000	The Shallow Geological Model: Mapping and Monitoring the Marine Landscape	Heather Stewart, Stevenson, A.G., Holmes, R., Long, D., Graham, C.C.
1000-1020	Efficient, robust modelling sediment transport over geological time	David Waltham
1020-1040	Classification of the Torres Strait - Gulf of Papua region based on predictions of sediment mobility from a three-dimensional hydrodynamic model	Mark Hemer, Harris, P.T., Coleman, R., Hunter, J.
1040-1140	Coffee & Posters	

SESSION 7: Habitat classification and prediction		
Chair: Craig Brown, Scottish Association for Marine Science, UK		
1140-1200	What's in a habitat: Are we mapping the right things?	H. Gary Greene , Bizzarro, J.J., Vallier, T.
1200-1220	Terrain modelling of the Gullmar Fjord – A tool for habitat mapping	Olof Nilsson , Bekkby, T., Ingvarson, N., Oskarsson, O., Rosenberg, R.
1220-1240	The possibilities and limitations of habitat models based on bathymetry	Lars Erikstad , Bakkestuen V, Bekkby T, Rinde E, Longva O, Storeid S-E, Christensen O
1240-1300	Evolution of a National Coastal and Marine Classification Standard for the United States	Becky Allee
1300-1420	Lunch	

1420-1540	Seabed classification discussion	All
1540-1620	Coffee	
1620-1700	Common habitat mapping grid discussion	All
1700-1740	GeoHAB publication editorial meeting	Gary Greene, Brian Todd and all contributors
1740-1800	Meeting wrap-up	Anthony Grehan

Day 4: Saturday 8th of May, 2004 Field trip to Connemara

0930-1000	Meeting at the Connemara Coast Hotel
1000	Fieldtrip departure
1300-1400	Lunch
1700	End of tour at Connemara Coast Hotel

GeoHAB 2004 - List of poster presentations

Poster no.	Authors	Title
1	Birchenough, S.N.R., Boyd, S.E., Roger Coggan , Foster-Smith, R., Limpenny, D.S., Meadows, W.J., Rees, H.	Ground-truthing acoustic surveys at areas of anthropogenic impact II: Seabed characterisation of an area licensed for dredge material disposal.
2	Cleo Brylinsky , O'Connell, V., Greene, H.G.	Identification of yelloweye rockfish habitat: geophysical survey data in comparison with fishery logbook data
3	Roger Coggan , Philpott, S., Limpenny, D.S., Meadows, W.J., Birchenough, S., Boyd, S.	Ground-truthing acoustic surveys at areas of anthropogenic impact I: Characterisation of habitats in an area licensed for aggregate extraction.
4	Alison Copeland , Bell, T., Edinger, E., Shaw, J., Gregory, R.	The Geohabitats of Newfoundland Fjords, Eastern Canada.
5	Don Gordon	Spatial utilization of benthic habitat by demersal fish (Canadian Department of Fisheries and Oceans)
6	Don Gordon	Towcam surveys (Canadian Department of Fisheries and Oceans)
7	H.Gary Greene , Barrie, V., Lopez, H., Palsson, W., Tilden, J., Endris, C.	Potential Marine benthic Habitats of an inland Sea, San Juan Islands and Transboundary Region of Canada and the U.S.: A successful international cooperative program.

8	Anthony Grehan , Todd, B.J., Brown, C.J., Stevenson, A., Thorsnes, T., Kelly, S.	Avoiding gridlock in the ICES area: a proposal for regional co-ordination and standardised production of an ICES geo-habitat map series.
9	Janine Guinan , Wilson, M.F.J., Grehan, A.J., Lebart, K., Redpath, D., Brown, C.	Underwater video sampling: What's in an image?
10	Veerle Huvenne , Henriët, J.P., Olu-Le Roy, K., Wheeler, A.J., Dekindt, K., Kozachenko, M., de Haas, H., & CARACOLE cruise participants.	Deepwater coral habitats in the Porcupine Seabight, NE Atlantic: 3 case studies, 3 different environments
11	Jessop, P., Goldfinger, C., Chris Romsos	ArcGIS tools for streamlining habitat map data integration
12	Peter Morris , Belchier, M., Wakeford, R.	Longline fishing activity and bathymetry in the South Georgia region
13	O'Connell, V.M., Wakefield, W.W., Greene, H.G., Cleo Brylinsky	Using In-situ Technology to Identify and Characterize Essential Fish Habitat for Classification As a Marine Reserve in the Eastern Gulf of Alaska
14	Parkes, G., Vilhelm, R., Burn, B., Grayer, C., Bailey, A., Copps, C., Wakefield, W.	Bayesian Network Models for Pacific Coast Groundfish EFH Requirements
15	Yvan Petillot , Cormack, A.	SeeTrack: On-site visualisation, sensor data analysis and data fusion of UUV sonar and video products.
16	James Riordan , Toal, D., Flanagan, C.	Sidescan Sonar Modelling for Imaging Performance Characterisation.

17	Kathy Scanlon, Ackerman, S.D.	Sedimentary Environments in the Flower Garden Banks National Marine Sanctuary, Northwestern Gulf of Mexico Outer Shelf.
18	Kathy Scanlon, Ackerman, S.D.	Geographic Database of Deep-water Coral Habitats off Eastern and Southern United States
19	Mattias Sköld, Lundälv, T., Nilsson, P.	Forum Skaggerrak II. Seabed mapping and biological groundtruthing of habitats on the Swedish west coast.
20	Brian Todd, Shaw, J., Kostylev, V.E.	New marine geoscience and benthic habitat map products from the Geological Survey of Canada
21	Unnithan, V., Anthony Grehan, van Weering, T., Olu-LeRoy, K.	Geo-habitat characterisation of deep-water coral mounds in the Rockall Trough, west of Ireland.
22*	Page Valentine, Fuller, S.J., Scully, L.A.	Terrain ruggedness analysis and distribution of boulder ridges in the Stellwagen Bank National Marine Sanctuary region, Gulf of Maine, New England
23	Phil Weaver and the HERMES Consortium	HERMES: Hotspot Ecosystem Research on the Margins of European Seas
24	Margaret Wilson, Guinan, J., Grehan, A.J., Brown, C.	Zooming in on the Irish National Seabed Survey: what can it tell us about benthic habitats?

GeoHAB 2004
Oral presentation abstracts

Evolution of a National Coastal and Marine Classification Standard for the United States

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As evidenced by organizations such as GeoHab and ever expanding efforts throughout the world, habitat mapping and classification have become hot topics. This is true in part because resource management agencies now recognize that successful conservation, protection and restoration of valuable resources must be approached at an ecosystem level. Scientists across many disciplines have come to accept and now promote this concept. Management of single species simply will not provide the level of conservation these resources require to ensure sustainability or even continued existence. The National Oceanic and Atmospheric Administration (NOAA) within the United States Department of Commerce recognized this some years ago after the U.S. Congress passed legislation mandating NOAA to conserve essential habitats of trust resources, and those habitats that support the food supply of those resources.

With the implementation of Essential Fish Habitat (EFH, defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity"), NOAA soon understood the dilemma the agency faced as information necessary to delineate EFH was simply not available. Taking a precautionary approach, the agency erred on the side of conserving too much habitat rather than risking oversight of potentially important habitats.

Following the philosophy of the National Gap Analysis Program for terrestrial habitats, NOAA began an initiative to develop a National coastal and marine habitat classification system in partnership with the Ecological Society of America. A synthesis of existing systems was compiled and, along with knowledge from expert habitat practitioners, the information was used to establish a starting point and critical habitat parameters for use in

the habitat classification system were defined. This system would be the first step toward establishing a geographically-based inventory of all coastal and marine habitats and their associated biological assemblages. The higher levels of this classification system address broad-scale parameters while the lowest level pulls in the biodiversity of a specific habitat type.

In the summer of 2000, the first product resulting from this initiative was released. The technical publication, “Marine and Estuarine Ecosystem and Habitat Classification”, presented the first National framework for a consistent classification system. Based on expert knowledge of habitat mapping and conservation practitioners, the report presented the concept of a quasi-hierarchical, descriptive classification system with 13 levels of organization (Table 1). Since the release of this report, the initiative has continued and the classification system continues to evolve into a user-friendly framework which considers past and on-going classification efforts. The current product is intended to allow existing systems compatibility while maintaining the integrity necessary to map and track all coastal and marine habitats on a National level allowing comparability among the rich diversity of habitats encompassed within the waters of the United States Exclusive Economic Zone.

During FY2002, NOAA Fisheries and NOAA Oceans and Coasts established a partnership with NatureServe, a non-profit conservation organization that provides scientific information and tools to help guide effective conservation action. While NatureServe was a new organization at that time, it was formed from what had been the scientific arm of The Nature Conservancy. Further, the principals at NatureServe had successfully established the National Vegetation Classification System, which is an FGDC-approved standard. The work begun in FY2002, built upon previous NOAA work to establish classification systems (most notably Allee et al. 2000) and NOAA’s efforts with the North American Commission for Environmental Cooperation (NA CEC) to establish a classification system for coastal and marine ecosystems.

Marine Habitat Classification and Mapping Using Sidescan Sonar : Examples of Mapping Shallow Water Marine Habitats in Australia

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A growing number of broad scale shallow water marine habitat mapping programs are currently underway or are planned in many states in Australia. Areas to be surveyed are typically chosen for a number of reasons:

- Planned for developments such as harbours and channels, pipeline routes and offshore structures such as for the oil and gas industry.
- Information required for resource management such as fisheries and marine aquaculture.
- Special features and characteristics of coastal areas and their suitability as marine protected areas.

These programs use a variety of acoustic (multibeam, single beam and sidescan) and optical techniques (aerial and satellite photography) to gain broad scale coverage of coastal and continental shelf areas. Georeferenced video towed and diver or grab collection techniques are typically used to provide validation.

The Coastal Waters Habitat Mapping Project is part of the Coastal CRC (Cooperative Research Centre), an initiative funded by a combination of government, industry and universities. Together with its partner programmes this project will develop and apply technologies for the rapid and cost effective assessment of shallow water marine habitats around Australia and overseas. The initial three year phase will emphasise a series of five study sites selected to represent the wide range of coastal benthic marine ecosystems found in Australia.

Under the umbrella of the CRC, the University of Western Australia has undertaken a

number of habitat mapping projects in Western Australia and New South Wales. In many of these projects, a broad scale, full or partial coverage map of the seabed is initially obtained using sidescan sonar. The sidescan mosaic is then segmented into acoustically distinct regions and boundaries between features that can be interpreted from satellite and aerial imagery are combined.

Representative samples of these regions, features and the boundaries between them are then validated by towed georeferenced video. This validation allows classification of the map produced from the segmented sidescan and optical imagery in terms of both the physical and biological characteristics of each region. It is common however to use the biological communities analysed from the video as surrogates for some of the habitat types. From this map further fine scale work is targeted that may involve diver or grab collection or acquisition of bathymetry by multibeam systems.

Exploiting the wide swaths of sidescan sonar survey and a targeted ground truth regime has proved successful, popular and most importantly, cost effective in the efficient mapping of shallow water habitats. There are however a number of considerations in the production of maps using these techniques that would benefit from and are undergoing further research. Although these issues are closely related to each other, they can be listed under the following topics.

1. Habitat classification schemes and boundaries and how they relate to survey technique.

Procedures used to classify habitats are directly related to the survey techniques applied. Whilst the sidescan imagery allows the accurate mapping of boundaries between habitat types such as coarse and fine sediment, reef and seagrass, analysis of the video validation data allows further delineation of communities or physical attributes at a much finer scale. This matter must be addressed when producing a map representing the spatial extent of habitats and community types analysed from video data as continuous boundaries cannot be produced from its tracks. Combination of the video classification

with broader scale data of another type such as bathymetric contours can however often sensibly delineate between habitat types. The example presented here concerns the rapid mapping of a marine park in NSW using such a composite of real (interpreted from aerial photography and sidescan sonar) and artificial (from video and bathymetry) boundaries between habitat types.

2. Classification of the sidescan image

Geometric and radiometric distortions inherent in the sidescan image can cause many difficulties in the segmentation of even the processed sidescan records. Here we investigate how boundaries between acoustically distinct areas can be produced either visually or automatically from the raw and processed sidescan images.

Whilst the need for a common classification scheme for shallow water marine habitats in Australia is clear, different survey techniques allow different types of habitats to be discriminated and a successful classification scheme should take this into consideration. This paper discusses the issues and limitations relating to mapping marine habitats in Australia using the techniques described above with reference to habitat mapping projects in Western Australia, Tasmania and New South Wales.

Marine Mining and Habitat: Issues for Western Canada

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¹Geological Survey of Canada – Pacific, British Columbia, Canada

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Extraction of aggregates (sand and gravel) and marine minerals from the sea is increasing every year as on land sources are depleted or access is denied. For example, marine aggregate production in northern Europe is extensive with the majority of the UK's sand and gravel consumption derived from marine sources. Similarly, marine mining for diamonds off the southwestern coast of Africa has become a billion dollar industry. The European aggregate extraction works under extensive site regulations that allow for monitoring of habitat loss or change while habitat damage due to the diamond extraction off Africa is largely unmonitored. In North America regulatory regimes and constraints on seafloor dredging for aggregates varies by region and has in the past been largely unregulated, resulting in significant habitat damage, both physical loss of nearshore areas and overall change of the habitat.

On the Pacific coast of Canada dredging for commercial aggregate was carried out in the Prince Rupert area from the 1950's until the early 1990's, when activity was shut down for environmental and legal reasons. Evaluation of environment damage from past mining and the impact on habitat was carried out at selected sites where the greatest quantity of material was removed, varying from 70,000 dry metric tonnes (DMT) to about 4,000,000 DMT, based on royalty records. No impact assessment or environmental data are available for any of the sites prior to, during and, in most cases, for some years after extraction ceased. Recent research cruises by the Geological Survey of Canada collected sub-bottom profiles and sidescan sonar data for the largest extraction sites, but in general aggregate removal occurred in intertidal or shallow subtidal areas. Of these, several selected sites were examined using helicopter overflights and foot traverses at the annual lowest tide, and by using towed underwater video system (SIMS) deployed from a

small vessel at high tide. Efforts were made to examine similar, undisturbed sites for comparison. Significant permanent physical damage was observed at several sites, including the removal of a tombolo and over-steepening of the foreshore resulting in beach erosion. Benthic habitats changed in response to the substrate change, however, overall change was minimal after 10 years of recovery.

Presently there is no terrestrial source of aggregate in the immediate area. There is, however, potential for significant future demand related to possible offshore oil and gas exploration and long-term shortages in southern British Columbia and the U.S.A. Offshore areas of Queen Charlotte Basin hold promise for future resources, but how such extraction will effect habitat is not clearly known. A large scale seafloor mapping program is now underway within the basin arising from the conflicts between the commercial fisheries, oil and gas exploration, marine wind farms, and offshore minerals. At present no specific guidelines exist in Canada for offshore mining and habitat protection. Suggested guidelines based on European experience and their applicability to the Pacific Coast of northern British Columbia are considered here along with recently adopted “Code for Environmental Management of Marine Mining” by the International Marine Minerals Society.

Mapping seabed habitats in the Firth of Lorn, west coast of Scotland: Evaluation and comparison of biotope maps produced using the acoustic ground discrimination system, RoxAnn, and sidescan sonar.

Brown C.¹, Mitchell, A.², Service, M.², Limpenny, D.³, Robertson, M.⁴, Golding, N.⁵

¹Scottish Association for Marine Science.

²Department of Agricultural and Rural Development, Northern Ireland.

³Centre for Environment, Fisheries and Aquaculture Science.

⁴FRS Marine Laboratory.

⁵Joint Nature Conservation Committee.

In recent years the application of acoustic mapping methodologies, in particular the use of acoustic ground discrimination systems (AGDS) used in conjunction with ground-truth sampling, has become common practice in monitoring and mapping seabed habitats at a number of Special Areas of Conservation (SACs) around the UK coastline. Whilst this approach offers advantages over more traditional style benthic grab surveys, the accuracy of the spatial distribution maps produced from such surveys has on occasions been questionable.

Previous investigations into the application of AGDS have gone some way to assess the benefits and limitations of such systems for continuous coverage seabed mapping. The findings from many of these previous studies were used to develop procedural guidelines for conducting AGDS surveys which are presented as part of the Joint Nature Conservation Committee (JNCC) Marine Monitoring Handbook. However, as the number of research/contract groups undertaking broad-scale seabed mapping activities at various sites around the UK coastline increases it is essential to improve communication between these groups and to further refine guidelines and recommendations on best practice for the production of full-coverage seabed biotope maps using AGDS. To address these issues a UK National Acoustic Ground Discrimination Workshop was hosted by the Scottish Association for Marine Science at Dunstaffnage Marine Laboratory in September 2003.

The workshop brought together a number of UK research/contract groups who use the AGDS, RoxAnn, for the production of biotope maps. The main aim was to critically evaluate this acoustic system for use in mapping seabed biotopes. A small test site on the west coast of Scotland, within the Firth of Lorn candidate SAC, encompassing a wide range of benthic habitats was chosen as the study site. The area was first surveyed using a sidescan sonar system and a mosaic of the output was produced covering 100% of the survey area. Interpretation of the mosaic identified three acoustically distinct seabed types, the spatial distributions of which were mapped. Four RoxAnn data sets were then collected over the same area of seabed applying different survey parameters (e.g. different survey grids, track spacing, survey vessels, survey speeds and RoxAnn systems). Extensive ground-truthing was carried out involving twenty-six drop-down video stations, and from these data six benthic classes (life-forms) were identified. Following interpolation of the RoxAnn track point data to produce full-spatial coverage data, these six life-form categories were used to conduct supervised classification of the RoxAnn data to produce full-coverage habitat maps of the area for each of the four RoxAnn data sets.

Comparisons between the four maximum likelihood classification maps produced from the four RoxAnn datasets was done using internal and external accuracy assessment techniques based on the video ground-truth data sets. These results revealed a moderate level of agreement in terms of the spatial distribution of the six habitat classes (life-forms) identified within the study area between the four data sets. The ability of the RoxAnn system to identify discrete seabed features mapped using sidescan sonar was also tested. RoxAnn consistently overestimated the percentage of rocky reef habitat and underestimated the percentage of mud habitat within the area compared to that measured by sidescan sonar. A number of recommendations relating to the use of AGDS for the production of continuous coverage maps and relating to the JNCC Marine Monitoring Handbook guidelines are proposed.

The MINCH project – the use of multibeam sonar and visual survey techniques to map cold water coral habitats in Scottish waters

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⁶British Geological Survey

The objective of the Mapping INshore Coral Habitats or MINCH project was to assess the current distribution and status of cold-water coral habitats to the east of the Island of Mingulay. Time and weather permitting, a series of additional areas were also to be examined on the Stanton Banks, in the Sound of Rum and to the west of Skye. The project was designed as a ‘demonstration project’ to show the effectiveness of wide-area environmental assessment using multibeam sonar as part of a habitat mapping exercise in the context of a project designed from both biological and geological perspectives. Before the survey, existing bathymetry and geology were reviewed to help guide the choice of survey areas.

Reefs formed by the cold-water coral *Lophelia pertusa* were identified in the surveys to the east of Mingulay where they formed characteristic seabed mounds. These mounds were clearly seen on the multibeam bathymetry and backscatter data records. The backscatter also revealed intriguing ‘trails’ extending downstream from some of these mounds. Their composition and cause are currently unknown. Preliminary analysis suggests that it may be possible to identify coral mounds of this type and size from bathymetry. However, future surveys must include sufficient seafloor inspection to ground-truth any such predictions. Video inspection of the seabed allowed a total of 16 different biotope types to be identified. Interpretation of the acoustic data in conjunction with the video ground-truthing allowed preliminary habitat maps to be produced.

**Improving seafloor data acquisition, integration and visualisation: the AMASON
(Advanced MAPPING with SONar and Video) project**

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Offshore mapping and seafloor imaging is a major requirement for scientific evaluation of coral carbonate mounds, trawling impacts and hazard assessment related to sediment stability, as well as ecosystem monitoring. AMASON provides this facility using small, commercial-off-the-shelf, sensors mounted on UUVs (Unmanned Underwater Vehicles) of opportunity.

The project has developed a modular system architecture, ensuring a scalable and re-configurable system. The Data Acquisition System (DAS) interfaces with the sensors and stores the raw data in a GIS (Geographical Information System) environment. The DAS also interfaces with the Advanced Processing Algorithms (APA) module. The APA module provides rapid object and region characterisation, classification, mapping and mosaicing for large concurrent data sets from the video, small sidescan, parametric sub-bottom and multibeam bathymetric sonars. Fusion of feature and symbolic data is used to improve confidence in detected events of scientific interest.

The AMASON project has recently carried out its mid-term trials in Crete, Greece. The trials proved the reliability of the AMASON DAS developed by Marine Informatics Ltd. The DAS was used to gather the data from the AMASON sensor suite developed by System Technologies. The sensors and DAS were mounted on IMBC's Max Rover ROV which was deployed from IMBC's research vessel *Philia* in Heraklion bay.

The data gathering trials took four days and a number of different missions were carried out. The multiple-sensor platform was carefully guided to best exploit the APA developed in Heriot-Watt University and in IFREMER. These algorithms help automate tasks normally carried out by scientists, such as assessment of trawling impact and monitoring of coral mounds and evidence of recent seafloor instability. In the final trials the post-processing will enter the mission planning loop, helping scientists make decisions based on the analysis of the most recently gathered data.

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Distribution, abundance and habitat associations of demersal fishes determined from ROV video observations on Heceta Bank, Oregon, USA.

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Fish, invertebrates and the lithology of Heceta Bank, Oregon, were mapped using the remotely-operated vehicle (ROV) ROPOS. Video observations from twenty-one ROV dives along line transects enabled the assessment of the populations of fishes, invertebrates and their habitats. Additional exploratory dives were used to ground-truth previously collected multibeam topography and backscatter imagery. From the video, it was seen that juvenile rockfish dominated the observed fish assemblages in rock ridge and boulder habitats with densities of ~1350 fish/ha, and cobble habitats were dominated by sharpchin rockfish (~2000 fish/ha). Fish densities in mud habitats were the lowest of all habitats that were explored, with flatfish (~400 fish/ha) and greenstriped rockfish (45 fish/ha) dominating assemblages in this habitat type. Heceta Bank, Oregon, has been a primary focus of groundfish habitat investigations since the late 1980s. The habitat associations, the distribution of habitat types, and habitat-specific abundances of the current study are compared with other fish-habitat studies along the West Coast of North America to identify generalities in the patterns of habitat utilization by demersal fishes.

Development of a framework for Mapping European Seabed Habitats (MESH)

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JNCC will lead an EU Interreg-funded international marine habitat mapping programme entitled 'Development of a framework for Mapping European Seabed Habitats', or **MESH** for short, which will start in spring 2004 and last for 3 years¹. MESH has twelve partners in the UK, Ireland, the Netherlands, Belgium and France and aims to produce seabed habitat maps covering the marine waters of north-west Europe, together with the development of international standards for seabed mapping. Further details of the project are given below.

Duration

May 2003-April 2007 (including preparation phase)

Background

The seas around north-west Europe support an exceptionally wide range of seabed habitats and rich biodiversity. These provide important food resources (fish, shellfish), contribute to essential ecosystem functioning (such as nutrient recycling) and yield valuable natural resources (oil, gas, aggregates). In addition the seabed is subject to increasing pressures from new developments, such as for renewable energy (e.g. wind-farms) and coastal developments for leisure activities and coastal defences.

These multiple uses bring ever-growing pressures on our seas and coasts, leading to increased risk of conflict between users and a greater potential for degradation of the marine environment and the essential physical, chemical and biological processes that maintain our marine ecosystem. We are responding to this challenge through recognition

¹ Initiation of the project is subject to finalisation of budget and contractual arrangements with Interreg IIIb North-West Europe Secretariat.

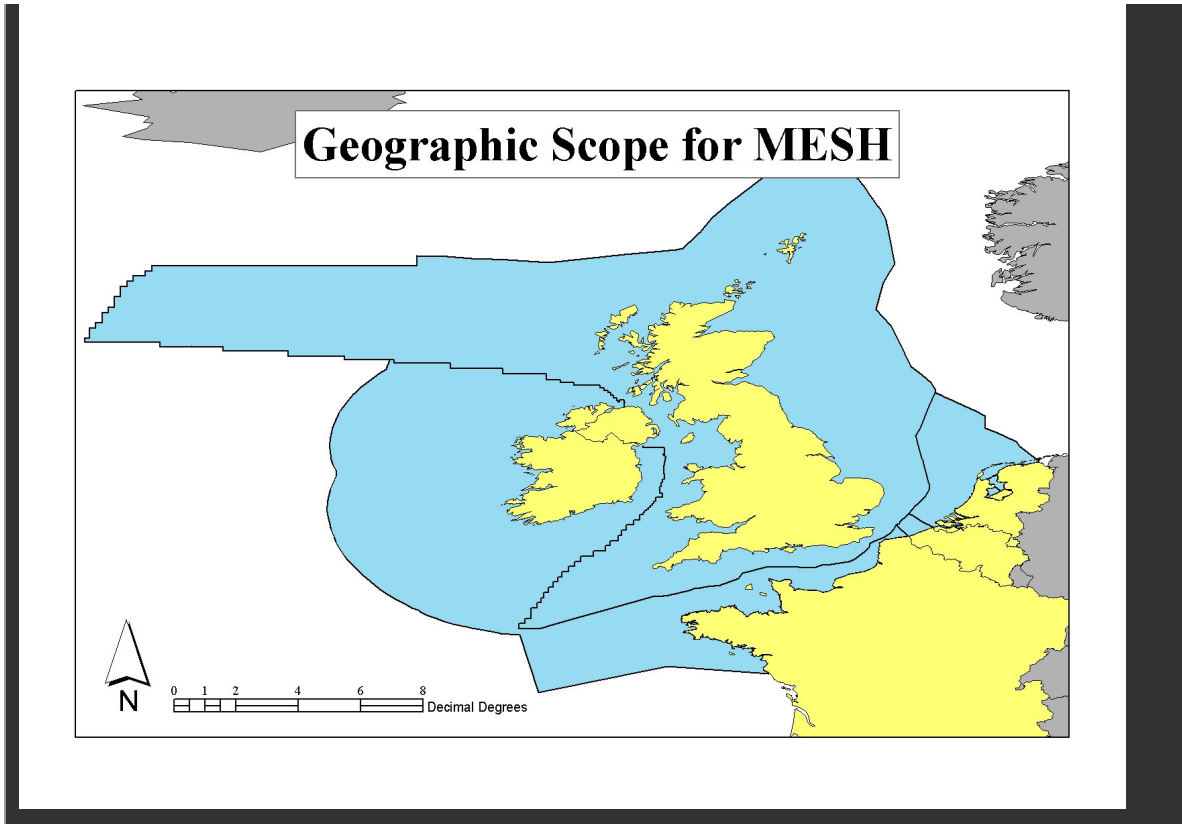
of the need for much improved integrated spatial planning for our seas (where traditionally planning has been very piecemeal or sectoral), as reflected by the new requirement for Strategic Environmental Assessments (SEAs) and issues raised recently within the developing EU Marine Strategy, by the OSPAR Commission and by Governments (e.g. the UK's Marine Stewardship Report). Additionally there are new and increasing international commitments (from the EC Habitats Directive and OSPAR) to protect certain marine habitats, including through the designation of a network of marine protected areas, whilst the EC Water Framework Directive and OSPAR require periodic assessment of ecosystem health, including its seabed biological communities. The assessment of coastal sensitivity to oil spills is currently hampered by the lack of proper data on habitats, as has been shown by the recent *Prestige* case in France.

All this creates a substantial demand for information about intertidal and seabed habitats, but is set against a background of patchy, inconsistent and poorly collated information on their distribution, extent and quality. There are no national programmes in the north-west Europe region (except in France) which collate such information and the information which is available is difficult to access, making very poor use of data which are expensive to collect. The recent increase in demand, coupled with advances in remote-sensing technologies over the past ten years, has led to a burgeoning of seabed mapping studies. These are undertaken using a variety of techniques, for a range of end needs (e.g. fisheries, commercial, nature conservation) and at various scales. The lack of international standards for these studies means the resulting data cannot readily be compared or aggregated and leads to an absence of regional, national and international perspectives on the seabed resource in spatial planning and decision-making.

MESH aims to address these key issues, as detailed below.

Geographic scope

The project will cover the sea areas mapped in blue. Boundaries are country EEZs (or equivalent), except France, where the southern boundary relates to southern limit of the Interreg North-West Europe area.



Key aims of MESH

MESH will address these issues in the following key ways:

- It will compile available seabed habitat mapping information across north-west Europe and harmonise it according to European habitat classification schemes (the European Environment Agency's EUNIS system and the EC Habitats Directive types) to provide the first seabed habitat maps for north-west Europe (see map).
- Because the available information will be of variable quality and patchy in nature, habitat modelling will be developed to predict habitat distribution for unsampled areas, from the more widely available geophysical and hydrographic data. The final maps will be presented with confidence ratings so that end-users can determine their adequacy for their decision-making and future survey effort can be strategically directed.

- A set of internationally agreed protocols and standards for habitat mapping will be developed, drawing upon best available expertise across Europe and elsewhere, to help ensure that future mapping programmes yield quality assured data that can be readily exchanged and aggregated to further improve the initial maps. The protocols will be tested through a range of field-testing scenarios involving trans-national co-operation to ensure they are robust and the results repeatable.
- Both the protocols and the habitat maps will be made available via state of the art Internet-based GIS (Geographical Information Systems), providing ready access to the information for a wide range of end-users at local, regional, national and international levels (e.g. spatial planners and managers; governments and other regulatory authorities, research institutions, educational establishments).
- The wide spectrum of potential end-users will be engaged from the start of the project to better understand their end needs, to encourage the supply of relevant data and to encourage the improved use of the mapping information in spatial planning, management issues and for environmental protection. This network of stakeholders will be valuable in helping to forge strategies within each country for the maintenance and further improvement of the seabed maps beyond the end this three-year project.

A strong Partnership of highly skilled and experienced organisations has been developed to deliver this challenging project. The Partnership covers all five countries in the Interreg IIIb North-West Europe area, bringing with it a balanced mix of skills including scientific and technical habitat mapping skills, national data collation and management expertise and experience in the use of habitat mapping in management and regulatory frameworks. This blend of expertise from scientific/technical through to management and policy, with a focus on regional, national and international level delivery is felt to be essential to effectively deliver the required end products in a readily useable format.

Partnership

UK	Joint Nature Conservation Committee (JNCC)
BE	University of Gent
FR	Ifremer
IRE	Marine Institute
NL	Alterra-Texel
NL	TNO Environment, Energy and Process Innovation
UK	Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
UK	Department for Agriculture and Rural Development, Northern Ireland (DARD)
UK	English Nature
UK	Envision Mapping Ltd
UK	National Museums and Galleries of Wales (NMGW)
UK	Natural Environment Research Council (British Geological Survey) (BGS)

Outputs from MESH

- The first collated and harmonised map of seabed habitats for the north-west Europe INTERREG-IIIB Area, presented in a Geographical Information System (GIS) according to the European Environment Agency's European EUNIS habitat classification system and the EC Habitats Directive types.
- Accompanying confidence maps, indicating the quality of mapping information in relation to its accuracy and precision at different scales of resolution.
- A meta-database of seabed mapping studies for north-west Europe, holding details on the location of each study, the mapping techniques employed and the range of data and end products generated.

- The first large-scale evaluation of the practical application of the EEA's EUNIS habitat classification and recommendations for its modification or improvement.
- A set of internationally agreed protocols and standards for marine habitat mapping. This will include guidance on mapping strategies, standards for undertaking remote-sensing and ground-truthing surveys for intertidal and subtidal mapping using a variety of techniques, and protocols for data storage, interpretation and presentation.
- A series of new mapping studies which test, evaluate and help improve the mapping protocols and standards.
- Models for the prediction of habitat type, based on physical and hydrographic information within different habitat areas and water depths.
- Case studies which demonstrate the political, economic and environmental use of marine habitat maps for spatial planning and management at local through to international scales.
- A web site providing wide access to the products of the project, including interactive GIS seabed maps for north-west Europe.
- National networks of habitat mapping practitioners and end-users in management, regulatory and planning authorities.
- A framework within each country for the continued collation and improvement of habitat maps at national level and their compilation and aggregation at an international level.

Habitat Mapping for Ocean Management on the Western Canadian Continental Shelf

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Seabed habitat research at the Geological Survey of Canada - Pacific focuses on three issues: (i) rockfish habitat mapping in the Georgia Basin (GB); (ii) groundfish habitat studies in the Queen Charlotte Basin (QCB); and (iii) unique sponge reef habitats found in both areas. Many rockfish (*Sebastes* spp.) populations have been in decline in inshore and offshore areas of British Columbia. In response the Department of Fisheries and Oceans (DFO) has designated approximately 90 areas on the west coast as Rockfish Conservation Areas. Surficial geology maps, compiled from multibeam backscatter, geophysical and sample data, will provide a base which will be utilized to drape parameters, such as rockfish abundance, extracted from submersible and towed video surveys, onto the surficial geological units. Habitat maps will be compiled from these data sets to obtain better estimates of rockfish populations, and details of habitat usage by rockfish, regionally.

The groundfish trawl fishery in the QCB is a multispecies fishery targeting an assemblage of about 29 species. Seafloor mapping of six representative pilot study areas, of interest to DFO groundfish managers, has shown that there is a strong correlation between substrates and groundfish species assemblages. Rock sole were found over coarse sandy gravel units. A mixed species group of Pacific cod, English sole and Arrowtooth flounder (turbot) was found on sandy bottoms and Dover sole were on muddy bottom types. These results suggest that stock estimates could be improved by habitat mapping and that catches of various species could be made more predictable if fishing effort was targeted at selected habitats. High resolution mapping of these habitats will be enhanced by the collection of multibeam datasets in the future.

Globally unique sponge reefs in the QCB exist at 165 – 240 m depth within tidally influenced shelf troughs. The sponge reefs cover approximately 700 km² of seafloor with reef mounds to 21 m in height and provide a complex habitat for many species. Many of the sponge reefs have been damaged or destroyed by the groundfish trawl fishery. The four main sponge reef complexes have been closed to trawling and are being considered as target Marine Protected Areas (MPA's) by DFO under Canada's Oceans Act. The multibeam mapping of the known reef complexes will be completed this year, which will allow for the determination of the reef boundaries and facilitate the MPA process. In the Georgia Basin in southern British Columbia, much smaller sponge reefs of a few square kilometres in area have been identified from 100 - 200 m depth, which differ in several ways from the larger northern reef complexes. These reefs were found by analysis of multibeam data, suggesting that other small reefs will be found in the future in offshore BC waters as multibeam data are collected in other shelf areas.

Seabed Data Management in the GSI (Geological Survey of Ireland)

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The Irish government has given the Geological Survey of Ireland (GSI) the responsibility of carrying out this data gathering task funded by a €32 million budget over the period 1999 – 2005, within the Irish designated area.

The initial survey plan was predicated on the assumption that a paper map final product was sufficient as a final deliverable. In line with this €127,000 was set aside in the initial estimate to finance the IT element of the project. In the first year of the project implementation this was revised to include a digital product capability. The IT element of the project financing was revised upwards to €1,270,000 to accommodate this new requirement.

As GSI deals almost exclusively with spatially located information, GIS plays an increasingly important role in our work and is applied across the organisation, and as we deal with a variety of datasets and clients, a wide range of **software** is employed in the manipulation of data, including:

- ESRI-ArcInfo, ArcView, ArcGIS, ArcIMS, Map Objects
- MapInfo (Groundwater area and for Local Authority Clients)
- AutoCad2000 (Digitising/GWPS)
- Caris (Marine Data Manipulation)
- Geosoft (Geophysical Data)
- CODA (Marine Data Manipulation)
- QTC (Marine Data Manipulation)
- Fledermaus (3D Visualisation & Fly-Through)
- Helical HHArchive (Seabed data database)
- LizardTech-MrSID (Raster Handling & Compression)

The GSI's largest project in terms of data volumes and cost is the Irish National Seabed Survey (INSS). Marine geophysical data, specifically multibeam sonar is processed using Questor Tangent's QTC software to derive a categorisation of seabed type.

ArcIMS is being used to provide corporate wide access to spatial datasets as part of a major database re-engineering project being carried out in conjunction with the British Geological Survey and funded by the Information Society at the Department of the Taoiseach. This project has provided a new corporate data model, ISO Standard metadata for all GSI datasets and will deliver Cold Fusion screens for query and input of the data when migrated from Geodata to the new database dubbed CONOR (Centrally Organised Network of Records). The use of ArcIMS internally has led to a greater awareness of datasets within the organisation, increased interest in GIS and led to cost savings in terms of substituting desktop software with browser access for certain users. The current instance, which is a thin client, HTML service to avoid the need for Java plug-ins, is also acting as a test bed for what will be the most visible external facet of this project, a GSI web mapping site, it went live in QTR1 2003.

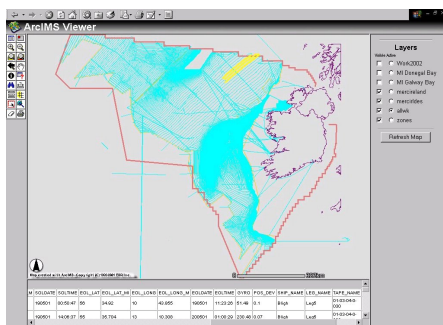


Figure 1. ArcIMS Browser view of progress in relation to the INSS.

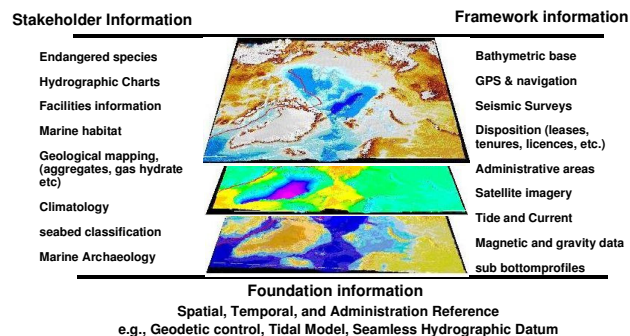


Figure 2 : The integrated marine information infrastructure

Two areas related to GIS use are still in development, both involving the handling of large datasets and file sizes.

The National Seabed Survey has generated a large dataset of geophysical data and to date produced a range of seafloor bathymetric maps for all of Ireland's western deepwater area (>200m). The raw and processed data is currently stored, as generated, on a line and point basis, within a Hierarchical Storage Management System. Coverages of survey lines and points, both planned and shot, along with ground truth sampling points are created in ArcView/ArcInfo and posted to the internal ArcIMS web-mapping server. From these browser accessible maps, project progress is charted and querying of the survey data is used in project planning and derivative processes (Fig 1). Clients and partners require the data for spatial areas of interest and in formats they can handle or integrate into their GIS and ideally would like to access this data via the web. GSI are currently evaluating the possibilities of meeting this requirement by utilising Helical Software's Self Defining Structure (SDS), possibly in conjunction with FME as a data format translator, based on the recommendations of a recent joint project with the Marine Institute (MI). Following on from this the MI is in beta testing stage of their web metadata catalogue. If the evaluation is successful other joint projects would then look at rolling out more solutions to interested parties, based on a marine data infrastructure (Fig 2).

Further information on any of the projects or datasets listed here can be got from our websites WWW.GSI.IE and WWW.GSISEABED.IE or from Archie Donovan Tel: 01-6782798, email :archiedonovan@gsi.ie.

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Overview and status report on Seabed Survey together with spin-offs in terms of industry/research collaborations

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The Irish National Seabed Survey is a seven-year project, which commenced in 1999. The survey area covers the Irish Economic Zone, an area of some 525,000km². The area was divided into three zones defined by water depth, Zone 1: <50m for, Zone 2: 50-200m and Zone 3: >200m. In the first three years of surveying was carried out over Zone 3. Work commenced on Zones 1 and 2 in 2002. Figure 1 shows the area currently covered.

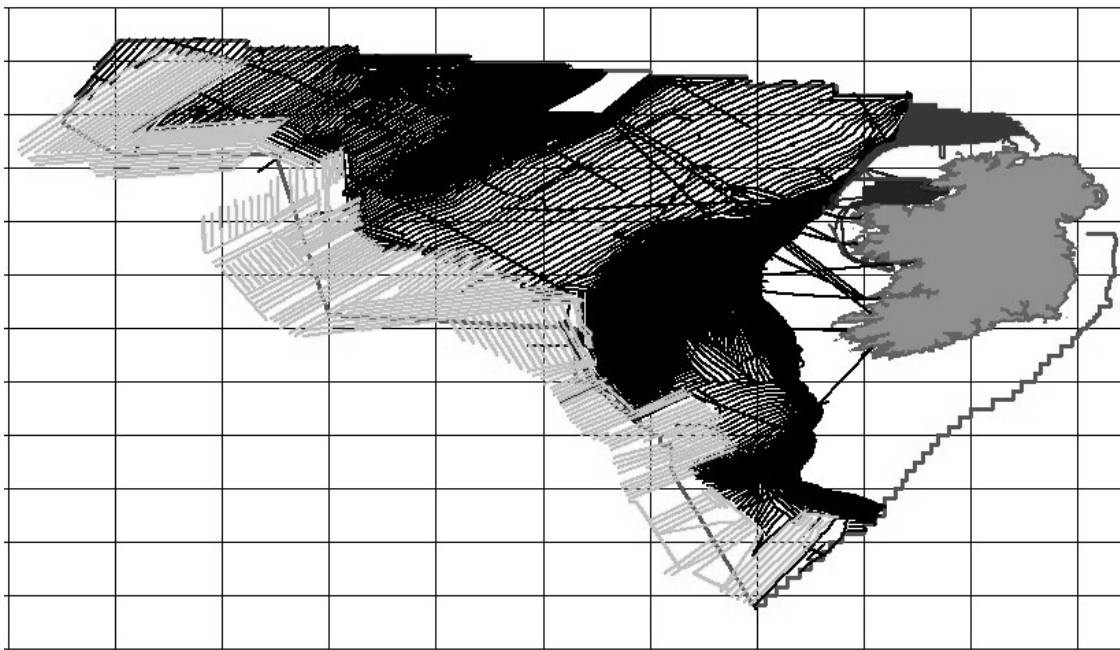


Figure 1. Extent of data collection up to end 2003.

The data, which is being collected, consists of multibeam, gravity, magnetics, and sub-bottom data. In addition, groundtruthing, deep seismic surveys and airborne laser surveys have been undertaken. This significant dataset is now being utilized by industry, the environmental sector and interested research parties.

The utilisation of the data is being advanced by the Geological Survey of Ireland through agreements with industry, for example the development of a chart plotting system for the fishing industry. A number of research initiatives have commenced including the analysis of the multibeam waveforms, mapping of specific areas, evaluation of slope failure, cable routing analysis and habitat mapping. These studies will increase our knowledge of the Irish seabed area and enhance our reputation for scientific excellence in marine science.

Marine Geographic Information Systems and High-Performance Computing Network

Declan Dunne

Coastal & Marine Resources Centre (Ionad Acmhainní Cósta is Mara) ERI, University College Cork

The recent increase in marine data volume acquisition has added to the large amount of existing data on Ireland's offshore territory. These include bathymetric datasets as part of the Geological Survey of Ireland's Seabed Survey, various marine-modelling activities, and data derived from associated physical, biological and chemical data collection projects that include satellite imagery. In this project the individual strengths of geographic Information System (GIS) and high-performance computing (HPC) are combined in an integrated approach to provide vital infrastructural support to many diverse marine research projects. The objective is to develop a system that will allow rapid modelling, manipulation and subsequent analysis, interrogation and visualisation of data. This project is a HEA PRTLII III funded research collaboration primarily between the Martin Ryan Institute (MRI), NUIG and the Coastal and Marine Resources Centre (CMRC), UCC, and is an active project in the Atlantic University Alliance.

This presentation will focus on one of the key components of the project, the research and development of an advanced 3D marine data visualisation tool that can be accessed via the Internet. The principle technologies utilised are Java, Java3D and VisAD (Visualization for Algorithm Development). VisAD is an open source Java component library for interactive visualisation and analysis of numerical data. Users can interact by zooming, panning, rotating, animating and data probing the various datasets selected to view. Users can also analyze this data using a suite of analytical and statistical tools. This marine visualisation tool brings together datasets from a number of different sources including the hydrodynamic model of Northeast Atlantic Ocean, the National Seabed Survey, atmospheric modelling, seabed imagery, ESRI shapefiles, and geo-referenced video.

The possibilities and limitations of habitat models based on bathymetry

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Because of the variety in water depth, terrain variation, sea-bed substrate, oceanography and weather conditions, the coastal zone of Norway has a great diversity of habitats and associated species. In Norway, extensive efforts have been put into developing a infrastructure for classifying habitat types.

To get a holistic understanding of ecosystems, processes and ecological functions, and predict the effects of activities, we need to get basic information on the habitats and the factors determining their distribution and abundance. Mapping marine habitats is complicated and costly, due to factor such as wind, waves, depth and lack of detailed data. Hence, we do not have as good information on habitat distribution in the marine environment as we have on land. We therefore need indicators based on available parameters. Several studies have documented that terrain structures (such as depth, slope etc.) and environmental factors (such as sea-bed substrate and degree of exposure) influence the distribution of habitats. Predictive models may therefore provide information on habitat distribution.

The projects presented here, aims to test the possibilities and limitations in the use of existing map data in modelling marine coastal habitats. They are concentrated in three test areas in south and southwest Norway and cover open coasts as well as more sheltered fjords and skerry areas. Terrain and wind exposure models are used in a GIS to get an impression of the geographical distribution on key parameters for marine habitats. The basic data source is topographical data showing the coastline, and a bathymetric data set in a regular grid with the resolution of 50m.

The habitat modelling is verified by site control, using underwater video equipment and data collection with high resolution side scan sonar instruments. This gives an opportunity to study effects of scale, both the scale in which different habitats occurs and the usability of bathymetric data input with different resolutions. The possibility of modelling habitats in Norway over large areas as a basis for practical management based on the principles of the EU water frame directive linked to the EUNIS (“European Nature Information System”) habitat classification system will be discussed.

The Irish National Seabed Survey – developing marine R&D capacity

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Ireland is an island nation with approximately 7,500 kilometres of coastline, and a currently designated continental shelf (extending well beyond the 200nm EEZ some 1,200 kilometers westward into the Atlantic) that covers approximately 657,960 square kilometres of seafloor to depths of more than 4,500m. The Irish National Seabed Survey of Ireland has been underway since 1999 in which time, over 450,000 square kilometers of seabed has been mapped; making the project the largest EEZ mapping endeavour in the world. Since 2003, survey work has employed the Marine Institute vessel, the R.V. *Celtic Explorer* as the primary survey platform. This presentation gives an update on the 2003 activities on board the R.V. *Celtic Explorer*, discussing in particular the equipment payload, survey coverage, underway data sets and planned diversity and integration of ancillary projects. These projects seamlessly piggyback on the core data gathering; adding significant value to large scale EEZ mapping initiatives, with little compromise to the daily overground coverage. The data includes observations, oceanographic measurements, biological sampling and sediment analysis. The development, implementation and cost of these ancillary projects are also examined.

A biogeological view of the Belgica Mounds (Porcupine Seabight): Synthesis of video surveying, TOBI sidescan sonar imagery and microbathymetric mapping

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The Belgica Mound province is one of three provinces where carbonate mounds are associated with cold-water coral species in Porcupine Seabight, west of Ireland. Sidescan sonar imagery has been acquired during the TOBI survey covering the Belgica mound provinces (RV Pelagia cruise) with a 30 kHz sidescan sonar mounted on the TOBI vehicle. Building upon existing datasets, the RV Polarstern ARK XIX/3a cruise, deploying the robotic submersible VICTOR6000 (ROV), was undertaken in June 2003 to acquire (1) a reconnaissance video line over numerous steep-flanked Belgica mounds and (2) a microbathymetric grid (obtained with the multibeam system SIMRAD EM 2000 mounted on the ROV) over some little incipient mounds ('Moirá mounds'). Visual evidence for a strong hydrodynamic regime in the vicinity of the carbonate mounds is found. The interaction between currents and sedimentation seems to play an important role in mound growth and development.

The reconnaissance video survey over and between several mounds in the Belgica Mound province visualised different sedimentary seabed facies and structures, supporting the interpretation of current-related features and different seabed facies seen on the TOBI sidescan sonar imagery. The eastern ridge of aligned mounds, from Challenger Mound

up to Poseidon Mound, revealed very little live coral cover, with asymmetrical drift accumulations burying the eastern sides of the mounds and sediment-clogged dead coral frameworks occurring at the western sides. Only Galway Mound, Thérèse Mound and a little mound in between the Galway Mound and the Poseidon Mound are covered with a high percentage of living coral. These mounds as well as the Moira Mounds occur in the western area of the Belgica Mounds that nowadays provides adequate conditions for rigorous coral growth. A clear increase of megafaunal concentrations and diversity of species on mounds with live coral coverage is noted.

A range of local current effects and local current intensifications are recognised between the mounds on the eastern ridge, expressed by the presence of washed-out dropstones and associated current marks. However, very few boulders show prolific growth of larger sessile animals such as gorgonians, antipatharians or corals (*Madrepora oculata* or *Lophelia pertusa*), which may be due to excessive current speeds. The overall image of the sedimentary patterns and bedforms shows a general northward directed slope current, probably centred, and most erosive, at the western side of this eastern ridge of aligned mounds. However, the buried eastern sides of these mounds also show that downslope orientated transport plays an important role in the interaction between mounds and alongslope sediment transport.

The microbathymetric survey sheds a new light on the environmental and sedimentological setting of the Moira Mounds within an area influenced by strong currents, indicated by large fields of ripples and sandwaves. The mounds occur on the tops of linear features formed under extreme currents that provided suitable substrates for colonisation. Contemporary currents facilitate sediment entrapment with coral frameworks as a driving mechanism for mound growth.

Coastal Zone Mapping Using the Latest Generation Airborne LIDAR Bathymeter

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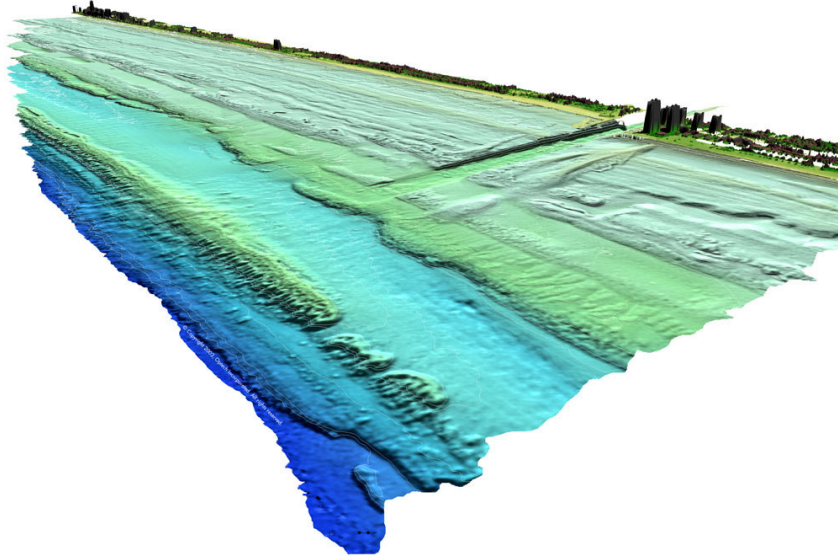
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This paper describes new methods that are now available for habitat mapping in the coastal zone, based on use of the latest generation Airborne LIDAR Bathymetry (ALB) technology. This near-shore zone, from the beach to depths of up to fifty meters, presents some of the greatest challenges to mapping using traditional acoustic survey techniques. The paper presents the latest ALB and integrated sensor technologies as an alternative approach to mapping this difficult area.

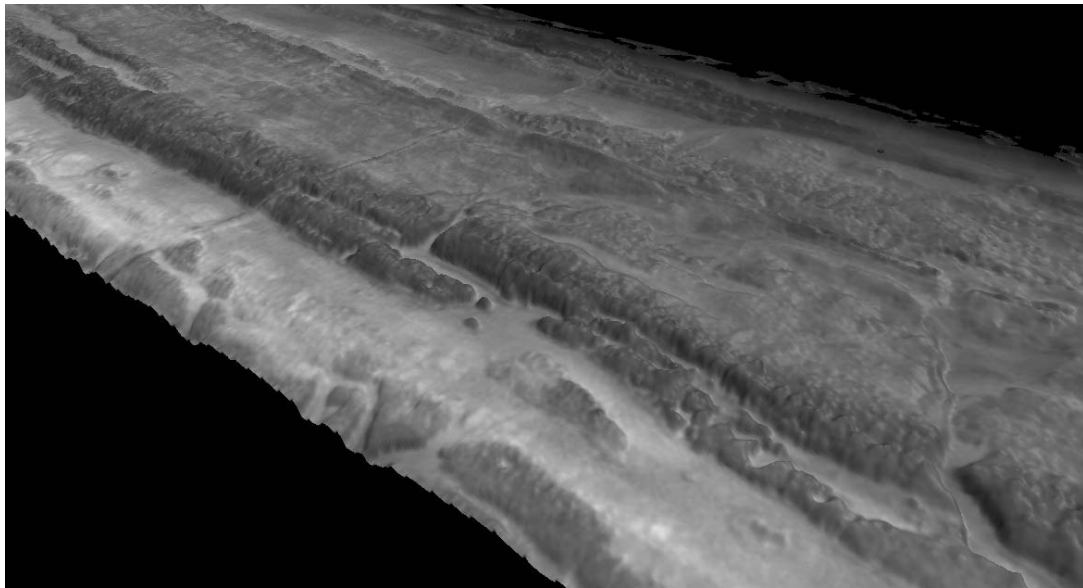
The SHOALS-1000T ALB system is a littoral mapping tool that is capable of acquiring both bathymetric soundings, topographic elevations, and geo-registered, high-resolution photography. High-resolution seabed imagery is now also available as a data product from the SHOALS-1000T. "Pseudo-reflectance" is derived through inversion of the bathymetric LIDAR equation and measurement of the bottom peak signal on each waveform. It results in imagery that looks similar to that of a sidescan sonar or multibeam backscatter and can be used to identify homogeneous areas of the seafloor. This is major technological advancement as it means that one can now use Airborne LIDAR Bathymetry to draw some conclusions about bottom type in addition to simply measuring water depths. In addition, developments are ongoing to add an integrated imaging spectrometer to the SHOALS-1000T system.

The system will be described, with its current and future capabilities. A description of current and future data products will be provided, and a variety of data examples presented. Products will include integrated topographic and bathymetric LIDAR digital terrain models, pseudo-reflectance imagery from the bathymetric LIDAR, orthorectified

digital imagery, and hyperspectral imagery. The paper will also expand on the research continuing in fusion of spectral data with LIDAR depth data. The data resulting from this integration will enable complete robust three-dimensional land cover and benthic mapping to be conducted.



Integrated Topo/Bathy Digital Terrain Model



Pseudo-Reflectance Imagery draped over DEM

Spatial Utilization of Benthic Habitat by Demersal Fish on the Continental Shelf off Nova Scotia, Canada

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A large team of scientists is undertaking a project to improve understanding of the relationships between seabed habitat, benthic communities and demersal fish on important fishing banks on the Scotian Shelf. Using historical scientific groundfish data (1970-2001), three paired study sites (10 x 10 km) have been selected on Emerald, Western and Sable Island Banks to represent areas with the highest and lowest probabilities of finding juvenile haddock. All sites have seabeds that are mixtures of sand and gravel. Depth range is 39-84 m. State-of-the-art acoustic, imaging and sampling equipment is being used to collect data on seabed habitat, benthic communities, and fish communities over different spatial scales (centimeters to kilometers). These tools include sidescan sonar, Biosonics DT and QTC acoustics, a towed body called Towcam (equipped with video and digital still cameras), Videograb (equipped with video cameras) and a Campelen trawl. All data sets are georeferenced and, as they become available, are entered into an ArcView GIS system for analyses. Careful data management is essential to the success of this project.

The fundamental layer for interpretation is a series of sidescan sonar mosaics that have been constructed for an area of approximately 1 x 5 km within each 10 x 10 km study site. With the help of Towcam imagery, the mosaics have been interpreted from a geological perspective into 14 different seabed classes on the basis of grain size and dynamic bedforms. Other features have also been mapped (i.e. boulder fields, gravel ridges). We are now beginning to overlay data on the distribution of benthic organisms

and fish and examine habitat associations. Recent examples will be given to illustrate our approach and preliminary results. Our immediate goal for the overall project is to develop predictions on the distribution of habitat, benthic organisms and fish on the basis of the best acoustic metrics and then test these predictions on a survey in late September 2004. A multibeam bathymetric survey is planned for May 2002 over all sites. The new understanding being generated in this project will be used to help define important demersal fish habitats on the continental shelf and map their spatial extent within the six sites. The methods and understanding of the relationships being developed will serve as a new model to be applied to regional benthic habitat mapping programs in Canada and abroad.

What's In A Habitat: Are We Mapping the Right Things?

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Modern technological advances have revolutionized the way we map the seafloor. Today, high-resolution images of seafloor morphology and texture can be constructed in great detail using multibeam bathymetry and backscatter and side-scan sonar data. These technologies have facilitated the geologic mapping of the oceans and led to the development of various thematic maps such as "habitat" maps, a term in current usage among scientists and fishery managers. However, the application of this term may be inappropriate or misleading. For instance, do these maps realistically characterize habitats or are they merely substrate maps? Many different components are needed to comprehensively image a marine benthic habitat including, but not limited to: depth, temperature, salinity, currents, nutrient availability, slope, rugosity (or vertical relief), substrate type (both geological and biological), and geomorphology. Even though much of the data needed to map a true habitat, such as physical, chemical, and biological information, are not available for most of the ocean, the foundation of marine benthic habitat characterization can be constructed by imaging the seafloor and inferring these conditions. Even so, a habitat implies the establishment of a faunal or floral association and this requires knowledge that is typically derivative of these maps or studies, not known a priori. Thus, unless we are considering all of these conditions, a true habitat characterization cannot be made. However, the mapping of the physical aspects of the seafloor can be used as a proxy to define marine benthic habitats and we therefore submit the term "potential habitat" in regard to maps that depict physical, chemical, and/or biological seafloor conditions but do not incorporate or imply faunal or flora associations. We present examples of how potential habitats can be mapped and used as the basis for developing marine benthic habitat maps.

Classification of the Torres Strait – Gulf of Papua region based on predictions of sediment mobility from a three-dimensional hydrodynamic model.

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The three dimensional hydrodynamic ocean model, MECO, was adapted for the Torres Strait Gulf of Papua region at 0.05 degree resolution. The model was forced using real tidal and low frequency sea levels at the open boundaries, NCEP-NCAR re-analysis wind forcing at the surface, and the density structure relaxed to the CARS climatology. The hydrodynamic model was validated with current meter data and calculated tidal sea levels in the region with good results.

The hydrodynamic model has been applied with two key marine geological questions of the region in mind. These being:

1. What are the main dispersal pathways and depositional sites for the sediments derived from the Fly River in Torres Strait? And;
2. What are the main physical processes controlling erosion, transport and deposition in Torres Strait?

Question 1 was investigated by introducing passive tracers into the model to represent suspended sediments at the Fly River Delta. The model identifies the main transport paths of suspended sediments in the region, and predicts that suspended sediment input to Torres Strait is approximately 10% greater during the Trade season than during the Monsoon.

Question 2 is addressed using predicted ocean currents (tidal, wind-driven, and density driven) from the hydrodynamic model, together with estimates of significant wave height and period obtained from the Bureau of Meteorology WAM model, to predict sediment mobility due to waves alone, currents alone, and from combined wave-current interactions for both Trade and Monsoon conditions. Our results suggest that sediment mobility in the Gulf of Papua is dominated by wave motion, whereas Torres Strait is controlled by both waves and ocean currents (tide and wind-driven) equally.

Such information is capable of providing useful predictions of sediment transport and resuspension events which, used in conjunction with sediment composition and grain-size data, allows a basis for understanding the spatial and temporal nature of benthic habitats.

**A strategy for regional scale habitat mapping –
An example from the Outer Bristol Channel, South Wales.**

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The Bristol Channel is a funnel shaped embayment off the coast of South Wales, which is open to the Atlantic. It is noted for one of the highest tidal ranges in the world and is swept by strong tidal currents.

A mature marine aggregate industry based on the extraction of sand from sand banks in relatively shallow water exists within the upper half of the Bristol Channel. New sources of sand for aggregate are being sought and a potential area in the outer Bristol Channel has been identified. Here a sand wave field with waves up to 19 m high lies within the central channel in water depths of 35 to 50 m. The field is extensive and includes an area of at least 35 by 35 km.

Available geological and biological data was primarily gathered in the 1970's. Its coverage is sparse with geophysical interpretations based on analog records. Resource management requires good quality baseline datasets for planning, exploitation and the monitoring of impacts. This study has been designed to produce baseline biological and geological data through an integrated survey programme utilising multibeam, digital sidescan and boomer sub-bottom profiler, ground truthed with sea bed video, photography and sampling for biological and sediment analysis.

The study area covers about 2400 km². Funding would not allow full multibeam and sidescan coverage therefore a survey strategy was devised based on discrete corridors up

to 40 km in length with kilometre wide multibeam and sidescan insonification. Eleven corridors were planned with centre lines at about 5 km spacing. They were aligned roughly parallel to the principal tidal stream and at right angles to the mean crest line trend of the major sand waves. The complete survey was planned to insonify about 15% of the study area. The majority of sampling was conducted within the survey corridors.

The survey strategy was devised to provide information and interpretations based on modern high resolution geophysical techniques at a scale which would identify the major sedimentary and biological regimes and also enable us to analyse the scale and relationships of the major and minor bedforms. The study is a three year programme and it is just coming up to the end of its first year. A biological and a geophysical survey were completed in 2003 and some of the data have been processed and are available to illustrate the utility of the survey strategy.

Mapping of coastal seabed habitats in Tasmania: development and integration of remote sensing techniques within a hierarchical framework

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Mapping of seabeds habitats is currently being conducted throughout Tasmanian coastal waters (0-50 m depth) through a combination of aerial photography and extensive single-beam acoustic, underwater video and sediment surveys. This mapping is being conducted to provide information on the spatial distribution of habitats relevant to issues such as Marine Protected Area planning, environmental impact assessment, habitat monitoring, pollution and oil spill response and fisheries assessments.

Consistent with most seabed mapping programs, this project, titled SEAMAP Tasmania considers several issues when planning specific mapping projects, including the need to: (1) define the objectives and intended use of the maps and spatial data; (2) select the scales and data resolution appropriate to the stated objectives; (3) assess the time and cost limitations of the various methods available to collect data at appropriate resolutions and spatial scales relevant to the objectives and level of habitat categorisation; (4) classify habitats within a hierarchical scheme based on nested bio-physical characteristics; (5) define and quantify spatial uncertainty, and (6) develop methods for integrating and displaying spatial data collected by a range of methods and at different scales and resolutions defined within the habitat classification scheme.

This paper details the methods employed in the SEAMAP Tasmania project to accommodate these various requirements, particularly within the context of delivering

cost-effective seabed mapping methodologies for coastal waters. This has required the use of existing coastal aerial photography for digitising habitat boundaries in shallow depths (generally <10 m), although for seagrass monitoring targeted digital aerial photographs are taken, requiring the development of protocols to establish ground control, minimise sun glint and refraction and standardise image-processing techniques. There is also extensive use of single beam echogram visualisation and echo integration of indices of roughness and hardness to define habitats based primarily on geomorphic characteristics (e.g. high profile rocky reef, sand, silt). Video and sediment sampling is used to ground-truth the acoustics and collect further information on habitat structure and dominant floral and faunal assemblages, all of which is presented as pop-up tables linked to each polygon within the map series.

A hierarchical classification scheme is used to define habitat levels and decision rules used to ensure consistency in boundary delineation. Protocols have been developed to integrate and display spatial data from the range of remote sensing techniques, including map series at variable scales, spatially referenced video and detailed metadata, including estimates of attribute accuracy. The current mapping methods employed in the SEAMAP Tasmania project will be presented and future research areas, such as use of satellite remote sensors (e.g. Quickbird) and quantification of morphological structure through stereo photography, will be outlined.

Grid Enabled Data Mining on the Irish National Seabed Survey

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INTRODUCTION

The Geological Survey of Ireland "G.S.I" at present has over 4 Tera-bytes of multi-beam data gathered over the last five years from the Irish National Seabed at cost of €33 million. The main problem that arises from having so much data is how to extract accurate information from the data-set, as this amount of data would make extracting knowledge from such a data set by human observers infeasible. The focus has turned to using Artificial intelligence and computational methods for assistance. Given the size of this data-set even current high powered machines would be insufficient for such a task, with the exception of some supercomputers. This has led to our attention being turned to a computational resource known as the "Computational Grid" as other methods lack its security infrastructure. The grid can be defined as a large collection of computers linked via the Internet so that their combined processing power can be harnessed to work on difficult or time-consuming problems.

The ocean floor, which covers approximately 70% of the Earth's surface, still contains vast areas which are largely unexplored. In truth less of the ocean floor has been mapped than either of the surfaces of the Moon or Venus, which has been mapped in recent years by NASA's Magellan spacecraft. Developments over the last 20 years have produced tools which allow the research community and industry to map the ocean floor in greater detail and over more extensive area than previously possible. These tools are exclusively remote sensing ones and are extremely varied. Their application covers a wide range of the electromagnetic spectrum and include ship-borne gravity and magnetic satellite measurement of sea surface height and temperature and seismic data. Reflection and

refraction, as well as side scan sonar and swath bathymetry techniques which produce images of the sea-floor. All of these methods, their associated processing techniques, and the interpretations they produce are invaluable for research into the processes which shape the ocean floor.

This project proposes to extract linearity's (anything with a sub-linear feature in the sea floor) in the data set using the Computational Grid. Linear features are often associated with objects of particular geological interest. On topographic maps, fractures (i.e. faults, joints and veins), fold crests and troughs all appear as sub-linear features. Layered sedimentary rock bed terminations also appear as linear features. The identification of such linear features is vital for interpreting the geological history of the area. The presence of fractures and fold crests are evidence of geological deformation and the orientations of these features help to identify the principal tectonic forces at work during deformation.

PRE - PROCESSING

The initial data is processed for water velocity corrections, boat motion and tidal corrections. The speed of sound in water which is affected by temperature, salinity and pressure, a SSP (Speed of Sound Profile) is calculated for each ping of the sonar. The boat motion is simply the yaw; pitch and roll of the sonar and the tidal correction are also allowed for in this pre-processing. The data is now termed to be raw data, the initial data been termed field data. The next stage is to be able to pick out anything with a sub-linear feature. The initial approach to the problem was to use a Neural Network. Neural Networks are an approach to computing that involves developing mathematical structures with the ability to learn. Neural networks have the ability to derive meaning from complicated or imprecise data and can be used to extract patterns and detect trends that are too complicated to be noticed by the human expert.

The main disadvantage with using Neural Networks for such a problem would be that the individual relations between the input variables and the output variables are not developed by engineering judgment so that the model tends to be a black box or

input/output table without analytical basis. Another approach was to find a way to represent a linear feature mathematically so an automated algorithm could be able to pick up such a feature, which would yield a more accurate result than using Neural Networks. A linear feature is basically a rapid change in slope in the bathymetry of the sea-bed. The seabed would have to be tessellated in order to find such rapidly changing slopes. The slope and the gradient of every region are worked out for the tessellated area. Then using a search of vertices within a certain distance from each triangle the gradient of each triangle within that distance, is used to calculate the variance of the gradients in that region indicating if there is a rapidly changing slope present. The algorithm initial stage was to tessellate the data-set into triangle.

The triangulation method used is Delaunay triangulation, this technique was invented by a Russian mathematician Boris Delaunay. The Delaunay triangulation of a set of points is defined by the empty circle condition, IE the triangle is a valid triangle if and only if its circumcircle encloses no other points of the point set. There are several Delaunay triangulation algorithms, such as Plane Sweep, Naive Algorithm, Divide and Conquer, Reduction from a Convex Hull in a higher dimension. The method selected is the reduction from a Convex Hull in a higher dimension.

KNOWLEDGE DISCOVERED IN DATABASES

The initial stage of the algorithm is to find the convex hull of a XYZ bathymetry. There are several algorithms that are available at present to find the convex hull for a 3-dimensional data-set such as Gift wrapping, Graham Scan, Merge hull, Quick hull and the Incremental Algorithm. The algorithm selected for this problem is called the Incremental Algorithm. It was selected for the following reasons: it is robust and fast and also there has a lot of work done on this algorithm so the literature available has well document problems that occur when coding the algorithm. The Incremental Algorithm works by selecting three points that are not co-linear by checking the cross product of the points is not equal to zero. It then determines simply adds another point to the hull in an incremental fashion. It first must check that this point is a non-coplanar point; this check involves checking that the volume of the tetrahedron formed is non zero. This calculation

for the bathymetry points exceeded the floating point limit, but a solution was already published for the same problem [2]. After the Hull has been generated the next step is to use the projection based technique [3]. This technique allows one to achieve a Delaunay triangulation of the data-set in two dimensions, which is a very effective tessellation of the data-set.

GRID

The application will run on the Computational Grid. The Computational Grid can be defined as a large collection of computers linked via the Internet so that their combined processing power can be harnessed to work on difficult or time-consuming problems. (Also called community computation).” [4]. The term “the Grid” has been coined in the mid 1990 's to denote a proposed distributed computing infrastructure for advanced science and Engineering. A new type of data intensive applications has emerged in recent years that involve the geographical dispersed extraction of complex scientific information from very large collections of measured or experimental data e.g. National Sea-bed Survey. The Data Grid provides essential infrastructure for such applications. One of the major problems faced by Data-Grids was “The use of multiple incompatible protocols for data storage effectively partitions the data-sets available on the Grid”[5]. A common data transfer protocol for the Grid is the solution to this Problem, it is called Grid FTP. The Grid-FTP protocol and family of tools were born out of the realization that the Grid environment is a very secure, fast and reliable transport mechanism. The Grid offers a secure environment for processing of the National Seabed survey. The middle ware on which the Grid Ireland Project is based is called Globus. The Globus Toolkit's implementation of the GSI (Grid Security Infrastructure) adheres to the Generic Security Service API (GSS-API), which is a standard API for security systems promoted by the Internet Engineering Task Force (IETF).

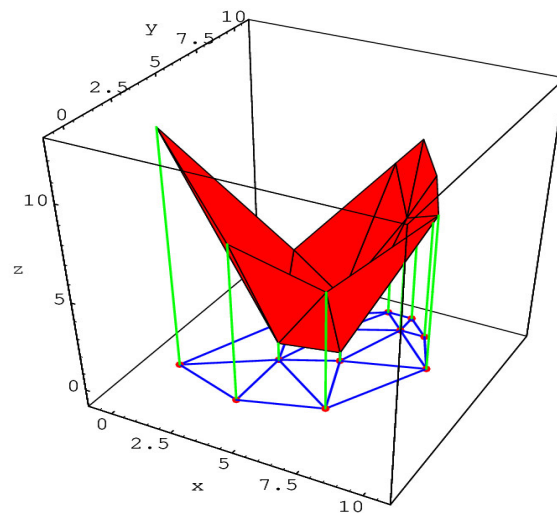
CONCLUSIONS

As the amount of information in the world, doubles every twenty months. There is a move towards Artificial Intelligence to derive meaning from large data-sets, particularly in the Geo- Physical science such as The National Seabed Survey. The recent

developments in sonar technology and the undertaking of such large scale mapping projects is leading to the development of tools such as the Grid and the advancement of Artificial Intelligence to help Scientists derive meaning from mountains of data.

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3D Convex Hull projected to 2D Delaunay Triangulation

Benthic Habitat Mapping on the Scotian Shelf

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Department of Fisheries and Oceans together with Natural Resources Canada are making a significant progress in understanding ecology and structure of seafloor habitats of Eastern Canada. Cooperative habitat mapping effort is applied through interdepartmental agreements as well as through informal horizontal linkages between scientists.

In this interdisciplinary framework on habitat mapping we are addressing the following key questions: Which areas of the seafloor are the most sensitive to human impacts and how to balance resource exploration and fisheries with available ecosystem services? These questions are answered through detailed mapping and classification of seafloor environment.

Our approach integrates interdisciplinary information on geology, biology and oceanography in digital maps and provides models of the effects of geological and oceanographic controls on benthic fauna. We define naturally disturbed or stable environments, as well as areas of high or low productivity, thus providing ecologically sound and spatially accurate information for decision makers. Ecological framework of the developed habitat model provides key information required for the achievement of conservation goals, namely prediction of ecosystem properties, diversity and life history traits of benthic fauna. Habitat stability and complexity is described on the basis of detailed geological mapping of seafloor structure and texture based on compilation of existing images, samples, geophysical maps, reports and publications.

Acoustic classification of nearshore seabed habitats based on echo-integration and visualisation

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Single-beam acoustics have been commonly used for many years to identify seabed hardness and roughness, and at one level can separate consolidated (i.e. reef) and unconsolidated substrates. Reef substrates are often a common feature of nearshore environments and in Tasmania provide habitats for most species of commercial importance, particularly rock lobster (*Jasus edwardsii*), abalone (*Haliotis rubra*) and banded morwong (*Cheilodactylus spectabilis*). Information on the spatial distribution of reef habitats is being increasingly seen as essential to improving the spatial management of these fisheries.

Given the distinct acoustic reflectance of reef and unconsolidated substrates, and the presence of distinct boundaries between the two, the distribution of these two geomorphic types can be determined through visual observation of the first and second echoes in the logged echogram. Echo integration of the tail of the first and the whole second echo can also be used in most cases to separate habitats at this level. However, reef habitats can often have a complex profile and heterogenous (i.e. patchy) structure, which is important to quantify as these characteristics can influence the macroalgal and faunal community composition.

Patchiness of reefs can occur at a range of spatial scales, which has considerable implications on the capacity to delineate structure using single-beam sounders due to

variable factors such as acoustic footprint size with depth, vessel speed, ping rate and sea conditions. Field surveys on a range of reef types defined within a hierarchical classification system are currently being conducted to examine the influence of these parameters on attribute accuracy from echogram interpretation and echo integration. This will particularly focus on defining the optimum patch size, or minimum mapping unit, that can be defined through both processing techniques and how this may be influenced by track spacing.

**The evolution of a post transgression littoral terrain – A case study from the
Bunurong Marine National Park, South East Australia.**

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The Bunurong Marine National Park

On November the 16th 2002, the state of Victoria, in South Eastern Australia, created 13 Marine National Parks and 11 Marine Sanctuaries along its coastline. These were created to protect a representative sample of a very diverse marine environment and together protect about 5% of the states territorial waters. One of these parks, the Bunurong Marine National Park (see Figure One), has a long history of protection. A small Marine Park, which only offered limited protection, was established back in 1991. During the planning process of extending this park, a survey of the parks environment was commissioned by Parks Victoria (Ferns and Hough 2002). Part of this survey was a side-scan sonar mapping exercise which was able to map major habitat on the basis of the observed terrain (Leach et al. 2002). The occurrence of this terrain naturally leads to an investigation of how it got there: how did it come to be like that?

During the last ice age Bass straight was dry. It underwent a marine transgression about 10,000 years ago. It is against this background that any interpretation of the history of the submarine terrain must take place. This is a sub-aerial landscape that has been flooded. While marine processes are operating now and have undoubtedly greatly modified the terrain, this is not a wholly marine landscape. This is, of course, true of most continental shelves.

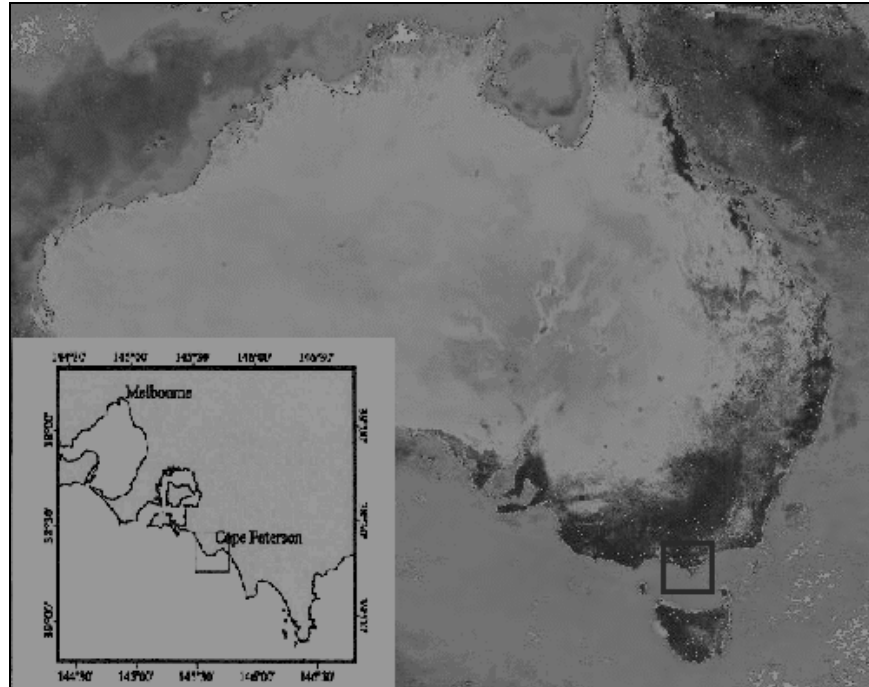


Figure One. Location map of the Bunurong Marine National Park.

Side-scan survey

As has been reported else where (Ferns and Leach 2002), six separate terrain units have been identified on the side-scan imagery: high-profile reef, low-profile reef, patchy reef, large bedforms, relic sub-aerial landforms and acoustically smooth seafloor (see Table One). This interpretation is based on tone and texture.

High-profile reef is the most dramatic unit in the imagery. It consists of clear, rocky topography with sedimentary bedding, geological folds and faults all being evident. There are ledges, some extending for many tens of meters, and deep gullies that are often filled with sand. This unit was located in the northern part of the survey area, particularly the north-west, where is occupied approximately half the survey area.

Low-profile reef is exhibited as a texture within the imagery but without any of the dramatic topography of the high-profile reef. The texture indicates a solid, presumably

rocky, substrate. It is often difficult to determine the boundary of this unit, as it is subtle and discontinuous. It forms a fringe around the areas of high-profile reef.

Patchy reef refers to areas where the high-profile reef breaks up into a series of isolated bomies. These often have a high-profile in relation to the surrounding soft sediment. This unit occurs along the boundary between high-profile and low-profile units, at the south-eastern end of a series of long, deep gullies which cut through high-profile reef.

Acoustically smooth seafloor refers to areas of the side-scan imagery where there are no features apparent. Video imagery used to verify the remotely sensed data indicate that this is an area of cobble plain.

There were some poorly defined features which have large, low amplitude rises separated by smaller narrow which occur in a small area at the extreme southern edge of the survey. These features were originally interpreted as gravel banks but are now believed to be relic sub-aerial landforms – the eroded remains of pre-transgression stream valleys.

Large bedforms are interpreted from a series of high contrast features, which have significant topographic expression, and the plan form of irregular dunes. These are believed to be active, mobile features. The features themselves will be composed of sand, and the swales may be made of sand, rubble or bedrock. They occur in a band in the eastern central part of the survey area, extending further westwards in the more southerly portions. Small patches occur throughout the eastern section of the area. The source of these bedforms is not known. Their form indicates that they are the result of the generally westerly tidal currents that occur in Bass Strait. However, they may also be a result of tidal currents from Anderson's Inlet to the north-east.

The distribution of these terrain features is shown in Figure Two.


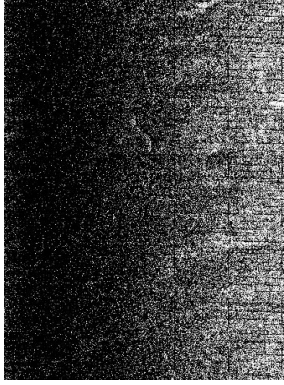
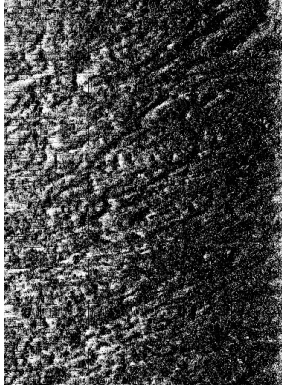
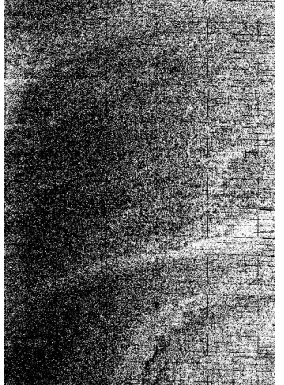

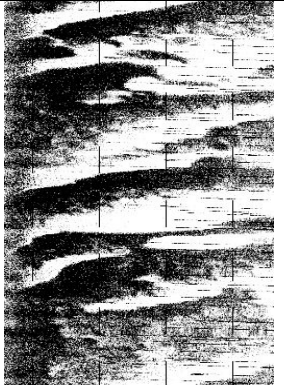
	
High-Profile Reef	Acoustically Smooth Seafloor
	
Low-Profile Reef	Relic stream valleys
	
Patchy Reef	Large Bedforms

Table 1. Side-scan Sonar Terrain Interpretation

Interpreted History

The high profile reef occurs predominately in the shallow, near shore regions, most evidently around Cape Patterson. The low profile reef forms a gradational unit between the high profile reef and the acoustically smooth plains, which occupy the deeper more offshore areas. These plains have been found to be composed of cobble. In the deepest part of the survey area, possible relic sub-aerial features have been found. It is suggested here that this terrain is a result of wave action modifying the original sub-aerial terrain. Where the wave action is most intense, in the near shore zone and around western side of Cape Patterson, all the fine and weathered material has been washed away, leaving the bedrock exposed as High Profile Reef. Around the edges of this area, weathered material has survived in the crevices but has been washed away from the surface, leaving Low Profile Reef. Below this, the smooth plain is formed by a deflation armour, where all the fines have been washed away but the cobbles from the saprolite remain. In the deepest part of the survey area, relic sub aerial features survive. This terrain is then the result of sub-aerial weathering eroded by sustained wave action. The process of the marine transgression itself seems to have left little mark.

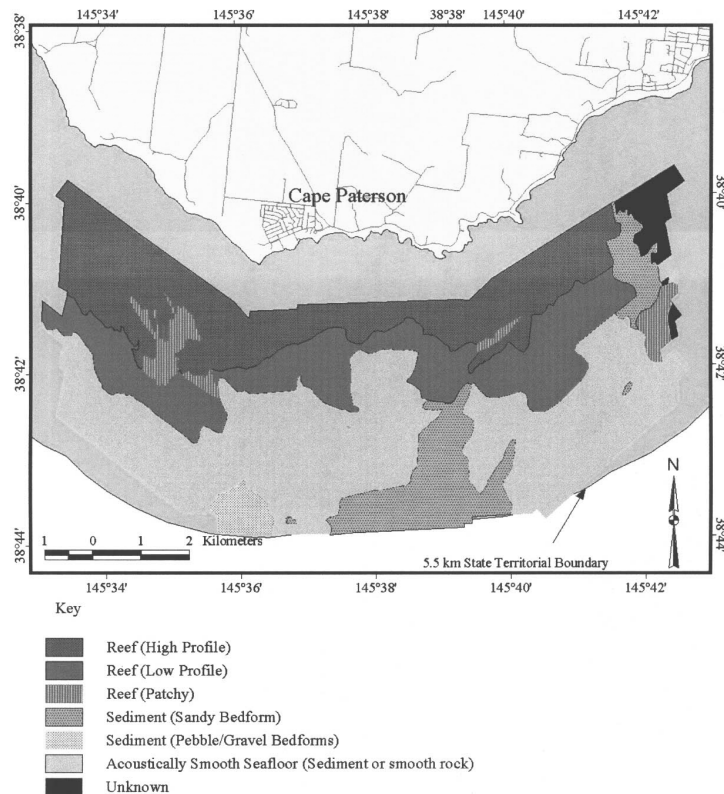


Figure Two. Map of the distribution of the terrain features within the Bunurong marine national Park.

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Towards a quantitative seabed classification using extended Biot theory

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Seabed characterisation with acoustic methods involves relating physical properties of the sediment (e.g., density, porosity, rigidity) to properties measured remotely (sound velocity and attenuation). For a genuinely quantitative seabed characterisation with acoustic methods one needs to employ model conceptions that can be described by a rigorous formalism. Using the Biot model of the acoustics of porous media as a general framework, two additional model conceptions are introduced to enable the resulting combined model to predict the velocities and attenuation of compressional and shear waves as a function of effective pressure in soft marine sediment. The first component of the model extension is an effective-grain model that is included to account for the mechanical properties of expandable clay minerals. In this model, the total grain material is treated as a two-phase medium consisting of the solid mineral phase with low-aspect ratio fluid-filled inclusions representing the intracrystalline water layers in the expandable clay minerals. The mechanical response of the grain material includes local fluid flow between the inclusions and the pore space described by frequency-dependent grain bulk and shear moduli. The second component is a formulation of the grain contact stiffness in granular media cemented by viscous fluid. This formulation allows calculating the frame moduli of the sediment as a function of effective pressure from the properties of the grains and the contact fluid. Because of the presence of viscous fluid at the grain contacts, the response includes intergranular local fluid flow leading to complex and frequency-dependent effective frame moduli. With the proposed model, velocity and attenuation of compressional and shear waves in a wide range of soft granular marine sediments can be calculated in terms of the mechanical properties of their constituents. Laboratory measurements of velocities and attenuation as a function of confining pressure on various unconsolidated materials like artificial glass bead packs and natural undisturbed deep-sea mud samples match fairly well those predicted by the proposed

model. The combined model is currently being used in forward modelling of unconsolidated sediments.

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Developing geological understanding from multi-disciplinary surveys: examples from west of Scotland.

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The MINCH project (Mapping INshore Coral Habitats) was designed as a ‘demonstration project’ to show the effectiveness of wide-area environmental assessment using multibeam sonar as part of a habitat mapping exercise in the context of a project designed from both biological and geological perspectives. Its particular objectives were to assess the current distribution and status of cold-water coral habitats to the east of the Island of Mingulay and time permitting examine additional areas on the Stanton Banks, in the Sound of Rum and to the west of Skye.

An important part of the project was the integration of existing bathymetry and geology data in the survey areas to assist habitat mapping and to review the conditions favourable to the development of cold water coral habitats. This integration has allowed a significantly better understanding of the environmental context of existing samples and the spatial aspects of geological features noted in the shallow section of seismic profiles. The multibeam data has allowed repositioning of legacy data and substantial amendment of published geological maps although at a finer scale than originally mapped.

In the primary area of survey, to the east of Mingulay, reefs formed by the cold-water coral *Lophelia pertusa* were identified. They were recognized on the multibeam bathymetry and backscatter data records where intriguing ‘trails’ extend downstream from some of these mounds. The mounds are located on a series of rockhead ridges,

locally rising more than 100m above the surrounding seabed. Previous seismic profiling and sampling indicate these ridges comprise both igneous and sedimentary rocks therefore indicate no lithological control on the distribution of coral reefs. The environmental controls include an upper limit of 110m water depth and a close proximity to deep water (>180m). Such information will assist future mapping of cold-water coral habitats.

**Multibeam seabed classification on the West Porcupine bank
Irish margin**

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During the first year of the Irish National Seabed Survey several multibeam lines were obtained on the west Porcupine Bank, at the continental shelf break. This is an area dominated by a cluster of giant carbonate mounds limited eastwards by a N/S fault scarp and to the west by the steep edge of the deep water canyon system, Porcupine Bank canyon. The large carbonate mounds occur between 700-1200 m water depth. They are up to 220m high, 800 m wide and 3 km long. The influence of hydrodynamic processes particular to banks and seamounts seem to have an important role in carbonate mound growth and distribution. Abundance evidence was found of strong bottom current regime in the study area.

This study presents preliminary results from the multibeam backscatter seabed classification, combined with high resolution bathymetry. The results have been confronted with sidescan sonar imagery (30 Khz) from the same region and existing groundtruthing (bottom sampling and video footage).

Terrain modelling of the Gullmar Fjord – A tool for habitat mapping

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Introduction

The Gullmar Fjord is situated on the Swedish west coast. It is the only real fjord in Sweden. The Fjord has been chosen as a location for several research institutions during the last century. The fjord is also a Natura2000 area with trawling regulation for depths less than 60 m. Modern research conducted by Trine Bekkby from the Kristineberg Research Station, in the field of predictive habitat modelling, required high resolution bathymetry data. In December 2003 the entire fjord was surveyed. The campaign was conducted by MMT and the results were delivered in January 2004.

Methods

The area was surveyed with total coverage of all areas deeper than 2 m using Simrad EM1002 95 kHz multibeam echo sounder, Simrad EM3000 dual head 300kHz multibeam echo sounder, Edgetech DF1000 384/100 kHz Side Scanner and Benthos Chirp II sub bottom profiler. 2 vessels were used, the Triad for the deeper parts and the Ping for the shallower areas. The habitat modelling was conducted using ArcView version 3.3 and ArcGIS version 8.3.

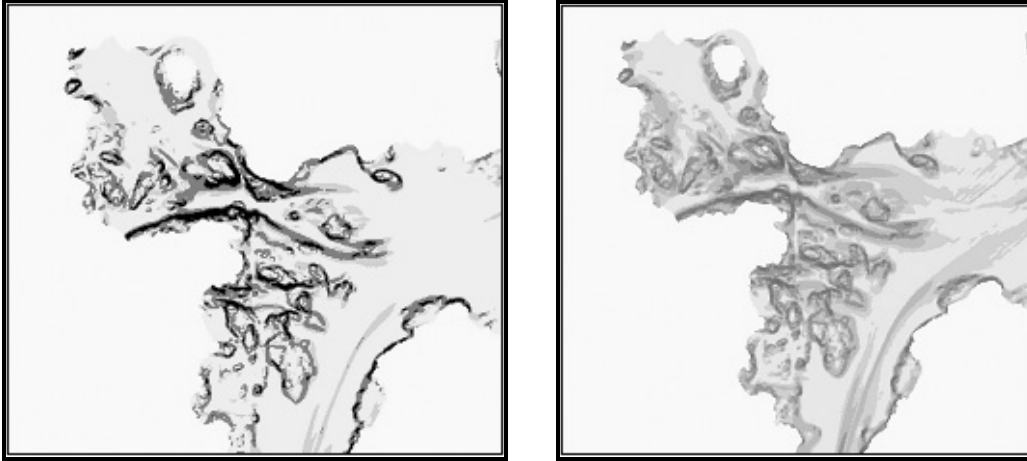
Results

The data is used in an ongoing project aimed at modelling the habitats and correlating habitat distribution and coverage to depth, slope, terrain variability, degree of wind exposure and seabed substrate type.

The data is available down to 2x2 m grid size for detailed studies in the future.

The ongoing project aims to model the distribution of habitat classes according to

- the EUNIS habitat classification system
- the EU habitat directive (the Natura 2000 habitats)



Slope index (left figure) and terrain variability index (right figure) from the fjord mouth.

The Hudson River Benthic Mapping Project – An example of process related classification of sedimentary environments

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Acoustic survey techniques have improved significantly over the last decade. They are increasingly used to investigate bottom types and benthic habitats of the sea floor as well as the bottom of rivers and lakes. Differences in the acoustic backscatter strength of sidescan sonar or multi-beam bathymetry data are often used to distinguish different bottom types that can be related to different benthic habitats. Commonly, these differences in acoustic backscatter strength are related to their grain size composition or bedrock outcrops. Here, we are presenting acoustic backscatter data from a section of the Hudson River Estuary that are better explained by sedimentary processes than by a variable such as sediment grain size distribution.

Funded by New York State, the entire 240 kilometers of the Hudson River Estuary have been mapped using sidescan, chirp sub-bottom profiling, and multibeam bathymetry as part of the Benthic Mapping Project of the Hudson River Estuary Program. As a result we acquired a comprehensive and detailed data set of unique detail and resolution. In addition to the acoustic data, hundreds of gravity cores, and grab samples provide ground truth for a classification of the river bottom into discrete substrate types.

Large sections of the Hudson River estuary are dominated by muddy sediments and do not show major grain size variations. However, the acoustic data from these parts of the estuary yield significant variations in backscatter strength. Analyses of sedimentary environments reveal patterns in backscatter strength beyond those that can be related to the the sediment grain size distribution alone. Sediment classes can be distinguished based on internal volume scattering, compaction, scattering from surface roughness, scattering from aquatic plants and their roots, shelly substrates, and presence of gas

bubbles. Many of the classes can be linked to dynamic processes including contemporary deposition, winnowing, erosion, and sediment migration in sediment waves. To distinguish different classes and related processes we utilized the complete data sets. Only the combination of sidescan, sub-bottom, and high-resolution bathymetry data allows the identification of the dominant process. The results provide a better understanding of the dynamic processes of the Hudson River Estuary and improve the interpretation of the acoustic backscatter data from fine grained sedimentary environments. Investigations in two sections of the Hudson River Estuary showed that the distribution of the benthic communities in these sections is better explained by the process related classification of sedimentary environments than by single parameters such as sediment grain size, organic content, and water depth.

High resolution mapping of the Swedish West Coast as a tool for fishery management

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Following investigations and consultations in 2003 the trawl boundary on the Swedish west coast was furthered out from 2 to 4 nm from the coast in January 2004. The aim of the measure was to protect demersal fish stocks, essential fish habitats and sensitive bottom habitats from bottom trawling. However, the fishery for Norway lobster *Nephrops norvegicus* is important along the coast, the stock is in healthy condition and the fishery was considered to be sustainable in areas of soft-bottom habitats under special regulations making the fishery selective for *Nephrops*. The zonation of the *Nephrops*-fishery was, however, difficult, as data on seabed structure was scarce or lacking along considerable parts of the coast.

To eliminate the lack of knowledge in the northernmost part of the west coast, the topography and reflection of a 598 km² area was surveyed in November 2003 for use by the National Board of Fisheries. The Swedish Armed Forces, who for their Naval Forces required high-resolution seabed data, also sponsored the survey. The survey operation was conducted by MMT. The area was surveyed with total coverage of all areas deeper than 10 m using Simrad EM1002 95 kHz multibeam echo sounder, Edgetech DF1000 384/100 kHz Side Scanner and Benthos Chirp II sub bottom profiler. 2 sets of maps were produced. Bathymetry and Backscatter maps in scale 1:25.000. The Backscatter data is

interpreted in 10x10m grid cells and classified in 5 classes Hard-Soft indicating presence of Bedrock, Gravel, Sand, Clay and Silty mud.



During negotiations between local fishermen, their organisations and the National Board of Fisheries the Swedish West Coast Fishermen Organisation collected data from their members and maps were produced displaying trawl paths from the fishing boats navigational systems. Discussions concerning revision of the trawl boundaries are now being held based on the data from the survey and the actual historical trawl paths.

Due to the high-resolution requirement from the Armed Forces, side scan data will be available for future trawl impact and habitat classification.

A National Marine Sediment Database for Australia – a vital step in marine bioregionalisation

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Understanding the nature and composition of the seabed is important in regional marine planning, as these factors play a significant role in determining the diversity and dynamics of marine communities. As a basis for mapping seabed sediments and their characteristics, Geoscience Australia is creating MARS – a national MARine Sediment database. MARS will serve as a framework for the ongoing collection and maintenance of marine sediment data from a variety of sources. The aim is to provide researchers with access to Geoscience Australia's extensive in-house dataset, as well as providing a comprehensive sediment dataset for the Australian Marine Jurisdiction.

A wide variety of data types can be stored in MARS, ranging from ship deck descriptions of grab samples to the latest underwater camera/video footage. It will be a versatile and comprehensive data repository and the first point of call for researchers studying the nature of the seafloor within Australia's Maritime Jurisdiction. MARS will also provide a secure, central repository for data collected in the future, ensuring that this valuable resource is available for on-going research.

The initial phase of the project is the identification of available data and population of the database. The data collected is being used to generate maps of seafloor properties, such as sediment grain size and carbonate content. Further interpretation includes modelling of sediment mobility and interpolation of sediment types against previously-mapped geomorphic units. These maps are providing a basis for regional marine planning in both

the northern planning area and Australia-wide. The project overall will provide information on the way in which sediment data can enhance understanding of benthic bioregionalisation, as well as guidance in the broader task of regional marine planning.

Development of a Regional Seafloor Surficial Geologic (Habitat) Map for the Continental Margins of Oregon and Washington, USA.

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Contemporary marine fisheries management is moving toward science-based techniques that incorporate seafloor habitats. On the west coast of the U.S., this reality is manifest as NOAA Fisheries and the Pacific Fisheries Management Council fulfill their responsibility to identify and protect habitats essential to commercially fished species. Many of the species harvested by these fisheries are known to be demersal or bottom dwelling. Knowledge of the benthic habitats that fish occupy, or utilize is essential, and required well in advance of management action. To address this specific problem, we have mapped regional physiographic habitats, and their surficial lithologies, along the continental margins of Washington and Oregon. These surficial map databases were developed using an iterative interpretive method to integrate disparate geological and geophysical datasets that included: bathymetric grids, sidescan sonar imagery, seismic reflection profiles, sediment samples, geologic maps of structure, and submersible observations. Each of these basic data types is comprised of individual datasets that varied in quality, resolution, and spatial density. This required an iterative approach to minimize mismatches between datasets, and to incorporate geologic interpretation in the process. The regional map development from such disparate data differs from automated or semi-automated classifications, as those generally require relatively uniform spatial coverage of seafloor data. A confidence methodology and layer were also developed to capture the relative values of the different datasets in habitat interpretation, the quality of the lithologic assignment from the data, as well as the relative quality and precision of navigation inherent in each dataset.

Keywords: geologic habitat, fisheries management, remote sensing, geologic interpretation

Shallow marine and freshwater surveys around Clew Bay, Ireland.

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Clew Bay is important to the local economy in the west of Ireland because of the tourist industry and its potential for aquaculture development. A series of surveys around Clew Bay has been conducted using interferometric acoustic equipment (Submetrix 2000 Series (235 kHz) Swath System) which provides simultaneous bathymetric and backscatter data. The surveys were designed to (1) obtain a high resolution bathymetric map that could give information on palaeo-sea level rises around Clare Island, (2) validate the precision of airborne LIDAR bathymetric data around the Dilisk Rocks, (3) obtain backscatter maps that could be used, in conjunction with grab samples, to discriminate seabed sediment types in Clew Bay, (4) correlate the seabed geology with the surrounding geology and make appropriate inferences about recent geological processes and, (5) correlate bathymetric and backscatter data with benthic habitats in two freshwater lakes, Lough Feeagh and Lough Furnace, used for salmon research by the Irish Marine Institute.

The surveys were conducted in a vessel of opportunity (~10m long) over a period of 15 days and provided 100% coverage over ~ 60km² in water depths 5-50m. Our preliminary conclusions are:

- The acoustic data are sufficiently high quality for geological and habitat mapping.
- A palaeo-coastline around Clare Island has been mapped.
- There is a good correlation between swath acoustic and airborne LIDAR bathymetric data in water depths up to ~ 25m.
- Several eroded/submerged drumlins (including Dillisk Rocks) were discovered

- The backscatter amplitude from the drumlins is large and indicates a rocky nature, consistent with erosion.
- A wide variety of sediment types and environments were encountered e.g. rocky ground, mud and coarse sediments (gravels?)
- The backscatter data have identified a terminal moraine with no bathymetric expression.
- Areas containing current/ripple marks may be scallop dredge or trawl marks.
- The bathymetric data are not of the highest hydrographic standards because predicted tide corrections were used instead of local tide gauges and short range Real Time Kinetic (RTK) Global Positioning System (GPS).

The Shallow Geological Model: Mapping and Monitoring the Marine Landscape

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Managing our seas without a sound knowledge of the sea-bed environment and the processes that shape the sea-bed characteristics makes it difficult to conserve key areas, maintain biodiversity and economically develop our marine resources in an efficient and sustainable way. Recent developments in marine landscape mapping, visualisation techniques and instant data access provide timely, proven technologies that are now in widespread use.

The British Geological Survey is responsible for the geological mapping of the UK land area and the continental shelf and margins. A wide range of marine geological data has been acquired, which provide information about the rocks and sediments both on and below the seabed. During the 1980's and 1990's these data were interpreted and published in a series of thematic maps and regional reports. More recently digital data derived from bathymetry, seabed sediment, Quaternary geology and solid geology, have been used to develop the BGS Offshore Geographical Information System.

These data have been used to produce a shallow geological model that provides tailored information for an integrated approach to the understanding of a study area. The model examines both static and dynamic geological processes, and modern and historical conditions to provide information on the geological processes that form geohazards and habitats both on and up to 1000m below the seabed. The wider geological setting such as the climate zone, oceanography, and the nearshore, shelf, or deep-water environment, are also incorporated into the shallow geological model.

This approach has been successfully applied in several geohazard and/or habitat studies worldwide. Areas studied include the passive continental margins of the glaciated UK

and mid-Norwegian regions, offshore West Africa, the active Alpine–Himalayan collision zone and offshore south-east Brazil. These areas represent a number of climatic and tectonic settings. The shallow geological model therefore provides a method by which habitats and potential geohazards can be characterised, resulting in improved understanding of the historical and modern processes that formed them. The model can also be used to predict areas where geohazards could occur and potential changes in habitat.

Multibeam Sonar mapping and Scallop Stock Assessment: GIS Data Integration in Support of Sustainable Fisheries Management

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This study describes the collection and subsequent GIS integration and spatial analysis of hydrographic, biological and geophysical data. The research is being undertaken as a principal component in a multidisciplinary approach to the development of a strategic plan for the management of scallop stocks (*Pecten maximus*) off the south east coast of Ireland. A series of GIS tools are used in conjunction with a geodatabase in order to assist in evaluating the relationship between seabed sediment type and scallop stock density. Hydrographic/geophysical data layers including multibeam sonar maps (MBES bathymetry, morphology and acoustic backscatter) and other seabed data layers (sediment samples, sub-sea video imagery, statistical sediment classifications) are overlain and analysed in combination with layers of quantitative biological data showing scallop catch rates. Initial results indicate that high scallop catch rates are strongly correlated with one of two predominant and acoustically distinct sediment types that occur extensively within existing scallop grounds. Seabed imagery acquired during ongoing field surveys with georeferenced underwater towed video cameras is being integrated within the GIS database in order to further analyse, ground truth and refine inferred sediment classes and their spatial configuration. Catch rate results from stock assessment survey transects positioned on the basis of sediment backscatter imagery have demonstrated the potential for applying integrated digital mapping techniques in order to predict and operationally target areas with a high potential scallop yield. Scope thus realised for improving catch efficiency (CPUE) may be used in concert with closed area and other conservation measures to scientifically underpin future sustainable management policy initiatives for this economically important fishery.

Mapping Benthic Sublittoral Biotopes on the shelf of Faial island and neighbouring channel (Azores, Portugal)

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Due to increasing anthropogenic influences on and threats to the bottom of the world's oceans, the demand for comprehensive environmental appraisals of benthic habitats and associated biological communities (biotopes) is growing. This need is also felt at the remote Atlantic islands of the Azores where studies on marine life have accumulated since the late 19th century.

The assemblages compounded by benthic species have been studied in a number of infralittoral coastal sites but neither a structured biotope classification resulting from taxonomically-comprehensive surveys has been produced nor maps exist of the distribution of the benthic assemblages along the coasts.

A series of projects have recently used on the islands' shelves a suite of modern geophysical technologies (e.g., multibeam, mechanically scanning pencil beam, side scan sonar, seismic reflection profilers) along with lighter methodologies for surveying of benthic biological assemblages based on physiognomic/visual approaches. These methods have facilitated the collection of fine-scale updated geophysical and biological data that can be used to analyse which main factors regulate the occurrence of biological assemblages.

The shelf of Faial and the neighbouring channel to Pico island will provide the case study given (i) their wide range of physical environmental conditions and biological assemblages, (ii) easy accessibility from the main marine research centre at the Azores, and (iii) high interest for conservation under the *Natura 2000*, *BIOMARE* and *MARBEF* networks.

The focus is the development of an integrated approach to the classification and mapping of benthic marine biotopes using a combination of geophysical techniques, *in situ* observations and mathematical modelling. This will be achieved through collation of geo-referenced information from various sources and collection of further environmental and biological data in a series of field surveys to be conducted over a period of 3 years.

Specific objectives are:

- to characterize the seabed in the area and identify the habitats present using a set of physical and geophysical techniques;
- to identify the variation of biological assemblages through appropriate sampling strategies using a physiognomic approach;
- to describe and classify under an hierarchical scheme the biological assemblages associated to the different sublittoral rocky habitats;
- to investigate the association/control of some physical habitat variables over the structure and distribution of benthic sublittoral assemblages;
- to develop validated predictive models of the occurrence of rocky sublittoral biotopes in a GIS environment.

The first results of habitat mapping based on the analysis of bathymetric texture and synthetic sidescan sonar images provided by data from multibeam surveys will be presented along with models of some environmental variables.

The experience acquired during this work is expected to have valuable implications for the future methodological design and implementation of more cost-effective strategies for biotope surveying, classification, mapping and monitoring within a large-scale operation that extends to the rest of the archipelago.

Note: The current work is being performed under the first author's PhD (funded by MCES/FCT grant no. SFRH/BD/12885/2003) at the SGG/UStA jointly with DOP/UAç where it is supported by research projects.

Coastal habitat mapping in Norway, with examples of interferometric sonar applications

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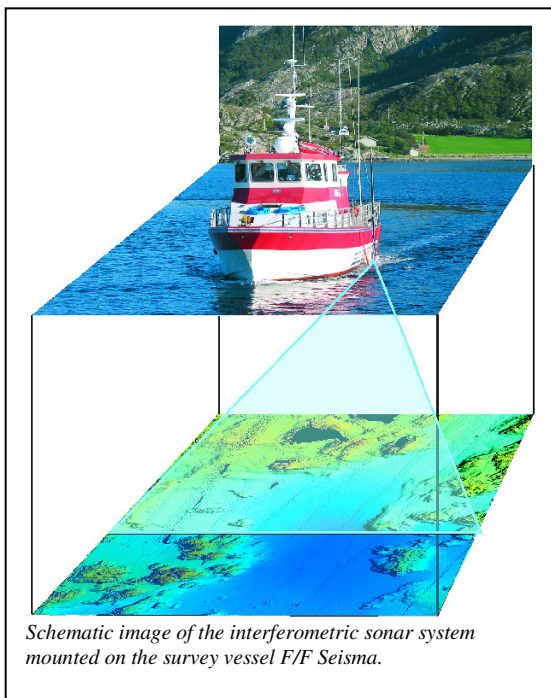
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Coastal zone management is of increasing importance in Norway, but adequate knowledge on habitats and physical conditions, including seabed sediments is basically missing. Due to long geological history and a variety of geological processes, the Norwegian coast zone has a high geological diversity. The length of the coast line is c. 21.000 km long when considering the mainland only, and in the order of 80.000 km when islands are included. The area inside the so called "Ground line" – a line drawn between the outer skerries – is c. 90.000 km².



Geologically, the coast zone range from overdeepened glacial fjords to a "skaergard" crowded with islands, skerries, sounds and basins. The skaergard is a biologically highly productive zone, with important fisheries. Aquaculture is already a very important business, and the expectations for future growth are high. While salmon farming presently dominates, other fish species are growing in importance. Lobster and shell – *Pecten maximus* – receives great attention, but has not been industrialised yet.

Altogether, this calls for a better knowledge of the physical environment in the coastal zone, of both the pelagic and benthic zone. Because of the large areas involved, there is a great focus on methods which can provide sufficiently detailed and adequate information at a reasonable cost. In line with this, the Geological Survey of Norway has started acquiring data with a shallow water interferometric sonar system, mounted along the side of our ship. The system is simply told a hybrid between traditional sidescan sonar systems and multibeam echosounders, which provides a georeferenced sonar image with good resolution simultaneously with a reasonably good bathymetric model. Compared to multibeam echosounders, the swathe width is significantly greater, and the sonar data better suited for seabed classification.

In a region 200 km northwest of Trondheim, locations well suited for fish farming and areas possible for lobsters are some of the results so far. A simple GIS exercise, where data from the regional Fishery Directorate were combined with our seabed data, showed a close link between areas where cod is normally found and seabed sediments, defining a cod habitat. Using the acoustic data, we were also able to refine the extent of shrimp fisheries reported by the local fishermen. In other regions, widely differing phenomena as coral reefs (*Lophelia pertusa*), kelp forests and big swamp colonies has been indicated. Ground truthing has been by means of grab sampling, underwater video & photography, and ROV, through cooperation with other partners.

Marine geology and benthic habitat of German Bank, Scotian Shelf, Atlantic Canada

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Multibeam sonar sea floor mapping technologies have provided the capability to accurately, and cost effectively, survey large areas of the seabed. Multibeam bathymetric and backscatter strength information provides base maps from which targeted groundtruthing surveys can be planned to map sea floor sediments and associated benthic communities. A seven-year program of contiguous multibeam surveys carried out on German Bank on the southern Scotian Shelf of Atlantic Canada has mapped an area of 5320 square kilometres. Water depths range from less than 30 m to 250 m. Four groundtruthing surveys carried out to sample and image the geology and biology of the sea floor have collected 2133 km of high-resolution seismic reflection profiles and sidescan sonograms, complemented by 1134 sea floor photographs, 97 sea floor video transects, and 86 sediment and biological samples. Bedrock outcrop, composed of Cambrian-Ordovician metasedimentary rocks and Late Devonian-Carboniferous granitoid plutons, dominates much of the bank and has a characteristic rugged and fractured surface. In the deeper parts of German Bank, glacial marine Emerald Silt overlies the Scotian Shelf Drift. Wisconsinan-age iceberg furrows are well-preserved in Emerald Silt. The Scotian Shelf Drift (mainly glacial till) was deposited over bedrock during Wisconsinan glaciation and occurs as a blanket of variable thickness. At the seabed, the till forms remarkably well-preserved and widespread moraines and drumlins and consists of cobbles and boulders embedded in a pebble and sand lag, commonly associated with broken shell fragments. Epifauna are typically more abundant on the boulders and on

bedrock outcrops, and include erect and encrusting sponges, tunicates, hydrozoa and bryozoa. Scallops and lobsters are also abundant in this habitat. In contrast, the fauna in deeper water areas floored by Emerald Silt includes polychetes and sea cucumbers. Surficial geological and benthic habitat maps, compiled and interpreted from multibeam and groundtruthing data, will be used by the Canadian government to establish and manage new fisheries on German Bank.

Efficient, robust modelling of sediment transport over geological time.

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Forward modelling of sediment accumulation over geological time-frames is a potentially valuable academic and industrial tool. Recent models involve calculating, in 3D, the sediment transport effects of currents, waves and slopes on scales of 10s of kilometres and time-scales of hundreds of thousands of years. This is computationally very demanding. In particular, sea-floor shear stress vectors need to be recalculated at every stratigraphic time step (typically ~100 years per step) since the sea-floor geometry and the externally imposed boundary conditions slowly change with time. Shear stress fields are then incorporated into bed-load and suspended-load sediment transport algorithms. The best existing models calculate waves using ray-tracing methods based on linear wave theory using a single, wind-strength controlled, wave-frequency. Currents can be efficiently modeled using depth averaged velocities and the law of the wall by assuming that quantities such as basal friction or total kinetic energy are minimized. However, these approaches miss a great deal of important sediment transport physics such as wave-breaking erosion, wave-generated under-tow, within-model wave-generation, multi-layered currents, hermo-haline circulation and anisotropic diffusion. This talk will explain the requirements and restrictions for sediment transport and deposition modelling in a geological context using existing approaches as illustrations. It is hoped that this presentation will stimulate the oceanographic community to help geologists build much better models.

GeoHAB 2004

Poster presentation abstracts

Ground-truthing acoustic surveys at areas of anthropogenic impact II: Seabed characterisation of an area licensed for dredge material disposal.

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Traditional sampling methods were combined with acoustic techniques, video images and Sediment Profile Imagery (SPI) to assess the spatial and temporal changes in macrobenthic communities at a dredged material disposal site off the North East Coast of the UK. Annually over 100,000 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 to inadequate impacts are developing. The site of approximately 2.7 km by 1.9 km in size was surveyed with a high-resolution sidescan sonar system producing a mosaic with 100% coverage of the survey area. A clear footprint of the disposal operations in the centre of the licensed area was revealed during the pilot survey. QTC was also used to delineate acoustically distinct areas. 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 total abundance of organisms, biomass and species richness in the vicinity of the dredged material disposal site. The use of SPI provided additional 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.

Identification of yelloweye rockfish habitat: Geophysical survey data in comparison with fishery logbook data

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The Alaska Department of Fish and Game (AFD&G) has been conducting a habitat based stock assessment of yelloweye rockfish (*Sebastes ruberrimus*) since 1989. Yelloweye rockfish are a large (90cm) marine fish that occur in rugged rocky terrain on the continental shelf of the Eastern Gulf of Alaska. They are an important commercial species and are taken in a directed bottom longline fishery and as bycatch in the halibut (*Hippoglossis stenalepis*) fishery. Biomass is derived as the product of density, average weight, and area of habitat. Density is based on line transect surveys conducted from an occupied submersible and average weight is estimated from port samples of commercial catch. Area estimates of yelloweye habitat are based on the probable distribution of rocky habitat inshore of 220 m. Information used to identify these areas include National Ocean Survey data, sidescan and multibeam data, direct observation from the submersible, and commercial logbook data from the directed DSR fishery. The estimates of yelloweye habitat are highly subjective. Although a defined protocol allows for a standard interpretation there is no way to estimate variance of this data.

Our use of geophysical data for bottomfish assessment may be of use to other countries interested in evaluating fisheries using a geological database. In areas where multibeam and/or sidescan sonar data are available the area of yelloweye rockfish habitat is delineated based on defined substrate types within the mapped area. For areas without these geophysical data sets we use the position data from 1993-2000 commercial fishery

logbooks, buffered to 0.5 mi from the start position. Longline sets must have at least a 0.04 yelloweye/hook catch rate to be included in the data. Prior to this assessment the commercial logbook data was not buffered and our estimate of yelloweye habitat was based on hand drawing polygons encompassing set start locations as well as NOS habitat data.

In 2001 we conducted a multibeam survey for a portion of seafloor off of Larch Bay, Baranof Island. Of the 293.7 km² surveyed offshore of Larch Bay, 112 km² were identified as yelloweye habitat based on interpretation of the multibeam bathymetry and backscatter data. A comparison of fishing data with the habitat interpretation from multibeam is illustrative of the problem with habitat definitions. In the Larch Bay multibeam site the habitat interpretation yielded 112 km² of yelloweye habitat. However, placement of the commercial fishing data yields an estimate of 65.6 km². This is a 41% difference in area. It appears from the fishing data that there is some difference in habitat within one of our habitat categories that is not resolvable from the multibeam data.

In the summer of 2003 we conducted submersible line transect surveys in the area that was defined as rockfish habitat by both the logbook data and multibeam data compared to the area that was defined as rockfish habitat using the multibeam data alone. Preliminary analysis shows a significant difference in yelloweye density between the two areas, with the fished area showing the higher density.

These results underscore the utility of using geophysical techniques to delineate habitats and aid in fisheries management. Geophysical surveys reveal the extent of all rocky habitats. Not surprisingly, fishermen target areas of high abundance; in the case of rockfish this equates to prime rocky habitat. Limiting of surveys to prime habitat may result in inaccurate stock assessments, as density may remain stable in prime habitat while declining in surrounding habitats. For example, indications of declining stock may be first noticeable in less desirable habitat, as fish will move into prime habitat as space becomes available. By assessing fish densities in all rockfish habitat, as delineated by geophysical surveys we may have a better indicator of stock condition.

**Ground-truthing acoustic surveys at areas of anthropogenic impact I:
Characterisation of habitats in an area licensed for aggregate extraction.**

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A site licensed for marine aggregate extraction off the south-east coast of England has been surveyed since 1999. Interpretation of early sidescan sonar surveys was relatively simple, mapping the site into four areas showing gross differences in their acoustic characteristics. These areas were ground-truthed using grabs, trawls and video to characterise the biota and the nature of the sediment. More detailed interpretation of later surveys classified the same area into nine distinct seabed facies, based on sediment type and bedform topography. These were ground-truthed in a similar manner, including a novel pattern of grab sampling designed to investigate variability within individual facies. Faunal analyses will examine whether infauna and epifauna map better to the four original acoustic areas or to the nine seabed facies. Video methods were used to examine the boundaries between facies, which appeared well delineated by acoustic methods.

A more extensive region (approx. 40 x 15 km) around the aggregate extraction site has also been surveyed, in order to place the site in a broad scale context. An initial survey with 7 parallel sidescan lines spaced 2 km apart has gradually been augmented with a pattern of 'in-fill' lines to achieve a progressively greater density of sidescan coverage. Given that 100% sidescan coverage of such an area can be costly and time consuming, these surveys have been used to explore the relationship between density of sidescan coverage and confidence in detecting and interpreting broad scale patterns and features.

Mapping Benthic Habitats in Newfoundland Fiords

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Substrate characteristics provide a primary control on benthic marine habitats. Changes in substrate provide an easily identifiable and quantifiable (texture, sorting, roughness) spatial boundary to delineate benthic habitats. The substrate reflects and defines the physical and environmental conditions occurring on the seabed. In glaciated environments the deglacial and paraglacial history is the primary influence on the character and spatial continuity of substrate types. This presentation illustrates the complexity and variability of surficial sediments in coastal fiord environments around the island of Newfoundland, eastern Canada, using multibeam and shallow seismic records in combination with grab samples and seabed photographs. We present initial results of a pilot project integrating multibeam backscatter and seismic reflectance with bathymetric, oceanographic, substrate, and biotic characteristics to delineate benthic habitat boundaries in Newman Sound, a 40-km long fiord located in Bonavista Bay, eastern Newfoundland. Characterization of seabed substrates is necessary to achieve a major goal of this project: to develop methodology for efficiently mapping benthic biodiversity for marine conservation.

Towcam Surveys (Canadian Department of Fisheries and Oceans)

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This poster describes Towcam, a new instrument for collecting imagery of the seabed which has been developed at the Bedford Institute of Oceanography. Towcam is towed a few meters above the seabed at a speed of 2-3 knots and collects continuous colour video and periodic still digital photos. It is fitted with a laser scale and can operate down to depths of at least 200 m. Since power is provided from the surface, there is no limit to transect length. Transects as long as 30 km have been run. Examples are given showing how Towcam is currently being used in studies of benthic habitat and commercially important species such as scallops, lobster and herring. Towcam is an excellent tool for collecting groundtruthing information for habitat mapping programs.

Spatial Utilization of Benthic Habitat by Demersal Fish (Canadian Department of Fisheries and Oceans)

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A large team of DFO and NRCan scientists, based at the Bedford Institute of Oceanography and the Northwest Atlantic Fisheries Centre, is conducting a three year project to improve understanding of the relationships between seabed habitat, benthic communities and demersal fish. Project modules include project management, data management, acoustic fish and seabed classification, imagery of habitat, benthos and fish, trawlable fish, and data synthesis and extrapolation. Using historical DFO groundfish data (1970-2001), paired study sites (10 x 10 km) were selected on Emerald, Western and Sable Island Bank on the Scotian Shelf. These sites have the highest and lowest probabilities of finding juvenile haddock. Using state-of-the-art acoustic, imaging and sampling equipment, a field program is being conducted to determine the present day differences in seabed habitat, benthic communities, and fish communities at these six sites over different spatial scales (10 km down to centimeters). Some initial products and results are presented. The new information being generated is being used to define important fish habitat and map its spatial extent in selected areas on the Scotian Shelf. The tools being developed can be used to map fish habitat over larger spatial areas more efficiently.

**Potential marine benthic habitats of an inland Sea,
San Juan Islands and the transboundary region of Canada and the US:
A successful international cooperative program**

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During the past three years extensive mapping of the waterways in and around the San Juan Islands of the US and adjoining areas of Canada has taken place as a joint operation between the Geological Survey of Canada and Moss Landing Marine Laboratories' Center for Habitat Studies. With the use of the Canadian Hydrographic Services Simrad EM1002 and EM3000 multibeam bathymetry systems onboard Canadian Coast Guard vessels and launches high-resolution bathymetry and backscatter data were collected in the geologically complex and glacially scoured inland sea of the San Juan Islands. Active tectonics since the Cretaceous time has resulted in the docking of exotic terranes, formation of nappes, and extensive deformation of metamorphic and sedimentary rock units. Deep ice scoured channels and sounds are remnant glacial features from the last glacial advance. All of this has resulted in highly diverse marine benthic habitat types that are now being characterized for bottom fish fisheries and Marine Protected Area (MPA) designation. Not only are highly rugose and complex bedrock exposures that are important habitats for rockfish (*Sebastes* spp.) imaged, but dynamic mega-bedforms have been mapped that may be significant habitat for migratory species of fish such as salmon and sturgeon. A detail potential marine benthic habitat of the inland sea of the San Juan Islands is presented.

Avoiding gridlock in the ICES area: a proposal for regional co-ordination and standardised production of an ICES geo-habitat map series.

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At the most recent meeting of the ICES Working Group on Marine Habitat Mapping in Brest, France, April 2004, it was clear that progress is being made by individual countries in the production of marine habitat/resource maps. France and Spain, for example, have begun ambitious inshore mapping programmes of their entire coasts. Other countries such as Ireland and Canada have conducted large scale high-resolution multi-beam surveys as a basis for the production of novel marine habitat maps. All of these maps are produced using local grids with different map projections and resolutions.

To streamline regional scale mapping and to facilitate co-operation between individual national and agency efforts, we propose that a common regional/global grid, map projection and scales should be adopted. This would improve data exchange, allow for the production of readily comparable maps and maximise the intuitive power of data visualisation tools allowing fly throughs over low-resolution landscape into hotspots with similar high resolution.

We propose to adopt an existing grid, map projection and scales for use as a regional standard. We will suggest a preliminary standard chart numbering system and make recommendations for map annotation. Two grid systems will be considered: a) Universal Trans Mercator and b) Marsden squares.

Underwater video sampling: What's in an image?

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Underwater video imagery combined with remotely sensed geoacoustic data collected under the Irish National Seabed Survey will improve our knowledge of the distribution of benthic seafloor habitats in the Irish offshore region. While acoustic imaging techniques provide valuable information on the physical properties of the seabed, high resolution underwater optical imagery reveal those characteristics of seafloor micro-habitats relevant to assessing, monitoring and managing ecosystem health in particular for designation and management of special areas of conservation (SACs). The classification of video and photographic imagery can be highly subjective, and time consuming, particularly for underwater video surveys generating large data sets. The value of collecting remotely sensed visual image data lies in the amount of useful information which can be extracted.

We will use underwater video imagery as a qualitative descriptor to classify seafloor benthic habitats along the Irish continental margin based on their dominant physical and biological attributes according to existing deep-water classification schemes. Further to this, quantitative information from underwater video will help establish species-occurrence and species-environment relationships for ecological statistical modelling to predict where benthic habitats are likely to occur and establish the species response to environmental gradients.

A number of factors influence the quality of quantitative information obtained from underwater video imagery. During a typical video survey, visual instrumentation is mounted on a vehicle or towed sled array which is in continuous motion above the seafloor. Accurate vehicle navigation and positioning is required to ensure images are

georeferenced to a specific location in space. Spatial distortions due to camera angle, varying field of view, variations in lighting conditions and specific lens characteristics, together with vehicle motion cause distance and scale inaccuracies which must be corrected.

A set of algorithms to detect features of interest in mission videos has been developed at Heriot-Watt University to reduce the amount of time required to analyse underwater video. The approach is based on supervised image classification "Large margin classifiers" (classifiers with good properties and performance) are applied to partition the image data into a number of classes, each pixel being attributed a label. The classes contain information associated with e.g. in the case of coral ecosystems; percentage live coral and percentage species cover. The scientist manually assigns labelled examples to the underwater imagery which is used to 'train' the algorithm to distinguish between different seafloor classes. The algorithms then have the potential to be used in the semi-automatic generation of thematic maps which summarise the results of the classification.

This work is evaluating the utility of using machine vision to automatically analyse underwater video to produce seafloor habitat classifications.

Acknowledgements

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Deepwater coral habitats in the Porcupine Seabight, NE Atlantic : 3 case studies, 3 different environments

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Deepwater corals, such as *Lophelia pertusa* and *Madrepora oculata*, together with their associated fauna, have been found on large mound structures in the Porcupine Seabight, along the NE Atlantic margin W of Ireland. Investigations during the last 10 years, including recent studies carried out within the framework of the European FP 5 projects Geomound, Ecomound and ACES, have shown that the mounds can reach heights of 160 m above the seafloor, and diameters of more than a kilometre. Furthermore it appears that they are at least partly built up of coral material and entrapped sediments. Three provinces of such mounds, or coral banks, have been identified in the Porcupine Seabight: the Belgica province is located on the steeper eastern flank of the Seabight, while the Hovland province occurs in the north. The Magellan mounds can be found to the NW of the latter province, but are mainly buried under packages of semi-stratified sediments. The three provinces have been studied with a range of techniques, including 3D and high-resolution 2D seismics, sidescan sonar imagery, multibeam bathymetry and different types of coring operations. Largely based upon previous acoustic and sampling results, the CARACOLE cruise was carried out in summer 2001, deploying IFREMER's ROV Victor 6000 in several dives on different mounds in different provinces.

One mound of each province was then studied in detail, in order to compare the deepwater coral habitats in the different areas. For each of the study sites, all of the available data sets (acoustics, sampling information, etc.) were integrated within a GIS

(ArcView 3.2) and combined with the video records of the ROV dives. This allowed a detailed mapping of the different sedimentary facies and geological aspects of each of these deepwater coral habitats. Areas with live coral, dead coral, coral debris, bioturbated, gravelly and sandy sediments were delineated, which gave insights in the structure of single mounds in each of the provinces.

The results clearly illustrate that the Belgica mound province is the most dynamic area, with (at least periodically) higher and more variable current speeds, resulting in the frequent occurrence of bedforms and coarser sediments. The sedimentary environment of the other two provinces is characterised by bioturbated fine sediments. This difference is reflected in the coral abundance and apparent species diversity : the richest faunal communities were found on Thérèse Mound in the Belgica province. Nearby, also small, possibly initial, mound structures were encountered ('Moirra mounds'). Propeller Mound in the Hovland province also carries a fair amount of live coral, although it is less abundant. Large zones with dead coral, coral rubble or a gravelly dropstone facies are found on it as well. It indicates that the conditions for coral growth are less favourable, although they seem to have been better before, as the mound reaches a height of 280 m above its initial base. Possibly the presence of elongated depressions in the seafloor of the Hovland province played a role; they may have caused locally enhanced currents. The poorest deepwater coral habitat was found on Mound Perseverance, in the Magellan province. Only a few live coral colonies are left, and large parts at the base of the mound are covered with bioturbated sediments. It seems that this mound will become buried, just as what happened to most of the Magellan mounds.

The comparison of these three case studies indicates that the interaction between sedimentation pattern and current regime clearly is an important factor in the determination of the suitability of a habitat for deepwater coral growth.

ArcGIS tools for streamlining habitat map data integration

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We have recently completed surficial geologic habitat maps for the Oregon and Washington continental margins. Through this process, several integrated techniques for habitat interpretation and data quality mapping have been developed and explored. Currently, we use density maps to represent a seafloor environment covered by data that is patchy and of variable quality. Raster maps of data density and quality help facilitate assessments of final geologic habitat map. Additionally, we use geo-positioned in-situ observational data (submersible observations) to verify or groundtruth remotely sensed acoustic data. While mapping large geographic regions covered by varied data types, many of the simple and repeatable processing steps required by these techniques become cumbersome and time intensive. Our goals are: (1) to make possible quick and easily regeneration of data quality layers as either new information becomes available or we change a quality appraisal for a particular dataset, (2) to make it easier to assign lithologic attributes to submersible navigation data. In addressing these problems, we are developing ArcGIS tools that streamline the regeneration of data quality layers and the assignment of attributes to time series point or polyline data (i.e. submersible navigation). The data quality tools encapsulate and automate specific processing steps used to create ranked data density maps from raw (raster or vector) input and utilize input/dialog boxes to prompt the user information. Dive attribution tools allows for an envelope selection of navigation fixes (points or polylines), and assign a unique lithology (determined from video review) to the selected records. The tool also renders the navigation layer according to a predefined, but changeable, color and display style. These automation tools make creating and re-creating data quality layers as well as editing dive navigation much easier and faster.

Longline fishing activity and bathymetry in the South Georgia region

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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 2000m 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. The firm, moist flesh makes toothfish a highly valuable commercial species. A longline fishery for toothfish has operated around the island of South Georgia since the early 1990's. 10 to 18 vessels are licensed to fish within the South Georgia maritime zone each year. The value of the catch is significant - of the order of £30,000,000 per year. Longlines of baited hooks are usually set in water depths of 1000m 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 provides valuable insights into the preferred toothfish habitats which will influence future strategy for fishery management and conservation.

Using In-situ technology to identify and characterize essential fish habitat for classification as a marine reserve in the Eastern Gulf of Alaska

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The Alaska Department of Fish and Game has used a submersible to obtain habitat-specific density estimates of demersal shelf rockfishes in the Eastern Gulf of Alaska since 1989. During these surveys we have made over 450 dives in depths between 40 m and 400 m between Dixon Entrance (54°30' N) and Fairweather Ground (58°30' N). Direct observation using in-situ technology has greatly increased our understanding of the linkage in the marine system between species diversity, abundance, and habitat complexity. It has also allowed us to identify areas that appear to be of critical importance to a variety of fish species. A specific habitat that is particularly important is an area off Cape Edgecumbe dominated by large volcanic cones, rising steeply from 140 m to 40 m. This pinnacle is flanked by immense boulders at the base, providing important refuge for adult fishes. Juvenile rockfishes occur in great abundance at the top of the pinnacles and use the dense assemblages of sessile invertebrates, including *Metridium* and hydrocorals for cover. Adult lingcod (*Ophiodon elongatus*) use the top of the pinnacles as a seasonal feeding platform after spawning. These fishes occur in extremely dense aggregations during the late spring and early summer. The small size of the area, large density, and feeding behavior make them extremely susceptible to fishing pressure. Lingcod egg masses have also been seen in the pinnacles habitat, occurring in much deeper waters than previously reported in the literature. (O'Connell, V.M. 1993. Submersible observations on lingcod, *Ophiodon elongatus*, nesting below 30 m off Sitka,

Alaska. Mar. Fish. Rev. 55(1) p 19-24.) Using a combination of technology, including submersibles, lasers, sidescan sonars, and multibeam sonar, we were able to characterize this habitat, determine habitat-specific fish densities, and complete detailed quantification of habitat. This analysis allows us to clearly defend the definition of this area as a Habitat of Particular Concern under the Magnuson-Stevens Fishery Conservation and Management Act. Based on this research the Alaska Department of Fish and Game proposed classifying the area as a no-take marine reserve. Proposals were submitted to the Alaska Board of Fisheries and the North Pacific Fishery Management Council requesting a closure to all harvest of groundfish and to prohibit anchoring. The Board of Fish closed the area to lingcod and rockfish harvest in February 1998 and the NPFMC closed the area to all other groundfish, halibut and scallop harvest. This is the first no-take groundfish reserve in Alaska.

Bayesian Network Models for Pacific Coast Groundfish EFH Requirements

Parkes, G., Vilhelm, R., Burn, B., Grayer, C.,
Bailey, A., Copps, C., Wakefield, W.

Authors *in absentia* – poster to be presented by H.G, Greene, C. Goldfinger, C. Romsos

SeeTrack: On-site visualisation, sensor data analysis and data fusion of UUV sonar and video data products

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SeeTrack is a post processing tool for rapid on-site data reduction, analysis and data fusion of sensor data, including sidescan, forward look sonar, imaging sonar and video. It is the first commercial software product to support Synthetic Aperture Sonar (SAS).

SeeTrack includes Hot Plugin's for instantly adding functionality: including vehicle personalities, sonar processing and video processing. It allows for rapid mission importing, geo-referencing both video and sonar, and displaying (a typical 2 hour mission with CTD data display and sidescan georeferencing takes ~5 minutes). Users are also able to run automatic object detection and dimensioning algorithms that provide the geolocation of sensor targets on display. SeeTrack generates automated HTML reports.

The SeeTrack GIS engine allows to overlay chart, sonar data, historic data and targets onto the bathymetry. It displays vehicle path in 2D and 3D views and allows for AUV mission planning and monitoring. It provides mosaicing and video stabilisation in video streams.

It is a highly modular system and is designed to perform on both notebook and desktop environments. It has been successfully employed since 2000 in US Field Battle Experiments, NATO SACLANTCEN GOATS 2000 trials, Kernel Blitz 2001, AUV Fest 2001, MREP 2003, Northern Lights 2003 and SMCM Demonstration 2003. It got glowing reports following frontline use with EOD Mobile Units in Operation Iraqi Freedom. It has sold many units including a copy to Kongsberg Simrad for mine warfare applications with HUGIN AUV.

SeeTrack is now also currently employed to support European Union 5th Framework Programme projects: AMASON and Autotracker.

Sidescan Sonar Modelling for Imaging Performance Characterisation

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Sidescan sonar images are often affected by two kinds of distortions: intensity distortions, which are deviations from the ideal linear relation between image intensity and backscattering strength of the materials on the seafloor, and geometric distortions, which correspond to discrepancies between relative location of features on the image and their true location on the bottom. Analysis of the distortions inherent in sidescan images and the development and validation of correctional algorithms requires ground-truth seafloor data to compare with the reconstructed imagery. However, in underwater acoustics this data is often difficult to obtain due to the nature of the underwater environment. This presentation describes the development of a Matlab® model for the simulation and generation of physically representative spatio-temporal echo data from a three-dimensional fractal model of the seabed topography and to permit direct visualisation of the composite sonar image formed from successive simulated echo lines. The goal of the simulation is to better understand system performance and limitations in terms of image resolution and accuracy and to assign a figure of merit for data. Individual sonar, environmental, and seafloor parameters can be isolated and altered during simulation to enable analysis and examination of the principle physical processes in isolation or in combination on the sidescan imaging process. Simulated backscatter and navigational data is recorded in XTF format and a Labview® graphical front-end is used for data visualisation as Labview is also used to interface to the actual sidescan sonar that is used for experimental validation of the simulated data.

Sedimentary environments in the Flower Garden Banks National Marine Sanctuary, Northwestern Gulf of Mexico Outer Shelf

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The distribution of sedimentary environments in East and West Flower Garden Banks National Marine Sanctuary and the surrounding seafloor has been mapped using multibeam bathymetry and backscatter data in conjunction with texture and carbonate content data from 107 sediment grab samples. The Flower Garden Banks lie in the northwestern Gulf of Mexico on the outer continental shelf about 170 km due south of the Texas-Louisiana border and comprise the northernmost tropical coral reefs in the United States. The tops of the reefs rise dramatically above the surrounding seafloor, some to within 20 m of the water surface. A fortuitous combination of biological, geological, and oceanographic factors (including uplift of rock strata by upward flowing salt diapirs, the formation of submarine brine pools, and currents that deliver larvae from Caribbean reef organisms) allowed the formation of these isolated reefs, making them a fascinating and important natural laboratory for interdisciplinary studies.

Four sedimentary environments were identified: 1. high-relief hardbottom, 2.) low-relief hardbottom, 3.) coarse-grained biogenic sediment, and 4.) fine-grained terrigenous sediment. The results are presented as shaded-relief maps and 3D perspective views. Texture and carbonate content of the sediments are correlated with their proximity to the high-relief hardbottom (living and dead reef) areas. Samples that were taken closest to the reefs (water depths between 70 - 120 m) have the highest carbonate content (generally >60%) and the coarsest texture (generally >50% sand or gravel). Those taken further from the reefs (water depths greater than 120 m) have less than 60% carbonate content and are finer-grained. This is expected because the coarse fraction is predominantly biogenic material derived from the reefs, whereas the terrigenous material is finer, being derived from distant continental sources, and dominates farther from the reefs. In

addition, winnowing of fine sediments from the reef areas by currents focused by the topography or as a result of higher energy conditions in the shallower water may contribute to the grain size difference.

The sediment maps presented here are being used in conjunction with additional biological, geological, physical oceanographic and chemical data to develop habitat maps of the Sanctuary.

Geographic database of deep-water coral habitats off Eastern and Southern United States

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The U.S. Geological Survey is compiling a Geographic Information System (GIS) of deep-water coral locations off eastern and southern United States. When completed, this database will enable easy visualization and analysis of the distribution of deep-water corals relative to other existing datasets and provide a basis for resource management decisions and planning of research activities. Analysis of the relationships between coral distribution and substrate geology, bathymetry, oceanographic parameters, and other data will further our understanding of the development of deep-water coral habitats and provide the infrastructure necessary for utilizing these corals for a variety of studies, such as paleo-climate change and predictive modeling of coral occurrences.

Data from published scientific literature is currently being compiled during the initial phase of the GIS development. Future phases will incorporate gray literature, anecdotal reports, and unpublished or in-progress research. Cooperation and collaboration with other government agencies, academic researchers, and private industry will ensure that a comprehensive, accurate, and interdisciplinary database will be produced.

Deep-water corals are important both for their intrinsic value (e.g., as potential pharmaceuticals) and for the complex habitat that they provide for other marine species. Although little is known about deep-water corals or their habitats off the eastern and southern U.S., at least one extensive deep-water coral habitat, Oculina Bank off eastern Florida, has supported a valuable reef fish fishery. Where similar ecosystems have been studied in northern Europe, they have been shown to provide important habitat for numerous species of marine organisms, some of which are valuable to commercial or recreational fishing industries. Deep-water corals are fragile and slow growing, making

them particularly vulnerable to human activities such as trawling, dumping of wastes, laying pipelines and cables, and oil and gas production operations. In order to manage and protect fragile deep-water coral ecosystems effectively, we need to know their locations, extents, and how their distribution has changed with time.

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

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The aim of the project is to carry out a survey of a selected offshore area to develop maps of sea bottom habitats. Following the survey the aim is to further develop a dialog with stakeholders and governmental authorities to use the achieved knowledge and, in the end, deliver results that can be used to set up a management plan for best fishing practices in the selected area. The selected area is situated in the Swedish economic zone and chosen because of indications of high biological values such as a being fishing ground for both recreational and commercial fisheries, reports that deep water coral reefs are present in the area, and because it provides a case where interregional interests operate and the fishery is under EU regulation.

One of the difficulties in studying and managing the offshore marine environment is lack of inventories of habitats and species of large areas. By the use of advanced techniques, i.e. multibeam scanning bathymetry and sidescan sonar, it is now possible to efficiently and in detail survey the seabed topography and structure. Together with biological groundtruthing and geological and biological interpretation of datasets, habitat maps can be developed. Virtually everyone involved in offshore activity will benefit from the results of such surveys - policy makers, industry, engineering, geologists, biologists, research groups e.g. universities, heritage and protection. Fish habitats are often controlled by the nature of the seabed, and fishery interests seek information which makes fishing more economical while minimising the environmental impacts of for example bottom trawling. The poster will present the ongoing project and results so far.

New marine geoscience and benthic habitat map products from the Geological Survey of Canada

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Within the Geological Survey of Canada, the Geoscience for Ocean Management Program (<http://gom.nrcan.gc.ca>) is developing a national sea floor mapping strategy. This strategy links with other Canadian federal government departments, academia, and the private sector to establish high-priority mapping areas. The focus on standard methods and standard outputs will facilitate the discovery and access to marine geoscience knowledge and data through web-based data discovery tools and enhance delivery of map products. A set of four “flagship” map sheets was produced for Browns Bank, a 3056 square kilometer area on the Atlantic continental shelf off Nova Scotia. The first two maps in the set are based on a regional multibeam sonar survey, and the latter two “value-added” maps are based on the multibeam data interpreted in conjunction with extensive geo- and bioscience groundtruth surveys. Sheet 1 shows the sea floor topography of Browns Bank in shaded relief view and colour-coded to depth. Descriptive notes detail the data collection, data display and the general geomorphology of the region. Sheet 2 shows coloured backscatter strength in shaded relief view. Descriptive notes outline the principals of backscatter strength and its relationship to sea floor geological materials, and depict the backscatter distribution in the map area. Sheet 3 shows sea floor topography in shaded relief view with colour-coded surficial geological units interpreted from geophysical profiles, sea floor photographs and sediment samples. Sheet 4 shows sea floor topography in shaded relief view with colour-coded benthic habitat. Statistical analyses of benthic fauna, identified to the lowest taxonomic level, distinguished habitats based on substrate, habitat complexity, current strength and water depth.

**Geo-habitat characterisation of deep-water coral mounds in the Rockall Trough,
west of Ireland.**

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The carbonate mounds, discovered in the mid-1990's on the Irish Continental Margin, are unique. It is not only their size (up to 300 m in height and 2-3 km in diameter), distribution (along the margins of the Porcupine Seabight, Rockall Trough, Fangorn Bank and Hatton Basin), abundance (> 1000 individual mounds) but also their association with deep-water coral species that has generated a great deal of interest in the scientific community. During the past 10 years a number of European Union funded projects concentrated their efforts on studying these deep-sea features. In spite of these concerted efforts, there still remains a great deal to be learnt regarding mound structure, dynamics and genesis. The basic questions why and how carbonate mounds are formed are still largely unanswered.

The CARACOLE (CARbonate And COLD water Ecosystems) Cruise in August 2001, was an Irish-French-EU inter-disciplinary research effort to study carbonate mounds and deep-coral reefs in the Porcupine Seabight and Rockall Trough, west of Ireland. The IFREMER led cruise aboard the French Research Vessel Atalante deployed the 'state of the art' remotely operated vehicle, Victor 6000 at a total of 5 mound locations. High resolution geo-referenced video and digital still photography accompanied by swath bathymetry on selected sites was used for detailed observation and mapping.

Two sites: the R1 site on the eastern margin of the Rockall Trough, and the R2 site located on the western margin of the Rockall Trough are being studied. Video and bathymetric analysis was carried out at both sites. The focus of the analysis was two fold: 1) Biological, encompassing the identification and mapping of coral habitats and associated species, and 2) geological which includes mapping of the morphology and nature (character) of the sea-bed. From the observations and analysis, preliminary models on mound formation, development and growth are put forward for discussion.

Terrain ruggedness analysis and distribution of boulder ridges in the Stellwagen Bank National Marine Sanctuary region, Gulf of Maine, New England

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The Stellwagen Bank National Marine Sanctuary, located off the coast of Massachusetts, is the focus of research directed toward the classification and mapping of seabed habitats. The sanctuary and surrounding region (3759 square kilometers) have been surveyed using multibeam sonar, video, photo, and geological and biological sampling techniques. Water depths range from 20 to 195 m. The sea floor is glacial in origin and displays highly variable topography and texture. During the last glacial advance, ice containing rock debris moved across the region, sculpting its surface and depositing sediment to form large basins, banks, ridges, and valleys. Other features were formed during the latter stages of deglaciation when much of the area was covered by stationary rotting ice, and when small valley glaciers and icefalls were active in and near areas of high relief.

As part of the seabed classification effort, the digital multibeam bathymetric data was analyzed using GIS techniques to quantify seabed ruggedness and to map sea floor features. One goal was to correlate ruggedness indices with areas having distinctive boulder ridges of glacial origin that are a characteristic of the region and that provide critical habitat for benthic fish species.

The Terrain Ruggedness Index (TRI) has been used by previous workers to compare the elevations of neighboring areas on land or on the sea floor. The TRI, as employed here, uses digital bathymetric data to calculate differences in elevation between neighboring small areas of the seabed. The TRI represents the average change in elevation between a center cell (image pixel) and its eight neighboring cells arrayed in a 3 x 3 pixel format. In

our data, each pixel represents an area 13 meters on a side. Therefore, the TRI shows the average change in elevation between a central pixel measuring 13 x 13 m (169 square meters) and the surrounding 8 pixels (1352 square meters). No part of the 8-pixel area lies more than 18.4 meters from the central pixel. The resolution of the bathymetric data set determines the resolution of the ruggedness indices that are generated by this analytical technique. For example, TRI indices derived from 13-meter pixel data are not necessarily comparable with TRI values of the same magnitude that have been derived from 10-meter pixel data.

The map region is characterized by topographic features of varying sizes and shapes. We have used a new approach to display seabed ruggedness values on maps so as to make it easier to visually delineate small complex features characterized by small average changes in elevation from large simple features with large average changes in elevation. Average changes in elevation (TRIs) are displayed on maps in ten-centimeter increments in the >0.3 to 1.0 m range, in half-meter increments in the >1 to 2 m range, and in one-meter increments in the >2 to 6 m range. Average changes in elevation less than 30 cm are not shown because they often represent noise in the bathymetric data.

Terrain ruggedness indices portrayed in 10 cm, 50 cm, and 100 cm increments (represented by 13 colors) are able to delineate relatively small but significant features (boulder ridges; irregular basin floors; deep elongate iceberg scours; sand dunes; low-angle slopes of banks, valleys, and basins) from large features (steep flanks of large banks bounding large basins; small banks separated by narrow deep basins; bank remnants that lie within large basins; steep bedrock hills). Seabed terrains with similar ruggedness indices do not necessarily represent similar bottom types. In the surveyed region, the least rugged seabeds (TRI of 0 to 30 cm) can represent relatively smooth mud, sand, or gravelly sand. More rugged seabeds (TRI of >30 to 100 cm) can represent boulder ridges, mud-draped gravel mounds, iceberg scours, or low angle slopes. The most rugged seabeds (TRI of >1 to 6 m) can represent steeply inclined flanks of sediment-covered banks or of bedrock outcrops. The Terrain Ruggedness Index is a

practical method for comparing differences in average seabed elevation to identify features, but without supporting topographic imagery, video and photographic imagery, and sediment texture analysis, it alone does not allow reliable interpretation or comparison of seabed compositions or feature shapes.

Boulder ridges were identified using several kinds of information that included the terrain ruggedness index (TRI), topographic imagery, seabed backscatter intensity, and video and/or photographic images of the seabed collected at 2868 stations. The TRI of boulder ridges lies in the >30 to 200 cm range. Backscatter intensity shows them to represent hard seabed. Video and photographic surveys reveal the ridges to have a rough surface of cobbles and boulders that touch and support each other in few places and are separated by voids (a defining characteristic) caused by the erosion of a sand and mud matrix that was present when the ridges were formed. Boulder ridges are typified by abrupt changes in elevation caused by the irregularity of boulder and cobble sizes. Boulder ridge polygons were digitized from topographic imagery using GIS techniques. They were divided into two groups, those less than 1 meter in height and those 1 meter or greater in height. Ridges in the second and larger group have an average height of 2.81 m and a maximum height of 18 m. Boulder ridges range up to 10s of meters in width and 100s of meters in length. The relatively few boulder mounds present range up to 10s of meters in diameter.

Topographic imagery shows boulder ridges and mounds to be irregular in plan view, to have sharply-defined crests, to be situated primarily on the tops and along the upper edges of banks and valleys, and to a lesser extent to lie in depressions that were formed by large stationary masses of melting glacial ice. They are accumulations of boulders and cobbles deposited by glacial processes to form eskers and moraines. Eskers are accumulations of sand and gravel deposited by running water within or beneath stationary glacial ice. Moraines are deposits of rock debris piled up at the edges of moving ice. The sand and mud that filled the spaces between the cobbles and boulders of the eskers and moraines have been eroded and transported away by currents during the post-glacial rise in sea level, leaving voids between the cobbles and boulders. At present, boulder ridges

lie at water depths of approximately 30 to 90 meters. Ridges that occur on bank tops and have relatively low profiles, poorly defined crests, and low TRIs are composed of a mixture of gravel and sand and generally do not display voids, possibly because they have a relatively low percentage of boulders. Ridges that occur in valleys and basins, and have TRIs similar to those of boulder ridges, do not have voids; their surfaces are partly veneered with sand and mud, and the matrix that separates cobbles and boulders has not been eroded.

Boulder ridges cover only 36.9 sq km, or approximately one percent, of the map region. However, the combination of hard substrate and voids that characterizes ridges provide habitats that are rich in structural complexity, both physical (cobbles, boulders, voids) and biological (sponges, bryozoa, hydrozoa, brachiopods, tunicates), and provide essential habitat for lobsters and groundfish such as redfish, cod, haddock, wolffish, cunner, and other species.

HERMES: Hotspot Ecosystem Research on the Margins of European SeasP.P.E. Weaver¹ and the HERMES Consortium¹Southampton Oceanography Centre, UK.Email: Phil Weaver ppew@soc.soton.ac.uk

HERMES is designed to gain new insights into the biodiversity, structure, function and dynamics of ecosystems along Europe's deep-ocean margin. It represents the first major attempt to understand European deep-water ecosystems and their environment in an integrated way by bringing together expertise in biology, geology, and physical oceanography, so that the relationship between biodiversity and ecosystem functioning can be understood. Study sites will extend from the Arctic to the Black Sea (Fig. 1) and include open slopes, where landslides and deep-ocean circulation affect ecosystem development, and biodiversity hotspots, such as cold seeps, cold-water coral mounds, canyons and anoxic environments, where the geosphere and hydrosphere influence the biosphere through escape of fluids, presence of gas hydrates and deep-water currents. These important systems require urgent study because of their possible biological fragility, unique genetic resources, global relevance to carbon cycling and possible susceptibility to global change and man-made disturbances.

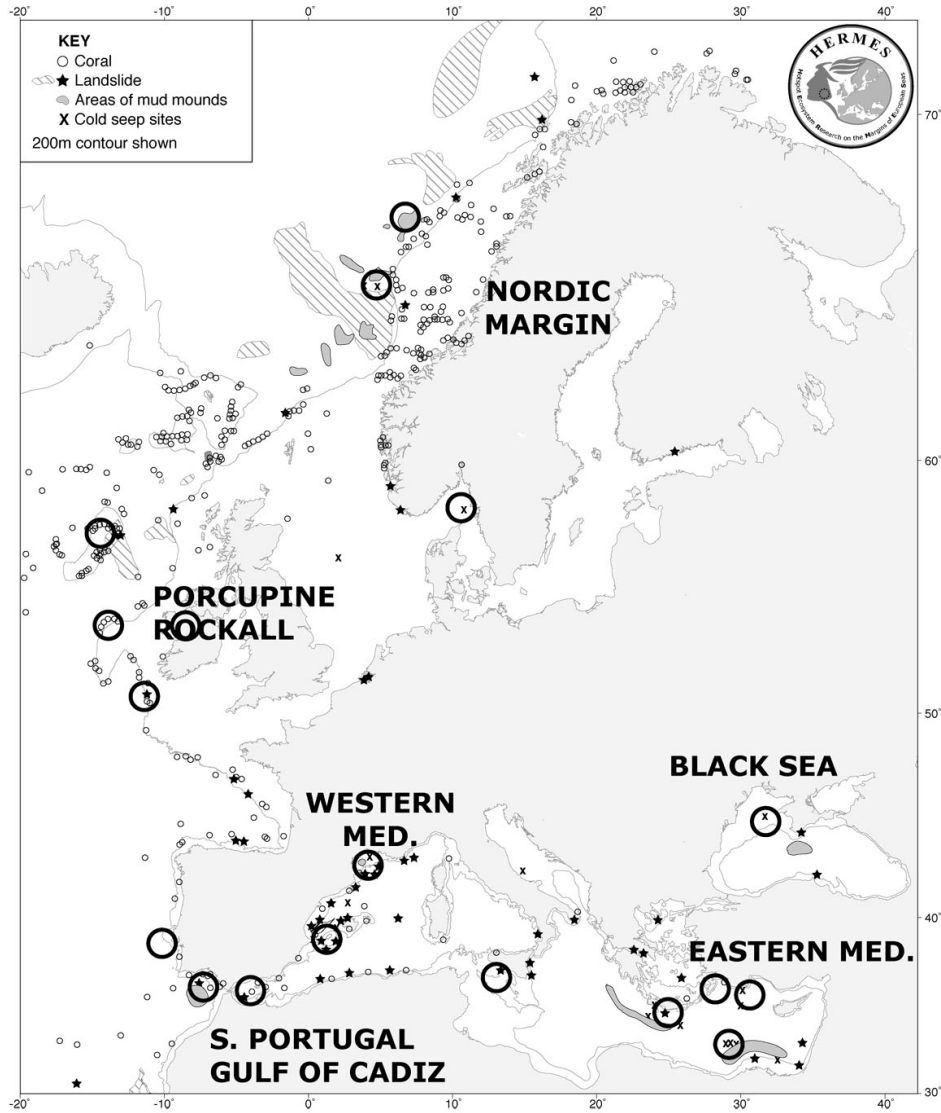


Figure 1: Map showing the HERMES study areas. Large open circles indicate specific study sites.

Zooming in on the Irish National Seabed Survey: what can it tell us about benthic habitats?

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Multibeam bathymetry and backscatter data acquired under the Irish National Seabed Survey (INSS) have recently been made available to researchers at the National University of Ireland, Galway. These data are being assessed for their utility in the production of geohabitat and resource maps along the Irish continental margin.

Benthic habitat is determined primarily by substrate type (sediment or rock) which reflects past and present physical processes in the near-bottom environment. The substrate determines to a large extent the presence or absence of a particular benthic species and modifies the effect of disturbance on the benthic community. Establishing a link between habitat identification and surficial geology (generated using acoustic remote sensing techniques) permits the realistic application of habitat classification schemes which is a fundamental step in the management of offshore marine benthic resources. The INSS multibeam survey has provided unrivalled coverage of Ireland's offshore territory, however the geometry of the system means that the resolution of the data decreases with depth which has consequences for its use in habitat mapping. Here we present some data examples illustrating the bathymetric detail visible at a variety of depths on the Irish continental shelf and slope.

As we move beyond the continental shelf into deeper waters the resolution from these remote surveys quickly diverges from the sub-metre detail relevant to the characterisation of benthic communities. This suggests that the use of near bottom acoustic survey techniques may be required to bridge the gap between the INSS remotely sensed data and ground truthing data collection (video or benthic sampling devices). Examples are presented elsewhere (e.g. Foubert *et al* (2004)) of successful ROV deployed multibeam

microbathymetry surveys at depth. Remotely Operated Vehicles (ROVs) offer an attractive, non-destructive means by which to obtain this detail, especially since they can serve as a platform for the acquisition of both near bottom acoustic and video data.

Conclusions

The INSS has provided an excellent baseline dataset from which geohabitat and resource maps can be developed and more detailed surveys planned. It is important that spatial scale and pattern is considered when designing groundtruthing surveys and benthic monitoring schemes. Optimal survey designs and mathematical analysis methods from research areas including landscape ecology and shallow water surveys are being considered and modified for the deep sea environment, using remote and *in situ* techniques as appropriate with due regard for operational logistics prior to upcoming field programmes.

Acknowledgements:

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GeoHAB 2004

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