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Workshop Proceedings

ALLIANCE FOR COASTAL TECHNOLOGIES

ACOUSTIC REMOTE SENSING TECHNOLOGIES FOR COASTAL IMAGING AND RESOURCE ASSESSMENT

Moss Landing, California
May 10-12, 2004

Funded by NOAA's Coastal Services Center through the Alliance for Coastal Technologies (ACT)

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An ACT 2004 Workshop Report

A Workshop of Developers, Deliverers, and Users of Technologies for Monitoring Coastal Environments:

Acoustic Remote Sensing Technologies for Coastal Imaging and Resource Assessment

Moss Landing, California
May 10-12, 2004

ALLIANCE FOR COASTAL TECHNOLOGIES

Sponsored by the Alliance for Coastal Technologies (ACT) and NOAA's Center for Coastal Ocean Research in the National Ocean Service.

Hosted by ACT Partner organizations Moss Landing Marine Laboratories (MLML) and the Monterey Bay Aquarium Research Institute (MBARI).

ACT is committed to develop an active partnership of technology developers, deliverers, and users within regional, state, and federal environmental management communities to establish a testbed for demonstrating, evaluating, and verifying innovative technologies in monitoring sensors, platforms, and software for use in coastal habitats.

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ACT Workshop: Acoustic Remote Sensing Technologies for Coastal Imaging and Resource Assessment

Executive Summary

The Alliance for Coastal Technologies (ACT) Workshop on **Acoustic Remote Sensing Technologies for Coastal Imaging and Resource Assessment** was convened May 10-12, 2004 at Moss Landing Marine Laboratories in Moss Landing, California with partnership from Moss Landing Marine Laboratories (MLML) and the Monterey Bay Aquarium Research Institute (MBARI).

The goals of the workshop were to: 1) convene a representative sample of the scientific community involved in research, management, and data collection within the coastal zone of North America to review the current state-of-the-art in seafloor and terrestrial acoustical imaging technologies, methodologies, and mapping techniques, 2) identify weaknesses in data collection (both technology limitations and regional implementation) within the shallow water coastal zone, and 3) stimulate discussion of how better imaging and monitoring techniques for the coastal zone can be designed.

Much of today's acoustic imaging technologies are oriented toward either deep-water (>30 m deep) bathymetric imaging or terrestrial topographic imaging. Significant advancement has recently been made in these fields. However, the most critical region in need of imaging and mapping is where sea meets land. This dynamic zone has proven the most difficult area to obtain high-quality, high-resolution data necessary for appraisal, management, and exploitation of its natural resources. The intent of workshop participants was to review benthic habitat and resource mapping technology in order to address the increasing demand to appraise and manage marine and coastal resources (both living and non-living), as well as to monitor this very dynamic part of the continental margin.

Workshop participants made several recommendations for technology developers, users, and managers: 1) to develop a cost-effective way to collect bathymetric/backscatter data that are of intermediate resolution over a large areal extent; 2) to use vessels of opportunity (such as fishing boats, coast guard and research vessels) outfitted with mapping systems, to address the broad-based, first-order informational needs for habitat characterization and monitoring; 3) to develop a consortium of users with pooled funds to cover surveys; 4) to develop modeling and/or statistical survey design methods to map relatively small representative coastal segments that could then be used to predict habitat characteristics over broader areas; and 5) to optimize methodologies that already exist, apply them to priority areas, then advocate for funding surveys in other regions of interest.

ALLIANCE FOR COASTAL TECHNOLOGIES

There is widespread agreement that an Integrated Ocean Observing System (IOOS) is required to meet a wide range of the Nation's marine product and information service needs. There also is consensus that the successful implementation of the IOOS will require parallel efforts in instrument development and validation and improvements to technology so that promising new technology will be available to make the transition from research/development to operational status when needed. Thus, the Alliance for Coastal Technologies (ACT) was established as a NOAA-funded partnership of research institutions, state and regional resource managers, and private sector companies interested in developing and applying sensor and sensor platform technologies for monitoring and studying coastal systems. ACT has been designed to serve as:

- An unbiased, third-party testbed for evaluating new and developing coastal sensor and sensor platform technologies,
- A comprehensive data and information clearinghouse on coastal technologies, and
- A forum for capacity building through a series of annual workshops and seminars on specific technologies or topics.

The ACT workshops are designed to aid resource managers, coastal scientists, and private sector companies by identifying and discussing the current status, standardization, potential advancements, and obstacles in the development and use of new sensors and sensor platforms for monitoring, studying, and predicting the state of coastal waters. The workshop goals are to both help build consensus on the steps needed to develop and adopt useful tools while also facilitating the critical communications between the various groups of technology developers, manufacturers, and users.

ACT Workshop Reports are summaries of the discussions that take place between participants during the workshops. The reports also emphasize advantages and limitations of current technologies while making recommendations for both ACT and the

ACT Headquarters is located at the UMCES Chesapeake Biological Laboratory and is staffed by a Director, Chief Scientist, and several support personnel. There are currently seven ACT Partner Institutions around the country with sensor technology expertise, and that represent a broad range of environmental conditions for testing. The ACT Stakeholder Council is comprised of resource managers and industry representatives who ensure that ACT focuses on service-oriented activities. Finally, a larger body of Alliance Members has been created to provide advice to ACT and will be kept abreast of ACT activities.

broader community on the steps needed for technology advancement in the particular topic area. Workshop organizers draft the individual reports with input from workshop participants.

ACT is committed to exploring the application of new technologies for monitoring coastal ecosystem and studying environmental stressors that are increasingly prevalent worldwide. For more information, please visit www.act-us.info.

GOALS FOR THE WORKSHOP

The workshop was intended to:

1) Convene a representative sample of the scientific community involved in research, management, and data collection within the coastal zone of North America to review the current state-of-the-art in seafloor and terrestrial acoustical imaging technologies, methodologies, and mapping techniques,

2) Identify weaknesses in data collection (both technology limitations and regional implementation) within the shallow water coastal zone, and

3) Stimulate discussion of how better imaging and monitoring techniques for the coastal zone can be designed.

The intent of workshop participants was to review benthic habitat and resource mapping technology in order to address the increasing demand to appraise and manage marine and coastal resources (both living and non-living), as well as to monitor this very dynamic part of the continental margin.

WORKSHOP STRUCTURE

The Acoustic Remote Sensing Technologies Workshop was held from May 10-12, 2004 at Moss Landing Marine Laboratories (MLML) in Moss Landing, California. The workshop was sponsored by the Pacific Coast ACT partnership comprised of MLML and the Monterey Bay Aquarium Research Institute (MBARI). An opening reception was held for participants the first evening at the Embassy Suites in Seaside, California. Over the following two days, participants convened at MLML for plenary talks about the challenges and needs for acoustic remote sensing technologies in coastal habitats (Appendix A).

There were 41 attendees (Appendix B) who were selected to include equal representation from three segments of the community: researchers, commercial vendors, and managers. In the afternoon, after the plenary sessions, participants were separated into three groups that included each of these communities. During these breakout sessions, all groups were asked to address the same set of questions/issues. After each breakout session, all participants were reconvened to compare recommendations among groups.

OVERVIEW OF EXISTING ACOUSTIC REMOTE SENSING TECHNOLOGIES

Acoustic technologies have enhanced the description of submerged terrains since the introduction of active sonar technology in the mid-1910's. Application of this base sensor technology continues to expand by improvements in acoustic sensor transducer-receiver design, deployment geometries and importantly, by innovations in digital signal processing electronics that now permit generation of near real-time imagery of the seabed. Improvements to global positioning system (GPS) receivers and increased access to differential GPS signals have enabled placing these acoustic image products in a reliable geospatial framework. These continuing advances have been leveraged by users to move beyond basic bathymetric mapping to classification of static and dynamic geological properties of the seabed that in turn permit generation of data products for monitoring coastal evolution and resources, describing consequences anthropogenic activities in the coastal zone, defining critical fisheries habitats and mapping of submerged navigational and environmental hazards and potential threats to homeland security.

While acoustic remote sensing represents a relatively mature field of technology, there is a wide range in the capacities for user-friendliness, improved resolution, deployment/survey design constraints and costs associated with different acoustic sensing tools. There were repeated requests during the workshop to provide a 'toolbox' summarizing the advantages and limitations of various acoustic technologies that could be leveraged by program and resource managers in their decision making process for submerged habitat and resource characterization. The information provided in Table 1 is gleaned from several recent reports (Kenny, et. al. 2003, Waddington and Hart 2003; NRC 2004), and highlights the importance of implementing coordinated ground-truth efforts in benthic survey design and data interpretation. Some shoreline, surf zone and adjacent shallow water survey regions may also benefit from integration of in-water acoustic data sets with emerging airborne optical imaging techniques such as active LIDAR (Light Detection And Ranging) and passive spectroscopic imaging sensors such as PHILLSII (Passive Hyperspectral Imaging Low Light Sensor).

A variety of acoustic seabed-mapping technologies are in routine operation at present and can be listed in order of increasing signal complexity as follows: (i) ground-discriminating single beam echo sounders (AGDS) and fish-finding echo sounders (the latter was the focus of the ACT Workshop "Developing Acoustic Methods for Surveying Groundfish" ACT-03-01), (ii) broad-single-acoustic beam swath systems, such as side-scan sonar (SSS), (iii) multiple narrow-beam swath bathymetry and backscatter systems or multi-beam echo-sounders (MBES), (iv) multi-beam side-scan sonars and (v) sub-bottom profilers. Representative imagery generated by these acoustic technologies is provided in Appendix C as Figs. 1 to 3.

TABLE 1. A toolbox of operational acoustic technologies for characterization of submerged habitats, hazards and geological resources, including required ground-truth measurements. The majority of the sensor performance characteristics are beam geometry, survey speed and depth-dependent and values are therefore provided as operational ranges.

Technology	*Areal Coverage (Km^2/h)*	*Operational Depth (m)*	*Feature Resolution (m)*	*Survey Costs* (~$ / day)*	*Direct Data Products*	*Ground-Truth*
Single beam echo sounder	1.5	>1	1% water depth	2,000	Line bathymetry, Bottom roughness, hardness	Grabs, Video, Acoustic signal calibration
Multibeam echo sounders	2-500	>5	0.1 - 100	9,000	Swath bathymetry, Seafloor texture, slope relief	Grabs, Video, Acoustic signal calibration
Side-scan sonar	3.5	>5	0.1 - 1	3,000	Object detection, seafloor morphology, sedimentary textures	" + bathymetric surveys
Chirp Side-scan sonar	10	5-100	0.1 - 1	3,500	Object discrimination, seafloor morphology, sedimentary textures	"
Synthetic Aperture sonar	3.0	>5	0.001-0.1	8,000	High resolution object discrimination, sedimentary textures	"
Multibeam Interferometric Sonar	3.0	>1	1 - 100	5,000	Swath bathymetry, high resolution seafloor texture	"
Sub-bottom Profilers	1	>5	0.1 - 100	2,500	Geological structure, seismic stratigraphy, texture	Grabs, cores, dredges
Bathymetric LIDAR	> 10	0 – 30 m	>2	50,000	Swath bathymetry, object detection, topography	Overlapping multibeam surveys

* Due to variable size requirements costs do not include vessel time or mobilization costs; post-acquisition data processing costs have not been included. All costs reported in 2004 US dollars.

Following a series of plenary talks highlighting current developments in acoustic data acquisition, data management and visualization and application to resource, habitat and hazard assessment (see Appendix A), working groups were charged with developing consensus answers to the questions related to the application of acoustic technologies in nearshore environments. The three discussion topics are provided as headlines to the following sections.

As a group it was decided that nearshore environments would be defined as regions landward of the 30 m isobath, as this region represents the greatest overlap in practical working zone of the existing bottom mapping technologies, a highly dynamic environment and also a region subject to state and federal jurisdiction depending on bottom topography.

BREAKOUT GROUP DISCUSSIONS

I. WHAT ARE THE CHALLENGES AND LIMITATIONS OF ACOUSTIC REMOTE SENSING TECHNOLOGIES FOR MONITORING NEARSHORE ENVIRONMENTS?

Current acoustic technology is sufficient to image coastal regions (<30 m depth), but these surveys are aided by complementary optically based surveys such as LIDAR, camera sleds, SCUBA and ROV supported video and still camera systems. An inshore limit is often imposed on acoustic surveys due to many reasons. It becomes more expensive to cover the same amount of ground in very shallow water as compared to deep water. For a given angular aperture, the swath width becomes narrower in shallow water and more lines are required to cover the same area than in deeper water. The presence of subtidal hazards such as rocks, and macrophyte dominated habitats impede boat operations near shore. Critically, the generally higher turbidity (suspended sediment and wave induced microbubbles) and increased swell nearshore contribute to a reduction in data quality due to lower signal to noise ratio and subsurface positioning accuracy. Ecosystem information, complete habitat description, was recognized as being critically important end product of all survey efforts.

Potential *disturbance of marine mammals is becoming more of a concern* and may also be an impediment to routine acoustic surveys. While this is more obviously associated with big air guns and deep seismic reflection surveying tools, it may become an issue for high frequency acoustic bathymetric surveys also.

In order to ensure data longevity and usefulness, data collection formats should be open (not proprietary) and algorithm descriptions should be publicly available. Standard data formats are also desirable but less critical. To calibrate backscatter data, instrument calibration information and processing parameters are needed. Manufacturers should provide transmit/receive beam patterns, absolute dB levels as well as source and receiver sensitivities. Shallow-water spatial velocity models are needed for consistent data processing.

Bathymetric LIDAR such as SHOALS (Scanning Hydrographic Operational Airborne LIDAR System), may be more cost efficient for mapping the 30 m and shallower water depth zone. This in part relates to LIDAR's ability to tie datasets across the surf zone to subaerial datum, thus allowing for construction of seamless maps across the coastline (Appendix C, Fig. 4). However, acoustic and optical backscatter signals are modulated by different sets of inherent in-water properties; in fact, in highly turbid water acoustic methods may be the only option for bottom characterization. Additionally, mobilization may be less expensive and survey data easier to obtain using acoustic technologies compared to LIDAR surveys (boat vs. plane). There was a strong desire among the group for ongoing development of optical (LIDAR) systems. The participants voiced the need to continue to encourage technology transfer of both acoustic and optical systems, identify procedures to reduce survey costs, and the technology easier to use.

The workshop participants also recognized that there is a distinct possibility that valuable acoustic data is being lost as water column returns are not normally recorded. This would be particularly true in the more heterogeneous and dynamic nearshore and estuarine waters were returns from fish, zooplankton and submerged vegetation may comprise a significant fraction of the acoustic signal. Therefore it was strongly recommended that monitoring of water column acoustic returns be routinely employed as part of all future survey efforts and that increased efforts be devoted to development of processing protocols to enable delineation of water column and seafloor returns in these habitats.

II. ARE CURRENT MAPPING METHODOLOGIES SUFFICIENT FOR COASTAL HABITAT CHARACTERIZATION AND MONITORING? WHAT IMPROVEMENTS IF ANY ARE NEEDED?

The consensus was generally that existing instruments and technology were adequate, but that the main focus should be on figuring out how to best use them. While acoustic and optical methodologies to map coastal habitats continue to develop and evolve, mature technologies already exist that if deployed in coast-wide efforts would greatly improve our understanding of coastal habitats, at least from a fisheries resource perspective. It was recognized that effort needs to be mobilized to ensure sufficient funding to apply these existing technologies at survey resolutions useful to resource managers for habitat characterization and monitoring over more of the coastal zone. The group felt that acoustic remote sensing applications were not currently limited by the tools available but more critically by the frequency and spatial extent of current survey efforts; these limitations could be resolved to some extent by developing standard protocols to help reduce survey and data processing costs.

Habitat mapping, even at the resolution to discern basic categories of rock and substrate types from soft sediment, is not currently taking place on a broad spatial scale coastwide. Mapping biogenic components of habitat at higher resolution is possible (Appendix C, Fig. 5), but is not being conducted broadly. Mapping the coastal area of the United States is a huge task (estimated to be on the order of 500+ yrs to map with multibeam at a 1-m grid resolution). Access to a variety of survey tools will be useful in expediting this task, however, there are trade-offs among speed of survey, resolution, area covered, and cost. To make improvements, adding a temporal component to habitat mapping in order to 'monitor', collecting more data, and using satellite-based Altimeric Bathymetry from Sea-surface Slopes (ABYSS; http://fermi.jhuapl.edu/abyss/ 90-m resolution) were suggested.

Existing technologies provide an opportunity to develop 3D water column models by integrating data from CTDs and other sensors with bathymetric data to more fully describe coastal ocean environments and to understand pelagic as well as benthic habitats. There is a need for systematic monitoring of bottom currents, turbidity sediment transport and related temporal change to habitats (Appendix C, Fig. 6).

Whether current mapping technologies can be implemented into regional Integrated Ocean Observing System (IOOS) efforts was addressed. It was agreed that this could be done with regard to equipment, but that we need to define and standardize survey procedures to insure quality and improved processing techniques. The benthic survey deployments of the Autonomous Benthic Expolorer (AUV ABE: http://oceanexplorer.noaa.gov/technology/subs/abe/abe.html) and technique and the CIBE classification algorithm address this for bathymetry editing.

There is a desire for higher resolution in ship-mounted mapping sonars (e.g. very small multibeams, chirp multibeam, or synthetic aperture side-scan/interferometry sonar), improved backscatter processing, and auto-classification. In deeper water, AUV's are important for getting high frequency sonars near the bottom. Knowledge of the seafloor is fundamental - mapping will be a component of any credible IOOS. Sub-bottom geophysical data is also required for most habitat surveys. Active scanning sonars can be used to detect and differentiate fish. IOOS efforts could include acoustic arrays to directly monitor fish stocks and should address geo-hazards particularly in near-shore waters.

Types of habitat survey tools viewed as useful components of regional IOOS monitoring efforts include AUVs deployed from fixed facility; inverted echo sounders; time-lapse video; forward-looking sonars; ADCPs. Underwater cabled networks such as the NEPTUNE and MARS Programs (http://www.mbari.org/mars/new/overview.html), with a series of underwater cables and nodes provide an ideal deployment platform for these habitat monitoring systems. However, little consideration has been given to coastal systems and processes within these undersea cable observatory programs. It is critical to make sure that underwater cable observatory programs address coastal problems and the workshop participants recommended that ACT help advocate for the collection of coastal information from these systems.

III. WHAT ARE THE IMPEDIMENTS TO IMPLEMENTATION OF ACOUSTIC TECHNOLOGIES FOR ROUTINE MONITORING AND MANAGEMENT EFFORTS IN THE COASTAL ZONE? WHAT ARE POSSIBLE SOLUTIONS?

First, a consensus was reached that there were substantial economic drivers that should be leveraged to promote expanded acoustic surveys of nearshore environments. These drivers include: 1) monitoring of coastal processes such as shoreline evolution and identification of beach replenishment resources and sinks; 2) characterization and identification of fisheries habitats and 3) harbor maintenance and identification of navigational and environmental hazards. It was recognized that these economic issues have fundamentally different user and manager bases and therefore it is critical to educate all concerned parties on the utility of geo-referenced data sets and use of their associated metadata.

Workshop participants identified that there are many critical "next steps" required to ensure progress is made towards characterization of nearshore benthic environments in the coastal zones of North America. First, regulators, managers, and ultimately politicians need to be convinced of the need to fund broad area bathymetric and backscatter/side-scan sonar mapping of coastal zones. This might be accomplished by publicizing the importance of mapping of benthic environments so it can become a political priority. The recent National Research Council report "A Geospatial Framework for the Coastal Zone" (NRC 2004), provides an excellent first step toward integration of coastal zone user needs.

Participants suggested that an inventory of available nearshore habitat data be conducted as a means to ensure that efforts are not duplicated unnecessarily, and that future mapping projects among government agencies and private institutions be coordinated to maximize data value and coverage. It was also recommended that funding agencies and private sector groups be brought together with scientists and technical industry specialists to determine user needs, standardize protocols for data collection, and to share data.

Workshop participants stressed the necessity to identify a "standard" set of requirements for field programs. Most importantly, to define these in terms of data required, as opposed to tools to use. Flexibility is needed to address changing geologic conditions and the tools required to obtain the necessary data. Another critical next step would be to establish a good set of "descriptors" from various user groups (oceanographers, ecologists, geologists, biologists, etc.) and parameters of interest (vegetated, mud, bedrock, cold, warm, on-bottom, above-bottom, surface, mid-water, etc). This should lead to the establishment of a continuum of characteristics, measurements, and standards necessary for all expert users so subsequent users will know how to interpret the data, understand the results, and to appropriately use existing data products or enhance the information value for their needs. It was suggested that manufacturers and developers could facilitate this move towards standardization by providing easier access to calibrated acoustic signals thereby facilitating the development of cross-survey classification algorithms.

Most of the remote sensing tools and the software used to analyze these data sets require ground-truthing. Thus a demand exists to update ground-truth techniques. As some remote sensing devices can infer physical properties of the seafloor and can collect data in locations that are difficult to physically occupy, a need to develop more sophisticated means to verify the results exists. It was suggested that ACT help promote the continued development of seafloor ground-truthing technologies. Additionally it was suggested that ACT should support the continued refinement and development of recommendations for standards, common data formats, and protocols for data acquisition, processing, archiving and distribution of seafloor imagery data, as well as promote education of the user community on validation processes available for new acoustic and optical survey techniques.

It is important to identify organizations that are engaged in acoustic remote sensing data collection and warehousing (such as NOAA's Coastal Services Center, National Geophysical Data Center, and the Minerals Management Service) to ensure that future data collection efforts meet common goals. Future workshops are important to insure that all remain aware of technology improvements and to make data from current nearshore mapping projects available to the larger scientific community.

Workshop Recommendations

- Develop a cost-effective way to collect bathymetry / backscatter data that are of intermediate resolution over a large areal extent (that is, between the very low resolution bathymetry information we now have throughout the EEZ and the high resolution [m-scale] data coverage available for only a few regions).
- Use vessels of opportunity (such as fishing boats, coast guard, and research vessels) outfitted with mapping systems, to address the broad-based, first-order informational needs for habitat characterization and monitoring. This type of collaboration is becoming more feasible with increasing shared management of resources between fishing industry and governments. [Estimated $15 million to outfit 100 boats with necessary equipment and training; there would be ongoing needs for sensor calibration and standardization].
- Develop a consortium of users with pooled funds to cover surveys. [This is already happening within NOAA: NOAA's Multibeam Mapping Working Group comprises several offices that share common objectives and priority mapping areas, but participation of university and private sector researchers is also critical].
- Develop modeling and/or statistical survey design methods to map relatively small representative coastal segments that could then be used to develop algorithms for predicting habitat characteristics over larger areas sharing coarse geophysical features.
- Optimize survey and sampling methodologies that are already in use, apply these standard methods to areas of priority as proof of concept, then advocate for funding broader regional survey efforts.

Charges for ACT

Participants discussed how ACT could best support future efforts towards continued development, refinement of existing acoustic remote sensing technologies or integration of acoustic with other technologies for monitoring coastal environments. It was suggested that ACT:

- Continue to provide opportunities for end users and manufacturers of these technologies to come together to discuss the needs and capabilities of existing and future remote sensing tools.

- Establish a series of forums or a clearing house which would provide a timely dissemination of information on what's in progress, what looks promising, what hasn't worked well (because technologies are often being developed which are years from reaching the published literature).

- Help determine what "end users" see as the most critical pieces of missing information and secure their cooperation in obtaining funding for R&D on the tools needed, or commit to using such tools if someone is willing to develop them.

- Convey the needs of mappers to the developers of technology and translate the physics to a point where someone other than an electrical engineer can understand the differences in systems.

- Facilitate organization of a consortium of potential researchers and users of coastal imagery data for the purpose of pooling funds and daisy-chaining surveys to maximize cost effort and regional diversity of data.

CONCLUSIONS

The general consensus of the participants attending the workshop was that technology exists today to adequately map marine benthic habitats, yet the methodology to fuse various nearshore and coastal data sets such as acoustics and optical data needs to be developed. However, it was agreed that the technology needs to be pushed to the point where new observations can be made such as distinguishing water column acoustic returns from seafloor returns and to determine if useful data is being lost either in acquisition or in processing. It was generally agreed that the present day accuracy of the technology allows for a four-dimensional (time being the fourth-dimension) acoustic mapping ability that would allow for time-series analyses in the dynamic coastal environments and that this type of mapping should be encouraged.

In addition, the participants strongly urged that protocols be established that would standardize the calibration or acoustic instruments used in imaging the seafloor, in a sense to determine a standard for normalized vs. calibrated data. In this regard, baseline studies would need to be undertaken and a "proving-ground" or test-bed established where verification of various seafloor-imaging instruments (different types and manufactures) can be accomplished using a well-known and stable substrate. It was suggested that perhaps even a seal of approval of some type be established for such instrument testing, yet not much enthusiasm existed for taking this on or suggesting who or what organization would be best suited to accomplish such a task. However, to initiate such an effort it was suggested that ACT support a literature search of instruments already tested and present the information on a web site, thus acting in its capacity of a clearinghouse on coastal technologies.

Of considerable importance to the managers and potential funding entities at the workshop was the lack of ability to accurately determine the economics of seafloor surveys. It became apparent that a need exists for establishing a cost analysis table from which such things as cost per scale, resolution per cost, productivity vs. time, or economics vs. goals can be determined as most funding entities consider present day seafloor imagery surveys extremely expensive. In this regard, it was suggested that ACT assist in the formation of a capacity building consortium that could bring interested groups and funds together for the purpose of supporting multipurpose surveys, thus reducing the cost to the individual participants. However, industry representatives stated that the end-users of data need to inform industry of what the political and economic drivers are, from a management perspective, for the collection and interpretation of seafloor imagery data. They suggested that ACT support a survey of the end-users to determine the various uses of the data and the critical objectives to be addressed by the interpretation of the data.

Although the establishment of a standard habitat characterization scheme was desirable and considered valuable, the participants felt that several investigators were generally addressing this and that NOAA and other organizations (i.e., Center for Habitat Studies, Moss Landing Marine Laboratories) were well underway to formalizing such a scheme. However, the participants expressed a desire to see a standard interpretive protocol be developed where a universal web- and GIS-based tool kit is used in the interpretation and presentation of seafloor imagery.

A general recommendation was made by the academic participants to encourage industry to release seafloor imagery data sets useful for marine benthic habitat mapping and seafloor resource assessment. Historical data sets would be extremely valuable for time-series analyses and might set a base to work from. It was suggested that ACT could be the advocacy organization for the collection and digitization of such data sets.

Finally, it was shown that the process of acoustically imaging the nearshore and fusing coastal optical datasets has significant application to homeland security. Obtaining knowledge about the coastal and nearshore areas of the US, which this workshop addressed, is beneficial to appraising the accessibility of coasts and determining appropriateness for transgression. This type of assessment is particularly significant when selecting areas to focus security resources.

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Photograph of ACT Acoustic Remote Sensing Workshop Participants
Martin's Point of View,
Moss Landing Marine Laboratories, Moss Landing, California
10-12 May 2004

This document is dedicated to the memory of Clive Moody who substantially contributed to the workshop but sadly and unexpectedly passed-away shortly after the meeting.

APPENDIX A. PLENARY SESSION TALKS

Speakers	Topic
Gary Greene	ARS Workshop Goals and Structure
Pete Dartnell	Characterizing the Seafloor Using Multibeam Bathymetry and Backscatter Data
David Caress	The MB System: Open source for processing multi-beam sonar data
James Case	Mapping techniques developed at the University of New Hampshire
David Millar	Airborne remote sensing techniques in mapping nearshore coastal environments
Keith Vickery	"Normalized" backscatter with co-located geoencoded bathymetry - Will it lead to more automated classification?
Pat Iampietro	Algorithmic analyses for seafloor classification being developed at CSUMB
Mary Elaine Dunaway	The need for non-living resources appraisal and monitoring
Judd Muskat	Role of ARS in defining threat from sunken vessels in coastal waters

Mid Workshop Talks

Speaker	Topic
Bill Collins	Single channel echosounder techniques & the QTC seafloor classification system
Hank Chezar	USGS Sediment Eye Camera System
Doug Lockhart	Snippets technology for multibeam backscatter processing

Copies of the presentation files are available upon request from jsmith@mlml.calstate.edu

Appendix B. Workshop Participants

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Appendix C. Examples of Acoustically and Optically Derived Imagery of Coastal Zone Environments

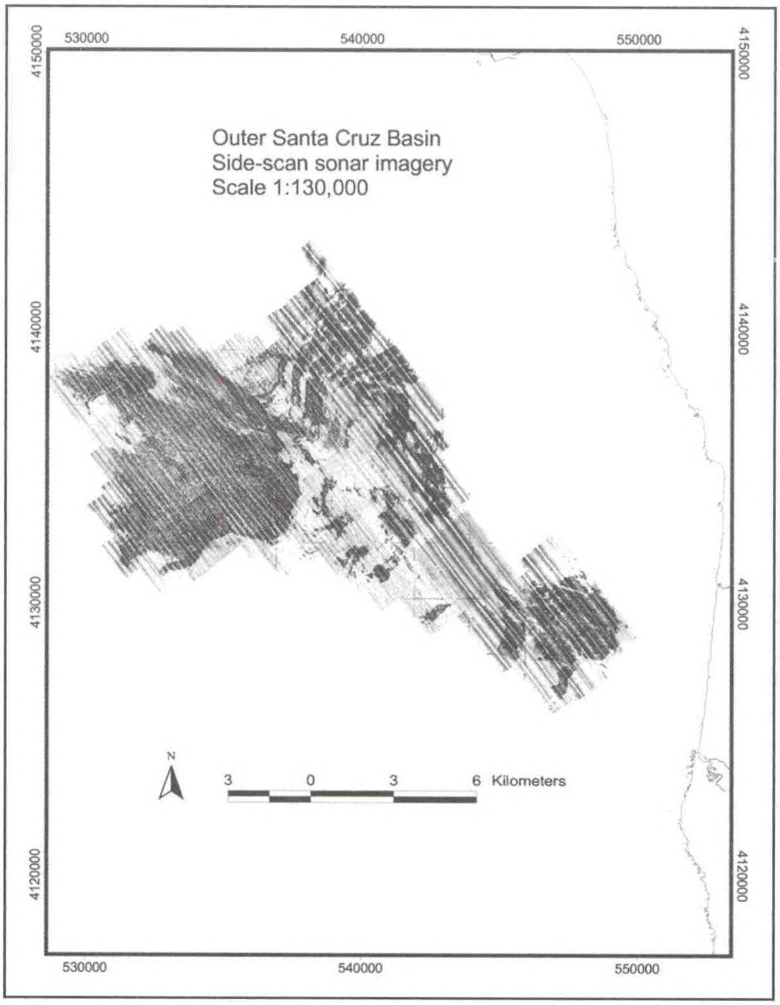

Figure 1. Example of side-scan sonar data collected by industry (*General Oceanographics*) offshore Half Moon Bay, California. Dark regions represent areas of high backscatter, likely hard substrate.

APPENDIX C. EXAMPLES OF ACOUSTICALLY AND OPTICALLY DERIVED IMAGERY (CONTINUED)

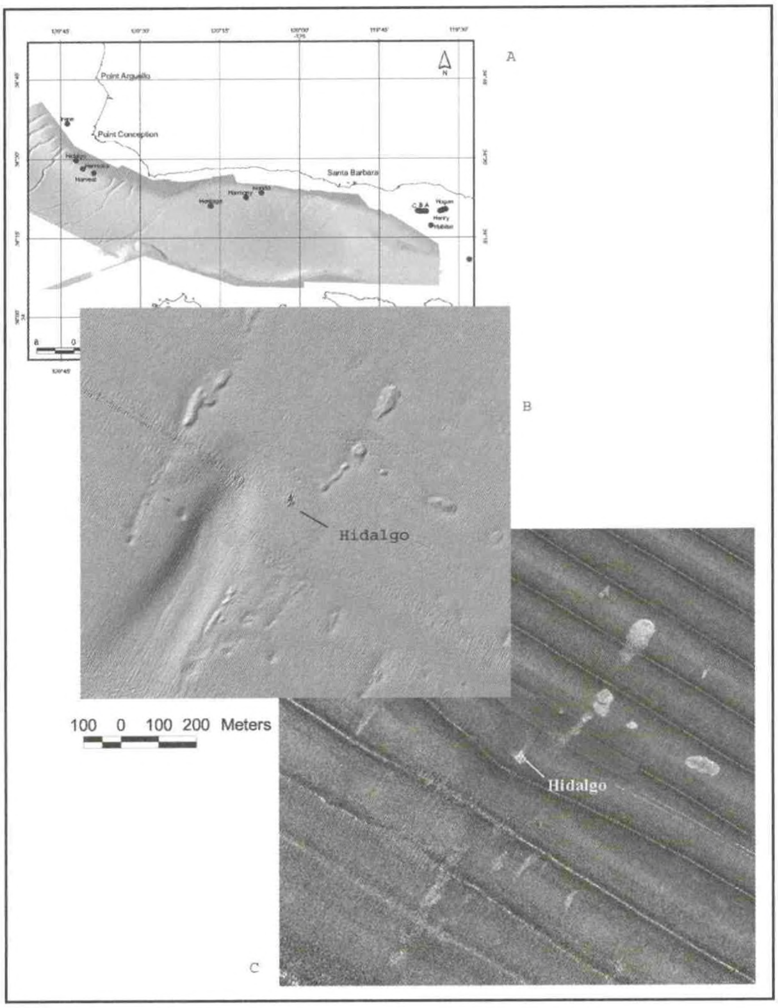

Figure 2. Example of a larger area acoustic survey offshore of Point Conception and submerged object detection. Hildalgo and other points represent oil platforms in this region (A). Detail of sun-shaded multibeam bathymetry (B) and backscatter (C) data (EM 300, 30 kHz) collected offshore. Images courtesy of *MBARI*.

APPENDIX C. EXAMPLES OF ACOUSTICALLY AND OPTICALLY DERIVED IMAGERY (CONTINUED)

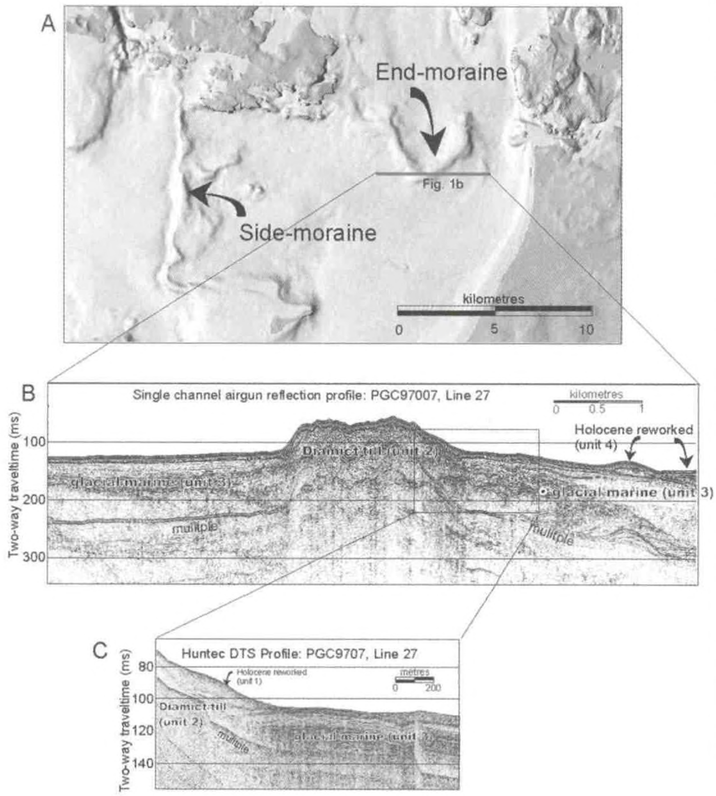

Figure 3. Example of intermediate (B) and high resolution (C) subbottom seismic reflection profiles collected in the NE Strait of Juan de Fuca over a multibeam bathymetric image of a terminal moraine. Dark regions indicate zones of high seismic reflection. After *Mosher, D.C. and Johnson, S.Y. (eds.), Rathwell, G.J., Kung, R.B., and Rhea, S.B. (compilers), 2000. Neotectonics of the eastern Juan de Fuca Strait; a digital geological and geophysical atlas. Geological Survey of Canada Open File Report 3931.*

APPENDIX C. EXAMPLES OF ACOUSTICALLY AND OPTICALLY DERIVED IMAGERY (CONTINUED)

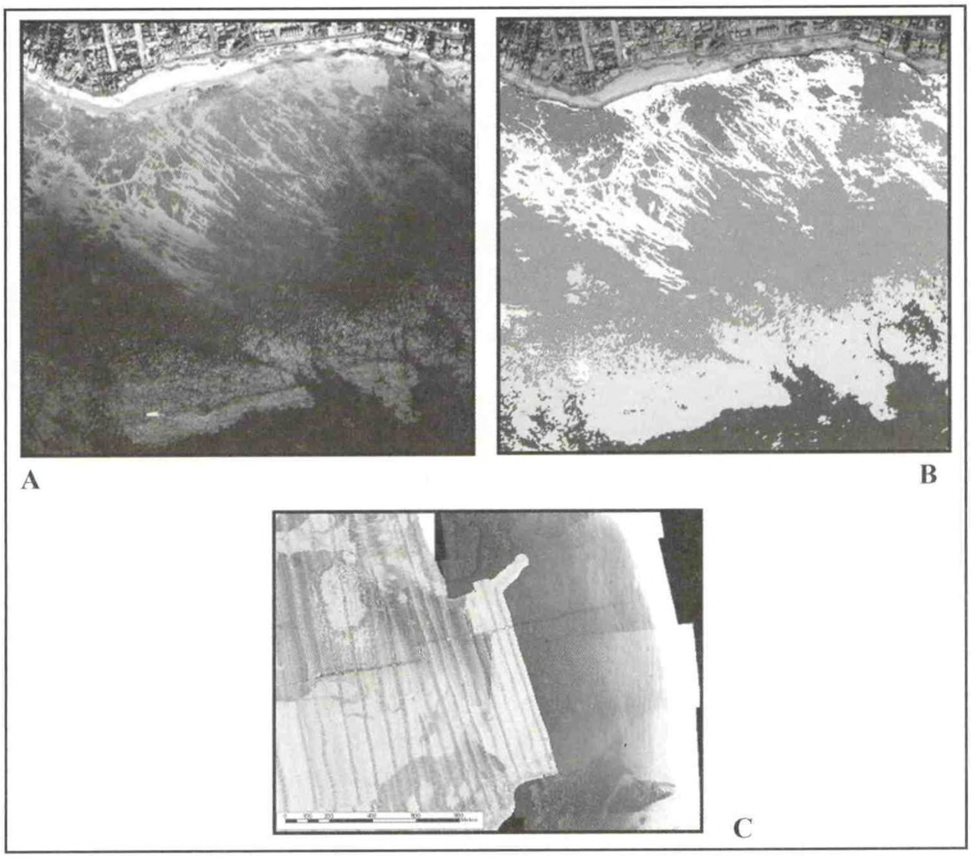

Figure 4. Example of digital photographic and Light Detection And Ranging (LIDAR) data collected in the SANDAG study area off San Diego, CA. Digital multi-spectral photograph, red zones are signal from kelp canopy (A). Color-coded bathymetric data obtained with bathymetric LIDAR corresponding to the area depicted in Image A, green regions are kelp canopy where optically based techniques cannot provide reliable bathymetry (B). Digital multi-spectral photograph georeferenced and integrated with multibeam backscatter data in region of kelp canopy demonstrating synergy of optical and acoustic survey methods for characterizing complex near-shore regions (C). Images courtesy of *Fugro Pelagos, Inc. of San Diego.*

APPENDIX C. EXAMPLES OF ACOUSTICALLY AND OPTICALLY DERIVED IMAGERY (CONTINUED)

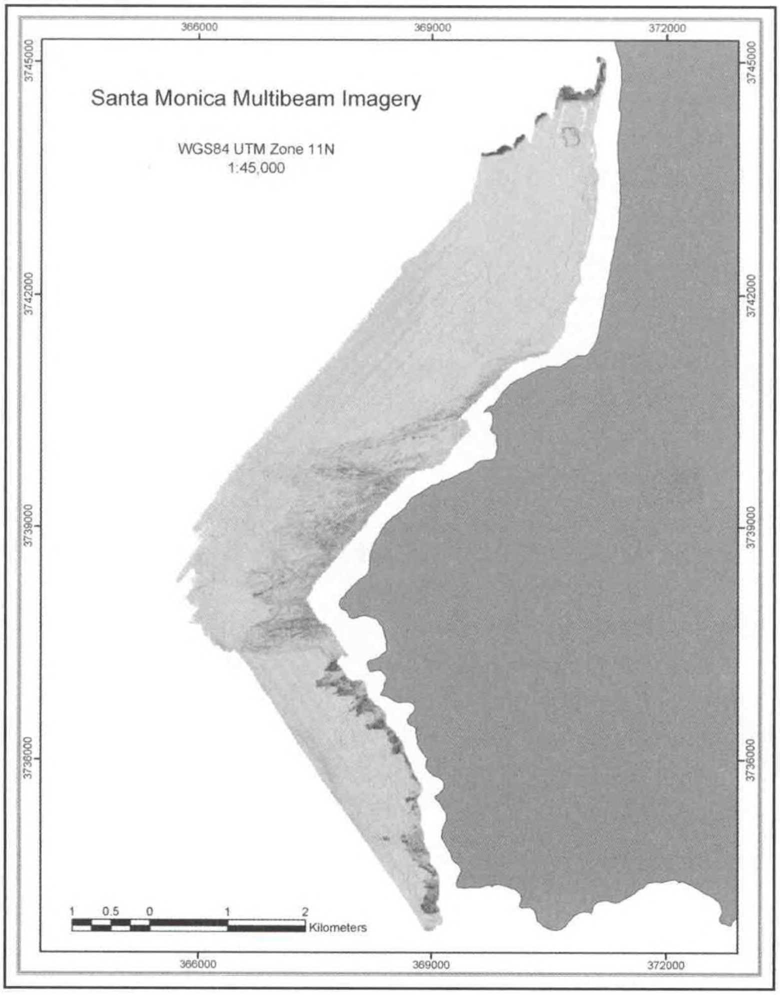

Figure 5. High resolution (Reson 8101, 240 kHz) multibeam bathymetric data collected in the nearshore areas of the Palos Verdes Peninsula south of Santa Monica Bay. Image courtesy of *CSU Monterey Bay's Seafloor Mapping Lab.*

APPENDIX C. EXAMPLES OF ACOUSTICALLY AND OPTICALLY DERIVED IMAGERY (CONTINUED)

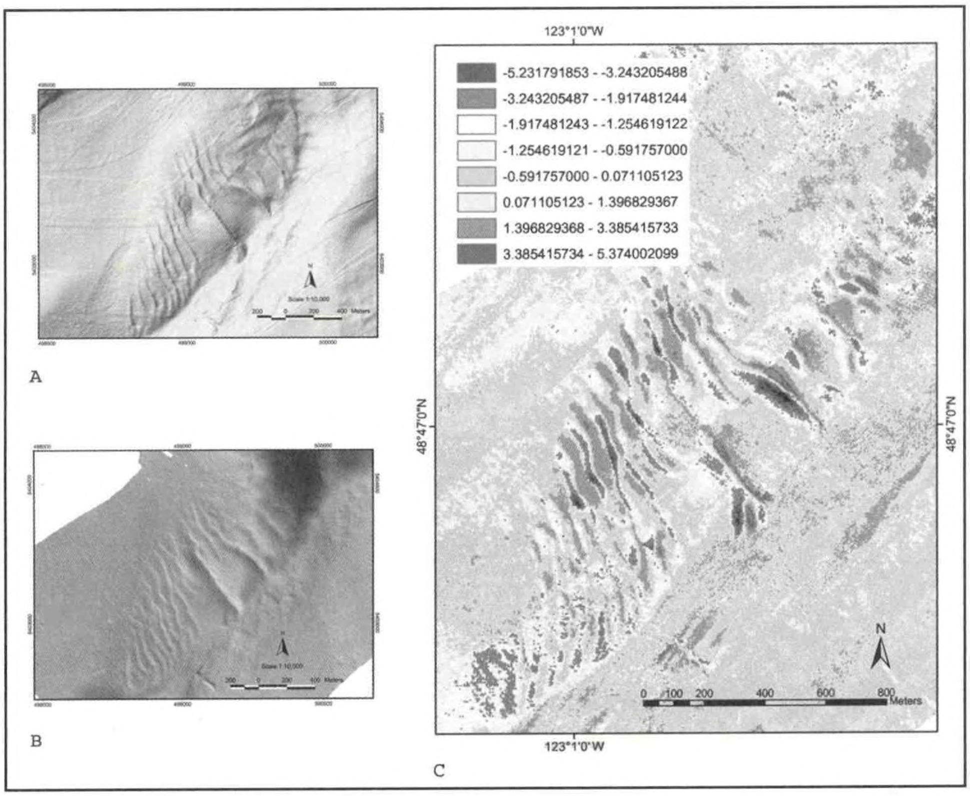

Figure 6. Example of how repeated acoustic imagery of dynamic bedforms can be used to illustrate time-series analysis of sediment shifts in a sand-wave field. Overlapping multibeam bathymetry surveys of region of interest (A, B). Difference representation of bathymetries generated between surveys with warmer colors indicating net erosion and greens net accretion of substrate (C). Images courtesy of the *Geological Survey of Canada*.

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