

I. INTRODUCTION

A. Title: ACOUSTICAL SEABED CLASSIFICATION AS GROUND TRUTHING FOR EVALUATIONS AND INVESTIGATIONS FOR CORAL REEF STUDIES, BISC-02-016

B. Date of Proposal: Summer 2002

C. Investigators:

Bernhard Riegl, PhD (PI)
National Coral Reef Institute
Oceanographic Center
Nova Southeastern University
8000 N. Ocean Drive, Dania
FL 33004
(954) 262-3671 phone
(954) 262-4098 fax
www.nova.edu/ocean/rieglb/rieglb.html

Richard E. Dodge, Ph.D.
Dean
Nova Southeastern University Oceanographic Center
8000 N. Ocean Drive
Dania, FL 33004
NSUOC <http://www.nova.edu/ocean/>
NCRI <http://www.nova.edu/ocean/ncri/index.html>

MacIntosh

Brian K. Walker
Biological & Geographical Information Specialist
National Coral Reef Institute
8000 N Ocean Drive, Dania Beach, FL 33004
(954)262-3675; Fax(954)262-4027
walkerb@nova.edu

Ryan Moyer
Coral Reef Specialist
National Coral Reef Institute
8000 N Ocean Drive, Dania Beach, FL 33004
(954)262-3675; Fax(954)262-4027
moyerr@nova.edu

D. Abstract:

We intend to use acoustic bottom classification equipment (QTCView Series 5, Echoplus) to produce maps of bottom types based on the acoustic backscatter of a signal sent from the surface. This work is in conjunction with, and planned in exactly the same areas as, the work proposed by the USGS (St. Petersburg Field Office) and NASA (Stennis Space Center) under permit BISC-02-016.

No sampling of actual material (sand, plants, or animals) will be undertaken, but after the boat based surveys (acoustic single-beam survey lines ground-truthed by towed video camera), divers will perform some transect sampling in strategic location in order to provide quantified ground-truthing points.

After the field work, the acoustically-derived seafloor classification data will be compared with the airborne and spaceborne remotely sensed classified data obtained by USGS and NASA.

This will allow to decide in which conditions optical remote-sensing is superior to acoustic remote-sensing and/or vice versa.

II. OVERVIEW

The USGS and NASA propose to continue research begun last year related to coral reef investigations and evaluations at Biscayne National Park. The National Coral Reef Institute (NCRI) wishes to collaborate with the above investigators by providing an additional layer of remote sensing capability to that work. Specifically, NCRI proposes to use and closely couple Quester Tangent Series 5 and Echoplus (Seatronics Inc., Aberdeen, UK) acoustical technology (QTC) with USGS/NASA airborne sensor survey efforts for the purpose of ground truthing airborne acquired data. If successful, the use of QTC technology will provide a cost effective, repeatable and reliable way in which to determine biota related to remotely sensed bathymetry. The use of QTC and Echoplus technology may be a particularly useful ground truthing tool at depths and locations impractical by other means (e.g. diver, photo, video).

*Indicate
Taxane*

A. **Statement of issue** – NCRI proposes to address the issue of providing reliable, repeatable and cost effective ground truthing of airborne remote sensing bathymetry and multispectral products. At the present scientists verify lidar or hyperspectral images by means of in situ diver observations, remotely operated vehicles (ROVs) drop or towed camera arrays and videography. In areas of poor visibility or high current regimes these methods are often not effective. Depths in excess of 40m often preclude research diver inspection of bottom formations. These methods often require large support vessels (ROV operation).

*Provide for
Signal as well*

NCRI will utilize different acoustical seabed classification data derived from QTC and Echoplus surveys to ground truth optical data obtained from airborne sensors.

B. Literature summary –

The use of acoustic methods for automated seabed classification in various marine settings has by now been verified by a number of authors (see a listing underneath) and NCRI has successfully used QTC view and Echoplus to differentiate not only different substratum types (i.e. rock from sand from rubble) but also different hardbottom assemblages (i.e. corals from gorgonians from algae, Moyer et al 2002). NCRI has successfully integrated acoustic (multibeam) and optical (LIDAR/LADS) data for reef mapping (Walker and Dodge 2002) and optical data from different sources (video survey and satellite imagery, Riegl et al. 2002) for seafloor classification.

To further the investigations into data compatibility, NCRI has embarked on further cross calibration of acoustic and optic dataset in two geographical areas: the Florida Keys (in August and October 2002) and the Arabian Gulf (in September 2002). The present permit application concerns the Florida Keys leg.

- Burczynski, J. 2000. Bottom Classification. Biosonics Online Technical Library (www.biosonicsinc.com/technical_library/bottom_classification.html)
- Chivers, R.C., N.C. Emerson, and D. Burns. 1990. New acoustic processing for underway surveying. The Hydrographic J. 56:9-17.
- Collins, W.T. and Rhynas, K. 1998. Acoustic seabed classification using echo sounders: operational considerations and strategies. Proceedings from 1998 Canadian Hydrographic Conference. Victoria, March 1998.
- Conover, W.J. 1980. Practical nonparametric statistics, 2nd ed. John Wiley & Sons, Inc. New York.
- Greenstreet, P.R., I.D. Tuck, G.N. Grewar, E. Armstrong, D.G. Reid, and P.J. Wright. 1997. An assessment of the acoustic survey technique, RoxAnn, as a means of mapping seabed habitat. ICES J. of Mar. Sci. 54:939-959.
- Moyer RP, Riegl B, Dodge RE, Walker BK, Gilliam DS (2002) Acoustic remote-sensing of reef benthos in Broward County, Florida (USA). 7th International Conference on Remote Sensing for Marine and Coastal Environments, Miami, May 2002

- Riegl B, Andrefouet S, Moyer RP, Walker BK (2002) Integration of satellite remote sensing of subtidal habitats with vessel-based video survey (Dubai, UAE, Arabian Gulf). 7th International Conference on Remote Sensing for Marine and Coastal Environments, Miami, May 2002
- Stanton, T.K., 1982 Effects of transducer motion on echo-integration techniques. J. Acoust. Soc. Am., 72(3):947-9
- von Szalay, P.G. and R.A. McConnaughey. The effect of slope and vessel speed on the performance of a single beam acoustic seabed classification system. Fish. Res. 54(2):491-504.
- Walker BK, Dodge RE (2002) 3-D visualization of coral reef habitat. 7th International Conference on Remote Sensing for Marine and Coastal Environments, Miami, May 2002

C. **Scope of study** – The study will take place at survey sites determined by the airborne sensing collaborating partner of this project. To the best of our knowledge these sites are located at Pacific Reef and Anniversary Reef, BNP. NCRI will coordinate the operation of its work with BISC-02-016 PI, Dr. John Brock, USGS.

D. **Intended use of results** – NCRI intends to publish its findings in collaboration with its Federal partners. No commercial use is anticipated.

III. OBJECTIVE/HYPOTHESIS TO BE TESTED

Due to enormous advances in ship-borne, air-borne and space-borne remote-sensing technologies, a host of sensors are available that can be used to provide data critical for the management of marine resources. Our main interest is in bottom classification, in particular the differentiation of different hardground (i.e. coral reef) biotic assemblages.

Most remote-sensing technology tends to be only as good as its calibration. Essentially, the limits of what can be "remotely sensed" have by far not yet been reached, however, each sensor is limited by its physical constraints and therefore performs best within a certain "window of operability". Therefore, the ideal "do it all" sensor does not exist yet (and possibly never will). It is becoming increasingly important to cross-calibrate the results from different sensors to assure:

- 1) that overlapping data produce the same results
- 2) identify the exact boundary where the user should switch from one sensor to the next
- 3) evaluate the efficiency of each sensor within its own "window of operability".

We therefore wish to integrate and compare data from: ship-borne (QTCView, Echoplus), airborne (EAARL, Lidar) and spaceborne (Ikonos, Landsat) sensors.

For the present permit, NCRI wishes to perform the ship-borne acoustical bottom classification analysis to integrate with the data product provided by the other project partners (NASA, USGS).

IV. METHODS

A. **Description of study area** – The proposed study area will be identical to the study area in BISC-02-016.

B. **Procedures** – As the work is experimental, all procedures will be jointly developed between USGS/NASA partners and NCRI. Basic NCRI component will be to perform acoustical surveys by means of small vessel (<10m). Data will be recorded by means of on board computers for later reduction and analysis.

C. **Collections** – No collections are anticipated

D. **Analysis** –

Detailed benthos mapping classifications in BNP will be accomplished using basemaps, LIDAR, bathymetry overlain with acoustically remote-sensed data. A component of the fieldwork involves ecological data-gathering for ground-truthing of remotely sensed information. A well-defined survey area with differentiation into all available habitat types will be chosen for study. Then remotely sensed habitat classifications will be produced and a ground-truthing plan will be initiated.

Ground-truthing plans will involve DGPS stamped video and in situ SCUBA diving. Prior data on ecological assemblages will be utilized for data-integration with previous studies and for characterization of benthic assemblages.

Mapping goals will incorporate, where possible, technologies to further differentiate reef units into zones, divisions, and groupings. These differentiations might have varying numbers of single or multi-variate ecological parameters, and therefore differing optical and acoustic properties, determined by the overall "shape" of the communities. Such parameters could include species diversity, richness, coverage, and numbers of individuals and/or species groupings and associations. In many areas, spatial patterns of "within-reef" zones have not been previously well recognized qualitatively or quantitatively. Therefore, this project will be designed to incorporate prior assessment data at increasingly fine scales that can be used to define habitat clusters or zones of organism associations. Data will not only be used to determine the degree to which statistical zones or habitats may be differentiated, but also the efficiency with which these zones can be recognized by different sampling regimes.

On board this vessel, two acoustic bottom type detection systems are installed together with a video-based quality control/quality assurance system. The acoustic bottom type classification can be operated on two frequencies (50 kHz and 200 kHz) either on a through-hull mounted system or an over over-the-side mounted system. Systems can be run simultaneously or in alternation.

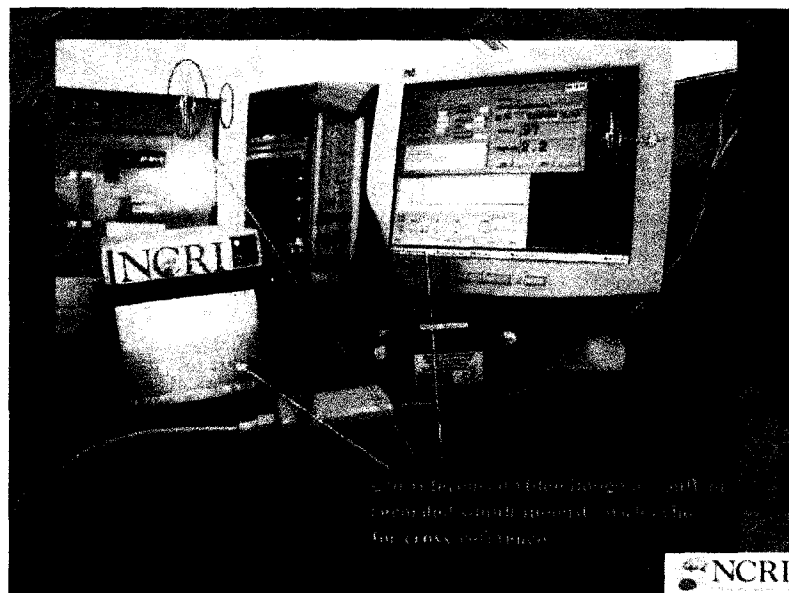


Figure 1: The computer screens of the four integrated systems used for acoustic bottom classification and quality control on board RV Researcher. In the foreground: 1) QA/QC by time-stamped and geo-referenced video 2) data capture of first 50 kHz echo return using QTC Series V (right monitor) 3) Data capture of first and second 50 kHz and 200 kHz echo returns using Echoplus (left monitor) 4) Suzuki ES 2025 depth sounder produces the pings on both 50 and 200 kHz.

A 50 kHz single-beam transducer (Suzuki ES-2025) is presently mounted through the hull and connected to a data-capturing and a data-processing computer on-board. The hydrographic survey package HYDAS (Quester Tangent Corporation) is preferentially used to determine sample grids, grid spacing and to provide guidance to the helmsman (other available hydrographic survey software includes HYPACK of Coastal Oceanographics). Sample grids are generally arranged along-strike the reef structures (coast-parallel) on a 50- m spacing. For quality-control purposes, a series of tie-lines is always run along dip (coast-perpendicular). The data-points at intercepting survey-lines have to provide the same classification, otherwise the data-set will be considered faulty and discarded in its entirety. Then the sampling would be computed on-board and the helmsman followed the lines outlined on the computer screen placed next to the steering wheel.

During the survey operation a continuous stream of WAAS augmented GPS information (NMEA encoded) or differential GPS fixes (also NMEA encoded) are time-stamped and collected in separate files from the raw-acoustic data, which are also time-stamped. Both time-stamping procedures use the CPU clock of the same on-board computer. This resulted in one processed, geo-referenced signal per second. These processed signals were then stored in separate files for quality control and statistical analysis. After the surveys, raw acoustic data are submitted to quality control and statistical evaluation.

Quality control of signals consisted of checking for correct time-stamping, filtering for incorrect depth picks (this is either done by displaying all signals on a bathymetry plot and removing obvious outliers or by running a filtering application that eliminates all depth picks above a certain variance) and correct signal strength. All signals that do not pass the appropriate procedures, procedures are discarded (Moyer et al 2002 a,b).

Overview of the physical basis of acoustic bottom classification:

The principle of acoustic remote sensing of bottom types is briefly explained underneath.. QTC View evaluates the first echo return on 50 kHz and essentially operates in a very similar way to Echoplus. The difference in the Echoplus system is that the latter is capable of collecting echoes on both 50 and 200 kHz. QTC View only analyzes the first echo, while Echoplus also analyzes the second echo. Both systems have advantages in their specific environmental setting – QTC View is ideally suited for surveys in shallow water whichwater, which is made possible by extremely rapid digitization rates and the analysis of only one echo. Since Echoplus analyzes first and second echo, it has to wait longer for the complete signal, which at least doubles the minimum depth the system can operate in (shallowest depth for QTC View is approximately 100 cm, for Echoplus approximately 250 cm water depth).

The physical process associated with acoustic bottom classification is as follows:

(A) The sound emitted from the transducer is spread over a wide angle. This sound travels to the seabed and the energy that encounters the seabed at right angle (i.e. is transmitted at normal angle to the seabed) is returned to the transducer. The energy that does not impinge on the seabed in a right angle is lost. The seabed is not flat, which also causes energy that was not transmitted at right angle to the overall substratum to be scattered back to the transducer. The rougher the surface, the more energy finds its way back to the transducer via backscatter. Therefore, a stronger signal is received.

QTC View and Echoplus differ in the way the received signal is processed. QTC View processes the entire first echo, while Echoplus only processes the tail of the first echo. This in order to concentrate on backscatter and to avoid contamination of backscattered energy with energy that has been directly reflected from below the transducer (Figure 4). This becomes important when the boat rolls, since the first echo leading edge is likely to be lost when the transducer is off vertical. The scattered trailing edge of the echo

Rosanne

25m most boats can not go in this shallow water

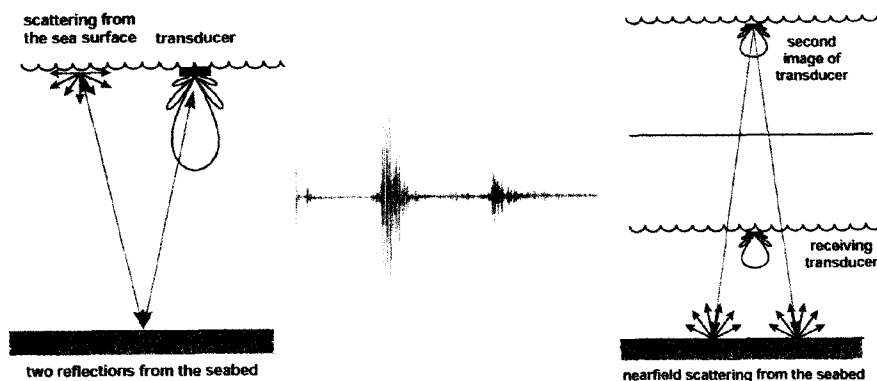


Figure 45: Scattering resulting in the second echo (red) and the two conflicting theories regarding the actual mechanism.

After data collection, the raw data are further processed. QTC Raw acoustic signals are digitized and manipulated by different algorithms. In the Echoplus system, the entire shape of the backscattered impulse is collapsed in to a single numerical index. Two such indices are produced for each outgoing ping: an index for the first echo, which is mainly determined by surface roughness, and an index for the second echo, which is mainly determined by surface hardness. The QTC system turned digitises the first echo backscatter and then turns it into signal envelopes, also called full feature vectors (FFV's). These can be graphically displayed. They are then time stamped and, the data are submitted to Principal Components Analysis (PCA) in order to obtain clusters of decreasing similarity that can be correlated to similarly obtained clusters of ecological data (see later sections, while PCA is the ordination method of choice for the FFV's, the different data structure of ecological data – non-normality and prevalence of zero-counts – suggested ordination by multidimensional scaling). Several iterations of clustering of the entire dataset are usually used before ideal cluster size is chosen. Ideal cluster size is considered such that allowed unequivocal identification of individual FFV's (i.e. the actual sampled area, the size of which is determined by the acoustic footprint of the sonar beam).

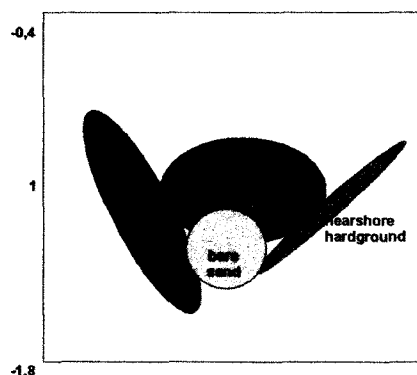


Figure 5: An example of a Principle Components Analysis output. The individual picks are contained within the clusters and color coded. These same colors are then displayed on the map.

Echoplus data are received as a string of univariate indices for roughness (first echo) and hardness (second echo). They can be plotted either against each other (roughness versus hardness), or, if calibration files

will, however, remain largely constant under conditions of pitch and roll. However, while constancy of signal is gained, some information is lost.

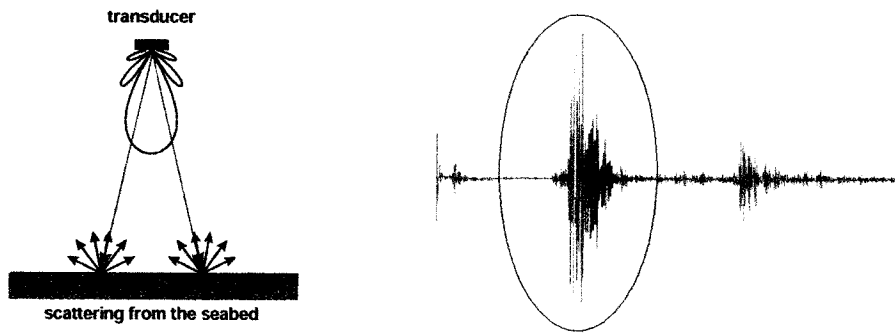


Figure 34: Scattering resulting in the first echo and the shape of the first echo (within the ellipse). QTC View uses almost the entire first echo information, Echoplus only the tail (in red).

(B) However, more than one echo returns to the transducer and Echoplus uses the second echo to obtain further information. The usefulness of this echo, and whether one decides to use it or not, depends on which underlying theory for its formation is used. The generation of this echo could be caused by the dominant ray paths undergoing scattering first at the seafloor (production of first echo), then at the surface, and then at the seafloor again (production of second echo). A competing theory claims that because of the presence of the sea surface, the configuration is actually bi-static, resulting in a virtual displacement of transmitter and receiver by twice the water depth. This would put the receiver into the near-field scattering zone and make the information contained in the second echo equivalent to the first echo.

In both cases, the energy contained within the second echo depends on seafloor hardness, therefore Echoplus analyses the entire second echo.

In general, the quality of the first echo is higher, and careful QA/QC is applied before use of the second echo. Also, since waiting for two echoes takes twice the time as waiting for one echo, Echoplus is limited to 2m minimum survey depth while QTC View can survey to shallower depths (about 100 cm).

were collected, they can be coded directly corresponding to the means and variances of the calibration files. Otherwise, they can be subjected to an equivalent analysis as QTC data (Riegl et al. 2002).

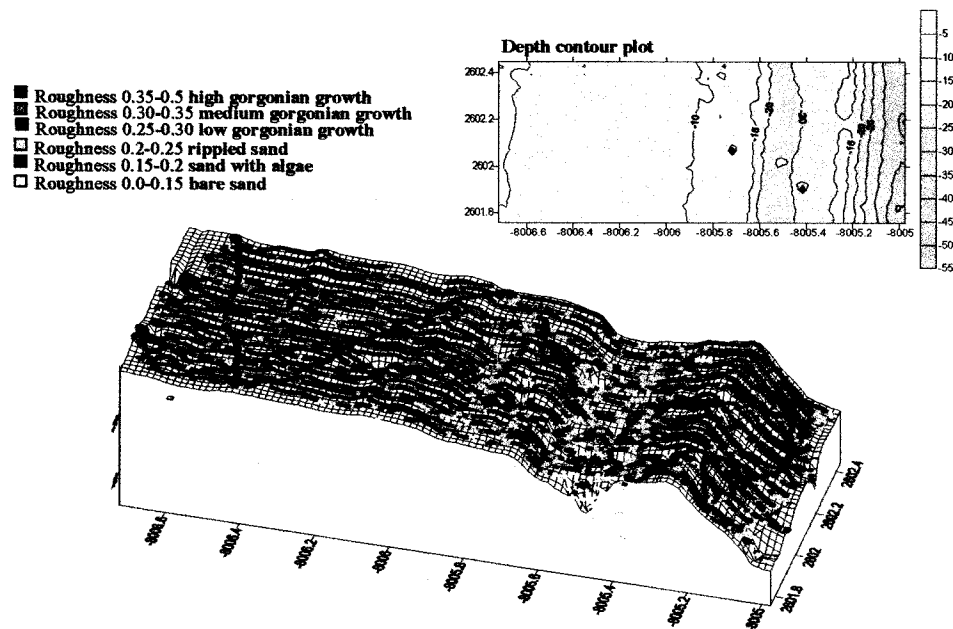
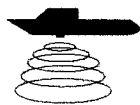
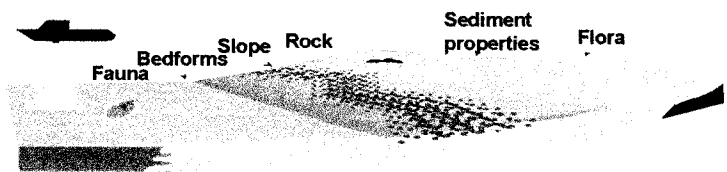


Figure 2: The echo classes obtained from statistical analysis are then graphically displayed over a bathymetry plot.

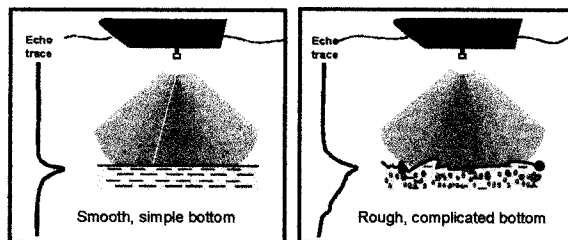
The "acoustic diversity" of an area is determined by its actual diversity of bottom types

The "roughness" of the seafloor determines how strongly the echo of a signal sent from the surface will be distorted as it is reflected.

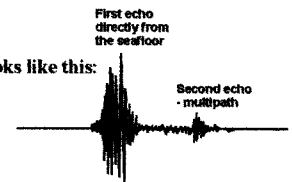
The "roughness" of the seafloor is determined by its composition and the benthic community growing on it.



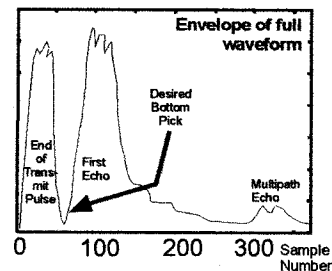
the echo of an acoustic signal emitted from the survey vessel is influenced differently by rough or smooth bottom



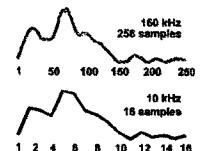
The actual returning echo looks like this:



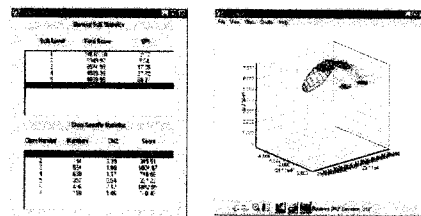
But the software digitizes it and changes it to the following shape:



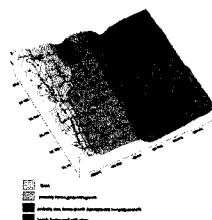
Digitization is extremely rapid, otherwise the quality of the wave-form envelope Would be insufficient



FFVs are then grouped into clusters of differing similarity by means of principal components analysis (PCA). While receiving guidance on the goodness of fit of the clusters, it is in the end the operator who decides how many splits are reasonable and can be interpreted.



Since the FFVs are geocoded, the clusters also represent the spatial distribution of the seafloor-types which now can be mapped.



Series of 5 echoes get stacked (an image of the digitized shape above) and are then further processed by a number of algorithms that use a suite of 166 characters to describe each now define Full Feature Vector (FFV). FFVs are then

- (1) geocoded to a time-stamped GPS-string
- (2) Subjected to statistical analysis for grouping

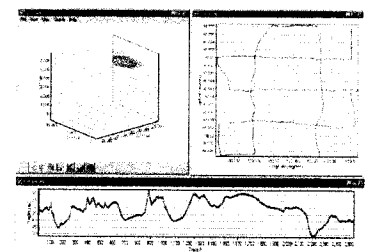


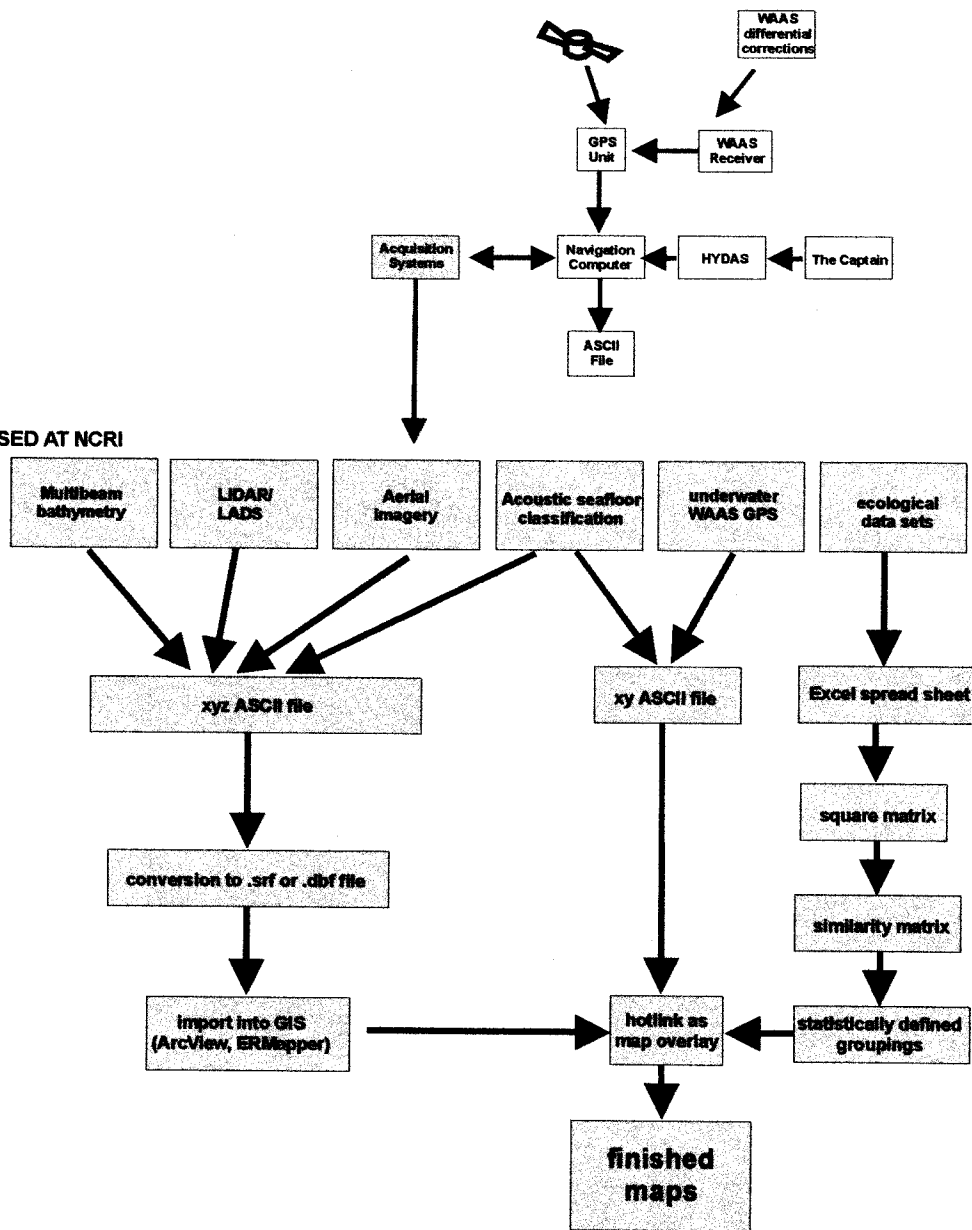
Figure 3: Flow-chart of acoustic bottom classification as performed with the QTC View system. Echoplus differs by using both the first and the second echo and leaving more freedom regarding data work-up.

After data work-up, acoustic bottom classes are then merged with other data sets from the study area, such as multibeam bathymetry, LIDAR or LADS bathymetry and/or aerial imagery in order to produce an integrated data product (Dodge et al. 2002, Walker et al 2002). This final GIS product allows multi-layered presentation of different types of data classes which greatly enhances visualization and conceptualization of hypotheses based on the data.

DATA ACQUISITION

DATA TYPES USED AT NCRI

PROCESSING STEPS



C. **Use of mechanized or other equipment** – NCRI does not anticipate the use of any mechanized or special equipment other than the QTC survey hardware it will provide. In the event NCRI requires the placement of temporary, small locator buoys, these will be installed in such a fashion so as not to negatively impact BNP natural resources. As example, small, ref polyform buoys may be used to define survey grid area. These might remain overnight, but would be removed as soon as their utility expired.

D. **Chemical use** – No chemical use is anticipated.

E. **Ground disturbance** – None anticipated.

F. **Animal welfare** – No animals will be involved in this research.

G. **NPS assistance** – NCRI wishes to moor its small (<10m) survey boat at BNP compound for duration of field work.

H. **Wilderness "minimum impact" protocols** – N/A

Walker BK, Riegl B, Dodge RE, Moyer RP (2002) Integration of remotely sensed optical and acoustic data for the delineation of reef-lines in Broward County, Florida (USA). *Proceedings of the 7th International Conference on Remote-Sensing in Coastal and Marine Habitats, Miami*

E. Schedule – Field schedule will be identical to that of USGS/NASA partners. A proposed schedule may be seen below.

July 31: travel to BNP, assemble equipment, load boat, + test station if possible

Aug 1 - Aug 9: in the field

Aug 10: pack up gear, depart BNP

F. Budget – This project is totally funded by NCRI internal funds. No funds are required or anticipated to be provided by BNP.

V. PRODUCTS

A. Publications and reports – NCRI anticipates collaboration between USGS/NASA principals regarding reporting of data. All NCRI publications will be in the public domain. Collection of data from the public is not a part of this research.

B. Collections – See Section IV. C.

C. Data and materials – Any products, such as photographs, maps, models, handouts, exhibits, software presentations, raw data, GIS coverages, videos will be made available to BNP and will be in the public domain.

VI. LITERATURE CITED

see literature cited in the individual section of permit application.

VII. QUALIFICATIONS

Bernhard to provide

VIII. SUPPORTING DOCUMENTATION AND SPECIAL CONCERNS

A. Safety – No special safety requirements are anticipated. All SCUBA work will be performed by AAUS qualified divers.

B. Access to study sites – NCRI will provide its own small vessel for purposes of performing QTC and Echoplus survey work. NB, NCRI requests permission to dock its small vessel within the BNP "compound," during the duration of the field work.

Figure 4: A flow-chart of the work and data flow in the suggested mapping project from acquisition to final product.

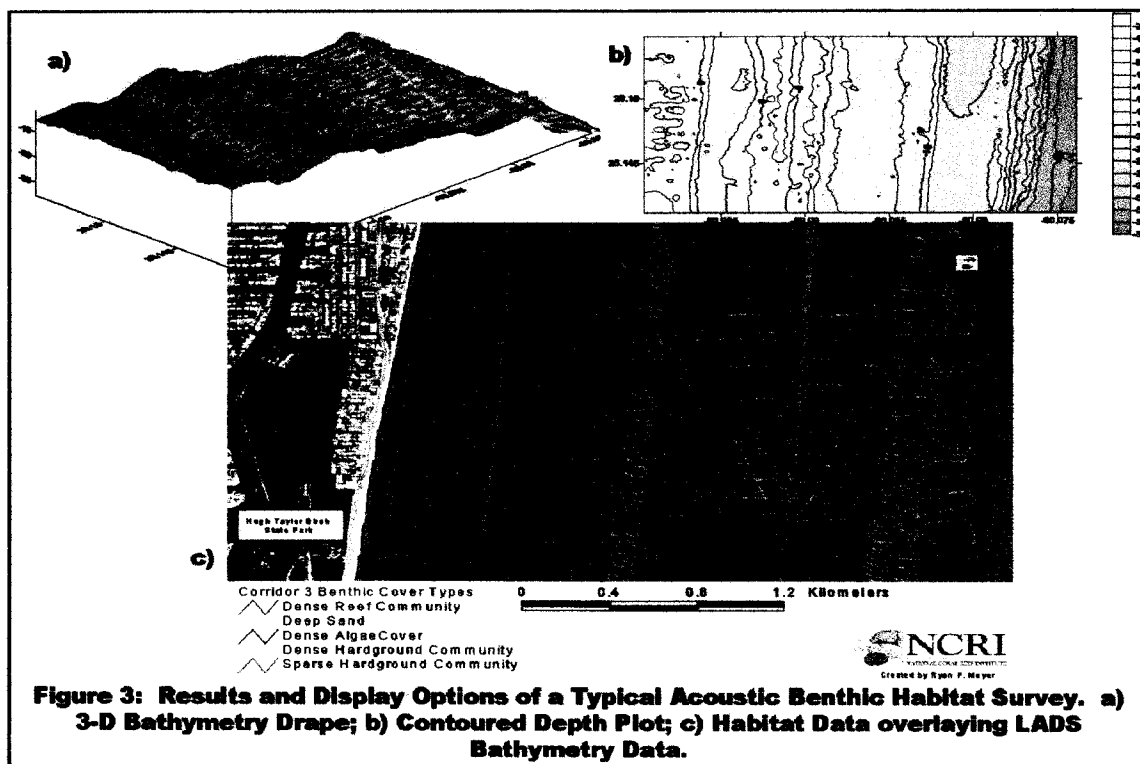


Figure 5: Example of a finished mapping print-out from a previous NCRI report (Moyer et al. 2002), which shows the overlay of the acoustic bottom classification over combination of LADS bathymetry and aerial photography.

References:

- Dodge RE, Walker BK, Riegl B, Moyer RP (2002) Mapping of drowned reefs in Broward County, Florida (USA) by remotely sensed optical and acoustic data. *American Geophysical Union, Oceans 2002, Hawaii* (Abstract and Poster)
- Moyer RP, Riegl B, Dodge RE, Walker BK (2002) Acoustic detection of different types of reef benthos in Broward County, Florida (USA). *American Geophysical Union, Oceans 2002, Hawaii* (Abstract and Poster)
- Moyer RP, Riegl B, Dodge RE, Walker BK, Gilliam D (2002) Acoustic remote-sensing of reef benthos in Broward County, Florida (USA). *Proceedings of the 7th International Conference on Remote-Sensing in Coastal and Marine Habitats, Miami*
- Riegl B, Moyer RP, Forbes H (2002) Dual-frequency acoustic detection of reef benthos in Broward County, Florida (USA), using Echoplus. *Oceanology 2002, London* (Poster).

Research Proposal

Drs. Yunqiu (Daniel) Wang;
Michael S. Gaines
Department of Biology
University of Miami

Title: Use of DNA Markers to characterize the mating system in red mangroves (*Rhizophora mangle* L.)

Statement of Issue:

Red mangrove (*Rhizophora mangle* L.), together with black mangrove (*Avicennia germinans*) and white mangrove (*Laguncularia racemosa*) are three mangrove species distributed along coastal region and marine influenced wetland areas in the Florida and the Keys. They form a major vegetation type in the southern three counties of Florida. Red mangrove species constitutes the dominant component of mangrove ecosystems. It occurs as the most seaward species and protects the mangrove wetland from tidal waves and storm surges. Litter fall from this dominant component supports the microorganisms and the benthic fauna of the ecosystem by nutrient recycling (Rao, 1987). Carter *et al.* (1973) estimated that as much as 80% of the organic budget of some bays in Florida came from the surrounding mangrove forest. The extensive aerial root systems of red mangrove species also provides crucial habitats for a variety of organisms, including fish, shellfish, birds, and a number of threatened and endangered species in the coastal environment. Hurricanes are a major climatic feature in southern Florida and these can have devastating effects on mangrove communities. Human induced stresses have also been considerable in southern Florida, including drainage for agriculture, reclamation for urban development and alterations to the salinity regime. Estimated losses of mangrove forest resources range from 44% in Tampa Bay to 82% in Biscayne Bay, south of Miami, and these losses were reported to have resulted in a 20% decline in commercial fisheries (Spalding, *et al.*, 1997). Generally speaking, the mangrove ecosystem as a whole is under severe threat, and the need for immediate efforts to conserve the flora, fauna and structural integrity of the ecosystem has been widely emphasized (Parani *et al.* 1997).

Population genetic studies of mangrove species could provide fundamental information for making management decisions when conservation efforts are to make. Even though, much ecological studies have been done in red mangrove (Tomlinson, 1986), little is known about the mating systems, amounts of gene flow, and population genetic structure of mangroves (Ge and Sun, 1999). Some reports on breeding mechanism in red mangroves mainly based on circumstantial evidences. Guppy (1906) was the first to suggest that *R. mangle* were self-pollinated. Kress (1975) and Teas and Handler (1979) demonstrated that insects are not necessary for pollination in red mangroves. From the observation of high ratio of pollen-to-ovule within the same flower, powdery and light pollen, and the lack of copious nectar secretion, Tomlinson (1979, 1986) and Cruden (1977) suggested wind pollination in red mangroves. Yet, as a primarily colonizing species, Primack and Tomlinson (1980) also argued that red mangroves would retain the need for self-fertility to preserve well-adapted genotypes if they are to establish populations in isolated localities. However, no direct confirmation of this hypothesis was provided until early nineties. Based upon the identification of individual trees heterozygous for chlorophyll-deficiency alleles, Lowenfeld and Klekowski (1992) reported an alarming high rate of inbreeding in red mangroves in Florida and San Salvador. Their conclusion was based on assumptions that the majority of mangrove trees are heterozygous for albinism and crosses between heterozygous trees are rare. They found as high as 95.2% of the embryos resulted from self-pollination (Lowenfeld and Klekowski, 1992), and high inbreeding rate was also found in both young and old red mangrove trees (Klekowski *et al.*, 1994).

It is clear that their conclusion resulted from the sole observation of one phenotype- albinism under circumstantial conditions. A more general and unconditional approach is needed to characterize the mating system in red mangroves across all population types.

We also have to realize that inbreeding in red mangrove decreases genetic variability. Red mangrove forms dense coastal forest of its own which forms both the tree canopy and the under story in the tropical coastal ecosystem. If inbreeding turns out to be prevalent throughout the range of this species, Lowenfeld and

A PROGRESS REPORT ON RESEARCH IN BISCAYNE BAY NATIONAL PARK BY NCRI IN 2002



Original aim of the survey:

- (1) obtain acoustic bathymetry that would allow the ground-truthing of FAARI. Lidar bathymetry (permit BISC-02-016).
- (2) Obtain acoustic bottom type classification in a patch reef habitat.
- (3) Develop an acoustic library of bottom classes.

Status and success:

- (1) ground-truthing lines were obtained but still need further work-up.

A PROGRESS REPORT ON RESEARCH IN BISCAYNE BAY NATIONAL PARK BY NCRI IN 2002



Original aim of the survey:

- (1) obtain acoustic bathymetry that would allow the ground-truthing of EAARI Lidar bathymetry (permit BISC-02-016).
- (2) Obtain acoustic bottom type classification in a patch reef habitat.
- (3) Develop an acoustic library of bottom classes.

Status and success:

- (1) ground-truthing lines were obtained but still need further work-up.
- (2) Successful ground-discrimination data were obtained.
- (3) The acoustic library proved problematic and needs more work.

Method

Surveys were run from NCRI's vessel "Surveyor", a 26ft Thompson. On board this vessel, two acoustic bottom type detection systems were installed together with a video-based quality control/quality assurance system. The acoustic bottom type classification was operated on two frequencies (50 kHz and 200 kHz) on an over-the-side mounted system.

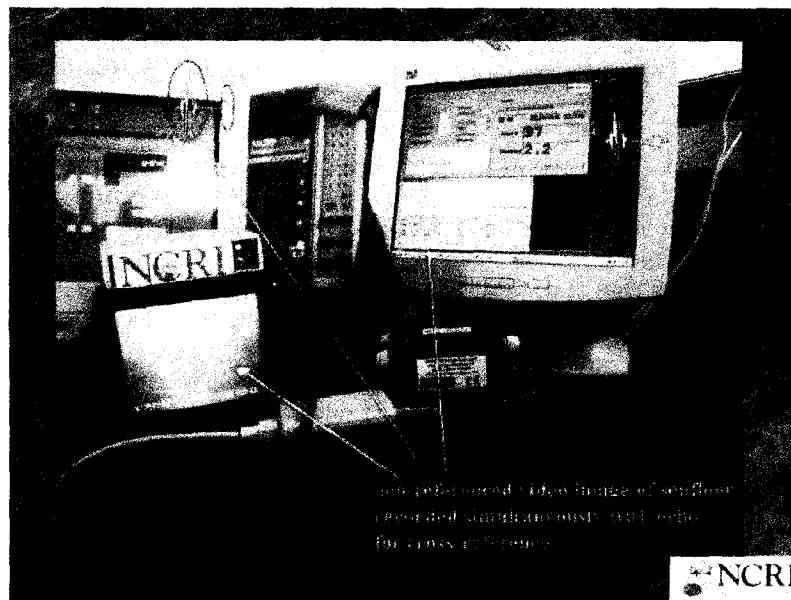


Figure 1: The computer screens of the four integrated systems used for acoustic bottom classification and quality control on board RV Researcher. In the foreground: 1) QA/QC by time-stamped and geo-referenced video 2) data capture of first 50 kHz echo return using QTC Series V (right monitor) 3) Data capture of first and second 50 kHz and 200 kHz echo returns using Echoplus (left monitor) 4) Suzuki ES 2025 depth sounder produces the pings on both 50 and 200 kHz.

NPS/CESU Project Proposal

Project Title: **Aerial Survey of Boater Use in Biscayne National Park**

PI Name: Drs. Jerald S. Ault¹, Steven G. Smith¹ and James A. Bohnsack²

Affiliation: ¹University of Miami RSMAS; ²NOAA Fisheries SEFSC

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NPS/CESU Project Proposal

PI Name: Drs. Jerald S. Ault, Steven G. Smith and James A. Bohnsack

Project Title: **Aerial Survey of Boater Use in Biscayne National Park**

1.0 Introduction

Situated at the northeastern end of the Florida Keys coral reef ecosystem, Biscayne National Park (BNP) is a unique tropical marine environment, renown for its productive coral reef ecosystem, diverse natural resources, broad fishing and boating opportunities, and spectacular scenic beauty. This ecosystem provides the foundation for multibillion dollar fishing and tourism industries in south Florida (Johns et al. 1991). Over the past several decades, however, the combination of rapidly growing human populations, fishing, habitat alterations, and changes in regional water quality have placed significant stress on the marine resources in the Florida Keys ecosystem, including BNP (Ault et al. 1998, 2001a, 2001b). To address these important issues within BNP, the Park has embarked upon the development of a comprehensive General Management Plan (GMP) as well as a comprehensive Fisheries Management Plan (FMP). The overall intent of this planning process is to implement policies that balance current Park visitor use and impacts on marine resources with the need to ensure the long-term biological integrity and sustainability of Park fish and invertebrate populations and their associated habitats for future generations of visitors.

Understanding the extent of boater uses in BNP waters is an important consideration for building sustainable resources in the GMP and FMP planning processes. In the 1970s, a statistical methodology for estimating total boater use of BNP waters was developed by determining the relationship between direct counts of boat trailers at the major public boat ramps situated in close proximity to the Park and counts of boats on BNP waters estimated from aerial overflights (Jim Tilmant, personal communication). This relationship was then used to predict total on-water boater use from relatively inexpensive trailer counts conducted on a daily, weekly, monthly, and annual basis. However, it has been more than two decades since the last aerial survey of boater use was conducted. Since this time a number of factors have changed which may have affected the underlying relationship between trailer counts and boater use: an expansion of Park boundaries; substantial increases in the regional human population; increased numbers of registered vessels; and, the addition of a major public marina (Black Point). There is a clear need to conduct a new study to update the statistical relationship between boat trailers at marinas and total boats in Park waters.

2.0 Goal and Objectives

Goal.- The proposed goal is to establish a cost-effective method for estimating boater use of BNP on a seasonal and annual basis.

Objectives.- There are three main study objectives:

- (1) to conduct an aerial census of vessels in Park waters;
- (2) to conduct a concurrent census of boat trailers at major public boat ramps in the vicinity of BNP;
- (3) to develop a statistical model for predicting total boater use from the data of (1) and (2).

3.0 Methods and Approach

3.1 Aerial Vessel Census

Direct counts of vessels within BNP waters will be conducted using small fixed-wing aircraft. The proposed survey track for a single overflight of Park waters is mapped in **Figure 1**. A single survey sample will consist of one complete circuit of the flight route. The aerial survey will extend to the easternmost boundary of BNP, encompassing the outer coral reef line. The investigators anticipate that a single complete survey flight will require approximately 3 hours, and have used this time for budget estimates. Flights will be conducted between 12 noon to 2 p.m. for maximum sighting efficiency, and the period of the day when, based on past studies, boater use and trailer occupancy at marinas are likely to be at peak levels (Jim Tilmant, personal communication). The angle of the sun during this midday period is also conducive for visual observation of vessels from an airplane. The exact timing of the aerial overflights will be aided by data on boat ramp traffic currently being collected by the PI as part of a survey of resource user preferences in BNP. Required personnel for a given daily flight are one member of our scientific team who will conduct the aerial data recording, and the aircraft pilot. Scientific personnel for this task will be drawn from members of Dr. James Bohnsack's Reef Resources Group at the NOAA Fisheries Southeast Fisheries Science Center who have extensive experience in conducting aerial boat surveys in south Florida coastal waters.

During a survey overflight the scientific observer will use a mobile GIS recording system to collect real-time data on vessels including: position (latitude and longitude); type and size class (e.g., sailboat 20-30 ft., motorboat <20 ft., etc.); and, disposition (e.g., in transit, anchored/moored, anchored-fishing, anchored-diving, etc.). This mobile GIS system will be modeled after one that is currently used to conduct aerial vessel surveys in Channel Islands National Park, California (Gary Davis, personal communication). The main components of this system are a digitizing tablet-screen connected to a laptop computer using a commercially available GIS package.

3.2 Boat Trailer Census

A census of boat trailers will be conducted on concurrent day and time frames (1200-1400h) with the flight surveys at six major public marinas in the vicinity of BNP: Homestead Bayfront Park (at Park headquarters); Ocean Reef; Black Point; Matheson Hammock; Dinner Key; and Crandon (**Figure 1**). The trailer counts will be conducted according to the established protocols of the BNP Recreational Creel Census. The trailer census will be a collaborative effort between University of Miami and BNP scientific personnel. University personnel will conduct the trailer counts in the two northernmost marinas (Dinner Key and Crandon), whereas Park personnel will be responsible for trailer counts in the four southernmost marinas (Bayfront Park, Ocean Reef, Black Point, and Matheson Hammock).

3.3 Statistical Model and Experimental Design

Paired observations of daily vessel counts and trailer counts will be used to develop a statistical model of the form

$$V_i = f(T_i) + E_i \quad (1)$$

in which the number of vessels V at day-time i is predicted as a function of the number of boat trailers T at day-time i , and E_i is the model error term. This relationship will be developed according to standard protocols for building generalized linear models (McCullagh and Nelder 1989, Neter et al. 1996).

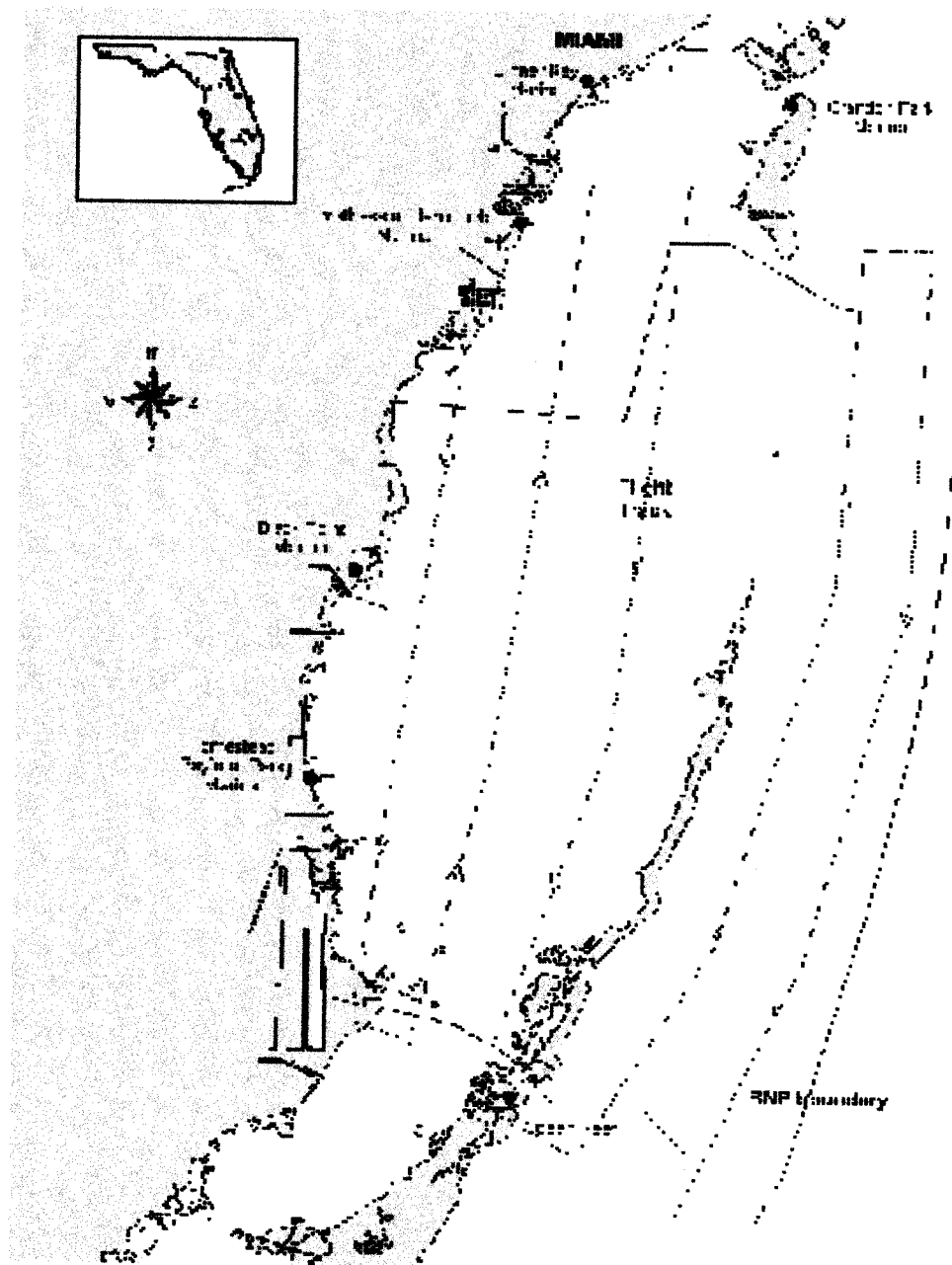


Figure 1.- Map of Biscayne National Park showing the position of the six major public boat ramps surrounding southern Biscayne Bay, and the proposed overflight track for the aerial vessel census.

As required, in the process of statistical learning and dealing with nonparametric error distributions, we may employ generalized additive models or other higher-order model building techniques (Hastie and Tibshirani 1990, Hastie et al. 2001). In light of the statistical model (Eq. 1), the main objective of the study's experimental design is to conduct the aerial vessel and marina trailer surveys on days that reflect the full range of boater use of Park waters, from lowest-use to moderate-use to highest-use days. Collaborators from BNP may participate in some ground-truthing of aerial observations through on-water counts by Park boats, or by seeding the boater pool with Park boats in specific locations. Due to the relatively high costs of conducting the overflight component of this study we will judiciously allocate survey sampling days to achieve a robust statistical model (eq. 1) with relatively high accuracy and precision utilizing a relatively modest number of daily surveys. Based on past experience, it is projected that a statistically reliable model for estimating total vessel use can be achieved from a sample size of approximately 30 daily surveys (Jim Tilmant and Gary Davis, personal communication). Due to the uncertainty in the actual per-flight cost of the aerial vessel census, we anticipate that at least 24 aerial overflight surveys can be completed during the study time frame under the present funding level available from BNP (see section 5.0 for further clarification of this issue). Allocation of sampling days will take into account season and day of the week as two important factors influencing boater use in BNP. The specific allocation within the scope of this project and budget frame is as follows:

Among seasons: One-half of sampling days (12+) during winter (December through February) and one-half during the primary summer tourist season (Memorial Day weekend through Labor Day weekend).

Within seasons: One-third of sampling days (4+) randomly allocated among weekdays (Monday through Friday excluding holidays), one-third randomly allocated among weekends and holidays, and one-third targeted for days expected to have exceptionally high (e.g., spiny lobster mini-season) or low (e.g., days with small-craft advisories in effect) boater use. We may find that excluded months and seasonal trends may affect interpretation and predictive capabilities, at which point a full year study may be recommended.

3.4 Additional Benefits of Study Database

Although the analysis component of this study will emphasize total vessel use in BNP waters, the GIS database will contain information on the composition of the Park visitor fleet (sailboat, motorboat, fishing, diving, etc.) as well as its spatial distribution. These data will be instrumental for a number of ongoing and future studies evaluating biological and socioeconomic aspects of BNP visitor use and fishing effects. For example, calibration of fleet composition information between the aerial survey and the BNP creel census will yield fairly accurate data on the spatial distribution of fishing effort in the Park. These data are fundamental inputs for the new class of spatially-explicit stock assessment models that analyze biological and economic effects of proposed or implemented spatial zone management policies (Bohnsack and Ault 1996; Ault et al. 1999, 2002; Meester et al. 2001).

4.0 Project Schedule and Deliverables

The proposed study time frame is from September 1, 2002, through September 30, 2003. The project schedule is as follows:

September-November 2002: acquire GIS data recording system and develop database; execute contracts for flight surveys; finalize sampling schedule.

December 2002-February 2003: conduct winter season aerial vessel and marina trailer surveys.

Late May 2003-early September 2003: conduct summer season aerial vessel and marina trailer surveys.

September 2003: complete regression modeling and produce final technical report.

The main project deliverables will be: (i) GIS digital database of aerial vessel and marina trailer surveys; (ii) statistical model for estimating boater use in BNP from marina trailer counts; (iii) final technical report detailing all scientific activities and findings.

5.0 Description of Secondary Support

This study is receiving secondary support from research funds awarded to the PIs by:

- South Florida Ecosystem Restoration and Prediction Program.
- NOAA Fisheries SEFSC Coral Reef Initiative.

Salaries and associated costs for scientific personnel who will conduct the aerial vessel surveys will be provided by NOAA Fisheries SEFSC via in-kind support. Biscayne National Park will provide personnel, equipment, supplies, and transportation for conducting marina trailer surveys at the four southernmost public boat ramps (as detailed in section 3.2) via in-kind support. In addition, we will attempt to capitalize on existing arrangements between NOAA Fisheries SEFSC and several federal agency flight groups to obtain aviation services (pilot, airplane, fuel, etc.) for conducting at least some of the aerial surveys via in-kind support.

6.0 Program Management

Biographical sketches for the Principal Investigators are found in the Appendix. This proposed research is a cooperative effort among investigators at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) under the direction of Dr. Jerry Ault, the NOAA Southeast Fisheries Science Center (SEFSC) under the direction of Dr. Jim Bohnsack, and Biscayne National Park. Drs. Ault and Smith will be responsible for overall program coordination and survey scheduling, as well as survey experimental design and regression analysis. Aerial vessel surveys will be contracted by the University of Miami with a reputable, licensed aviation vendor who will provide an airplane, pilot, fuel, etc. Scientific personnel for aerial surveys will be provided by Dr. Bohnsack's Reef Resources Team at NOAA Fisheries SEFSC. Marina trailer surveys will be conducted by graduate students from the University of Miami RSMAS, and by biological technicians from Biscayne National Park.

7.0 Budget Description and Justification

To carry out the proposed study, we are requesting funds of \$45,600. These monies will primarily support creation of a subcontract for airplane overflight operations in BNP, computer hardware and software for the onboard GIS data recording system, local transportation costs for University of Miami survey sampling personnel, and salaries for University of Miami personnel. We estimate that funds allocated for aviation vendor expenses (\$18,000) will enable conducting approximately 24 daily aerial surveys. We anticipate that some additional aerial surveys (4-10) will be conducted using in-kind aviation services from federal agency flight groups (see section 5.0). An itemized budget is attached.

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JERALD STEPHEN AULT

Current Position.- Associate Professor of Marine Biology and Fisheries (Tenured), University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149, (305)361-4884 ph; (305)361-4791 fax; ault@shark.rsmas.miami.edu

Education

Postdoctoral (1990), Population Dynamics, University of Maryland

Ph.D. (1988) Fishery Management Science/Applied Statistics, University of Miami RSMAS

*** (1983) Biological Oceanography, Scripps Institution of Oceanography, University of California at San Diego. ***Completed 1-year of post-M.S. coursework.

M.S. (1982) Natural Resources (Fisheries), Humboldt State University

B.S. (1979) Fisheries, Humboldt State University

A.A. (1977) Mathematics/LifeSciences, San Diego Mesa College

Research Interests.- Dr. Ault's interests include theory and application of quantitative methods for investigating the response of marine populations to exploitation, biological-physical ocean coupling, and recruitment processes.

Dr. Ault is a Fellow of the American Institute of Fisheries Research Biologists, Certified Fisheries Professional by the American Fisheries Society, and also a Member of the Scientific and Statistical Committee of the South Atlantic Fishery Management Council, Statistical Advisory Panel for Florida Fish and Wildlife Commission, Science Advisory Committee for Bering Sea Ecosystem Program, Technical Advisory Committee for Florida Keys National Marine Sanctuary, and Founding Member of Bonefish-Tarpon Unlimited, Inc.

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Collaborators (last 48 months)

E. Baker, J. Bexley, J.A. Bohnsack, S. Cantrell, T.R. Capo, E.P. Chassignet, M. Chiappone, R. Clark, D.G. Clarke, R. Claro, C.G. Cosner, M. Coyne, M.P. Crosby, D.L. DeAngelis, N.M. Ehrhardt, J. Gentile, R.N. Ginsburg, P.W. Glynn, D.E. Harper, M.A. Harwell, J. Hunt, T. Lee, K.C. Lindeman, B. Luckhurst, M. Lutcavage, J. Luo, B.A. Megrey, A. Mehrotra, S.L. Miller, M.E. Monaco, H. Norris, D.B. Olson, E. Prince, R. Pugliese, E. Reese, B.J. Rothschild, P.J. Rubec, T.W. Schmidt, J.E. Serafy, S.G. Smith, K. Voss, J.D. Wang, G.T. Waugh, W.D. Wilson, C.I. Zhang

Last revised: 8 August 2002

STEVEN G. SMITH
Abbreviated Curriculum Vitae

University of Miami
Rosenstiel School of Marine and Atmospheric Science
Division of Marine Biology and Fisheries
4600 Rickenbacker Causeway
Miami, Florida 33149
Telephone: (305) 361-4783
Fax: (305) 361-4600
Email: sgsmith@rsmas.miami.edu

Education:

- 1998 Postdoctoral, University of Miami
Fish Population Dynamics/Biostatistics
- 1997 Ph.D., University of Maryland, College Park
Marine Estuarine Environmental Science
- 1984 B.A., Occidental College, Los Angeles, California
Biology (Honors), Marine Emphasis

Professional Experience:

Dates	Organization	Position
2002-present	University of Miami RSMAS	Associate Research Scientist
1998-2002	University of Miami RSMAS	Assistant Research Scientist
1997-1998	University of Miami RSMAS	Postdoctoral Fellow
1993-97	Univ. of Maryland Chesapeake Biological Lab.	Graduate Research Assistant
1993	Univ. of Md., College Park, Biometrics Program	Graduate Teaching Assistant
1991-92	The Rothschild Ault Group, Inc.	Director of Research
1987-91	Univ. of Md., Chesapeake Biological Lab.	Graduate Research Assistant
1985-87	Occidental College Redondo Beach Marine Lab.	Project Manager

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JAMES ANTHONY BOHNSACK

Abbreviated Curriculum Vitae

Current Position: Research Fishery Biologist, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, Florida 33149. (305) 361-4252 FAX: (305) 361-4499; Jim.Bohnsack@noaa.gov

Education

- 1979 Ph.D. (Biology) UNIVERSITY OF MIAMI, Miami, FL
- 1976 M.S. (Biology) UNIVERSITY OF MIAMI, Miami, FL
- 1969 B.S. (Biology) TULANE UNIVERSITY, New Orleans, LA

Recent Positions Held

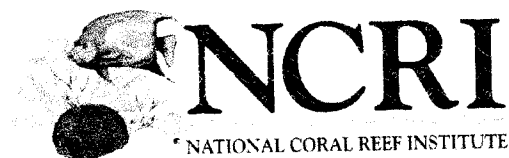
- Research Fishery Biologist**, Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149. (1984-Present)
- Adjunct Professor**, Division of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway Miami, FL 33149. (1984-Present).
- Board of Directors**, Reef Environmental Education Foundation (REEF). (1995-Present)

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A PROGRESS REPORT ON RESEARCH IN BISCAYNE BAY NATIONAL PARK BY NCRI IN 2002



Original aim of the survey:

- (1) obtain acoustic bathymetry that would allow the ground-truthing of EAARI. Lidar bathymetry (permit BISC-02-016).
- (2) Obtain acoustic bottom type classification in a patch reef habitat.
- (3) Develop an acoustic library of bottom classes.

Status and success:

- (1) ground-truthing lines were obtained but still need further work-up.
- (2) Successful ground-discrimination data were obtained.
- (3) The acoustic library proved problematic and needs more work.

Method

Surveys were run from NCRI's vessel "Surveyor", a 26ft Thompson. On board this vessel, two acoustic bottom type detection systems were installed together with a video-based quality control/quality assurance system. The acoustic bottom type classification was operated on two frequencies (50 kHz and 200 kHz) on an over-the-side mounted system.

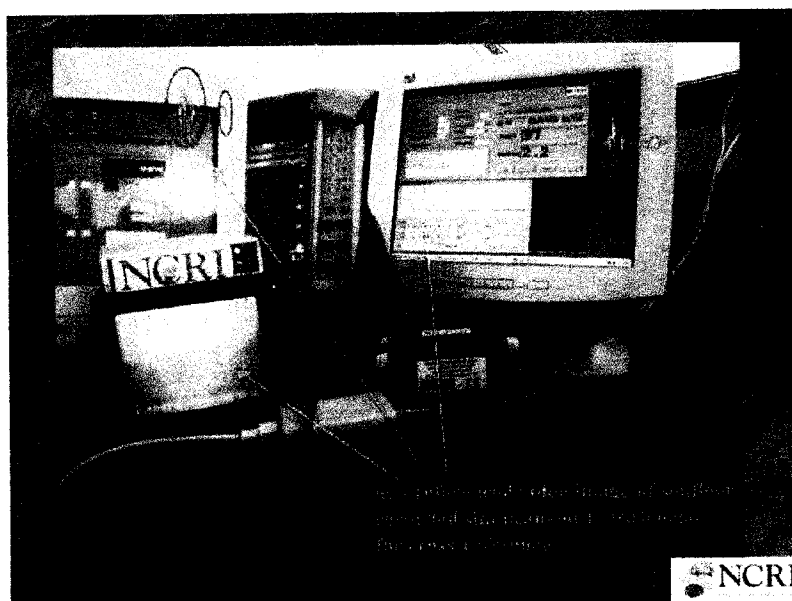


Figure 1: The computer screens of the four integrated systems used for acoustic bottom classification and quality control on board RV Researcher. In the foreground: 1) QA/QC by time-stamped and geo-referenced video 2) data capture of first 50 kHz echo return using QTC Series V (right monitor) 3) Data capture of first and second 50 kHz and 200 kHz echo returns using Echoplus (left monitor) 4) Suzuki ES 2025 depth sounder produces the pings on both 50 and 200 kHz.

A 50 kHz single-beam transducer was mounted alongside a 200kHz transducer and the signal was produced on a 10 Hz pinging rate by a Suzuki ES-2025 depth sounder. The hydrographic survey package HYDAS (Quester Tanager Corporation) and HYPACK were used to determine sample grids, grid spacing and to provide guidance to the helmsman. The survey vessel sailed lines that co-incided with overflight lines by the EAARL Lidar plane. It was thus possible to obtain a dataset that allows ground-truthing of the airborne bathymetry.

During the survey operation a continuous stream of differentially corrected GPS information (NMEA encoded) was time-stamped and collected in separate files from the raw-acoustic data, which are also time-stamped. The GPS base-station was situated on Elliott Key. This resulted in ten processed, geo-referenced signal per second. These processed signals were then stored in separate files for quality control and statistical analysis. After the surveys raw acoustic data are submitted to quality control and statistical evaluation.

Quality control of signals consisted of checking for correct time-stamping, filtering for incorrect depth picks (this was either done by displaying all signals on a bathymetry plot and removing obvious outliers or by running a filtering application that eliminates all depth picks above a certain variance) and correct signal strength. All signals that did not pass the appropriate procedures are discarded.

Overview of the physical basis of acoustic bottom classification:

The principle of acoustic remote sensing of bottom types is briefly explained underneath. QTC View evaluates the first echo return on 50 kHz and essentially operates in a very similar way to Echoplus. The difference in the Echoplus system is that the latter is capable of collecting echos on both 50 and 200 kHz. QTC View only analyzes the first echo, while Echoplus also analyzes the second echo. Both systems have advantages in their specific environmental setting – QTC View is ideally suited for surveys in shallow water, which is made possible by extremely rapid digitization rates and the analysis of only one echo. Since Echoplus analyzes first and second echo, it has to wait longer for the complete signal, which at least doubles the minimum depth the system can operate in (shallowest depth for QTC View is approximately 100 cm, for Echoplus approximately 250 cm water depth).

The physical process associated with acoustic bottom classification is as follows:

(A) The sound emitted from the transducer is spread over a wide angle. This sound travels to the seabed and the energy that encounters the seabed at right angle (i.e. is transmitted at normal angle to the seabed) is returned to the transducer. The energy that does not impinge on the seabed in a right angle is lost. The seabed is not flat, which also causes energy that was not transmitted at right angle to the overall substratum to be scattered back to the transducer. The rougher the surface, the more energy finds its way back to the transducer via backscatter. Therefore, a stronger signal is received.

QTC View and Echoplus differ in the way the received signal is processed. QTC View processes the entire first echo, while Echoplus only processes the tail of the first echo. This in order to concentrate on backscatter and to avoid contamination of backscattered energy with energy that has been directly reflected from below the transducer (Figure 4). This becomes important when the boat rolls, since the first echo leading edge is likely to be lost when the transducer is off vertical. The scattered trailing edge of the echo will, however, remain largely constant under conditions of pitch and roll. However, while constancy of signal is gained, some information is lost.

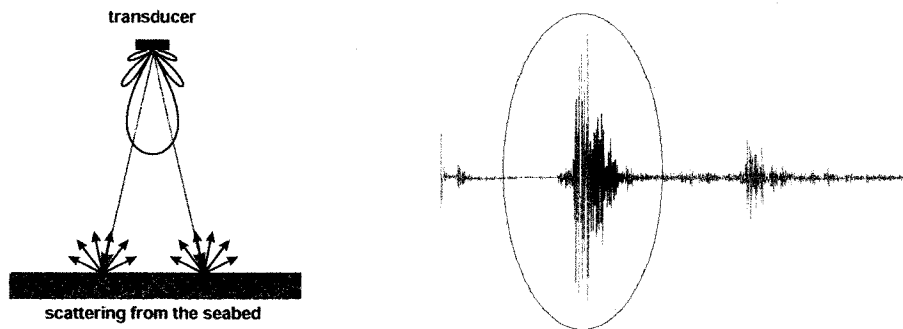


Figure 2: Scattering resulting in the first echo and the shape of the first echo (within the ellipse). OTC View uses almost the entire first echo information, Echoplus only the tail (in red).

(B) However, more than one echo returns to the transducer and Echoplus uses the second echo to obtain further information. The usefulness of this echo, and whether one decides to use it or not, depends on which underlying theory for its formation is used. The generation of this echo could be caused by the dominant ray paths undergoing scattering first at the seafloor (production of first echo), then at the surface, and then at the seafloor again (production of second echo). A competing theory claims that because of the presence of the sea surface, the configuration is actually bi-static, resulting in a virtual displacement of transmitter and receiver by twice the water depth. This would put the receiver into the near-field scattering zone and make the information contained in the second echo equivalent to the first echo.

In both cases, the energy contained within the second echo depends on seafloor hardness, therefore Echoplus analyzes the entire second echo.

In general, the quality of the first echo is higher, and careful QA/QC is applied before use of the second echo. Also, since waiting for two echoes takes twice the time as waiting for one echo, Echoplus is limited to 2m minimum survey depth while OTC View can survey to shallower depths (about 100 cm).

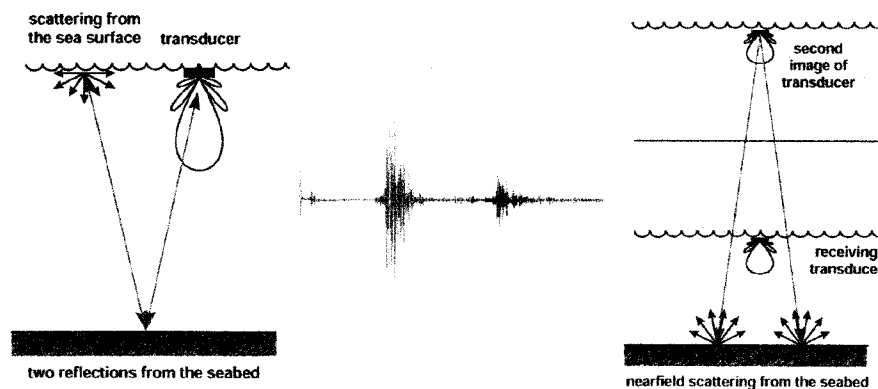


Figure 3: Scattering resulting in the second echo (red) and the two conflicting theories regarding the actual mechanism

After data collection, the raw data are further processed. Raw acoustic signals are digitized and manipulated by different algorithms. In the Echoplus system, the entire shape of the backscattered impulse is collapsed in to a single numerical index. Two such indices are produced for each outgoing ping: an index for the first echo, which is mainly determined by surface roughness, and an index for the second echo, which is mainly determined by surface hardness. The OTC system digitises the first echo backscatter and then turns it into signal envelopes, also called full feature vectors (FFV's). These can be graphically displayed. They are then time stamped and the data are submitted to Principal Components Analysis (PCA) in order to obtain clusters of decreasing similarity that can be correlated to similarly obtained clusters of

ecological data (while PCA is the ordination method of choice for the FFV's, the different data structure of ecological data – non-normality and prevalence of zero-counts – suggests ordination by multidimensional scaling). Several iterations of clustering of the entire dataset are usually used before ideal cluster size is chosen. Ideal cluster size is considered such that allows unequivocal identification of individual FFV's (i.e. the actual sampled area, the size of which is determined by the acoustic footprint of the sonar beam).

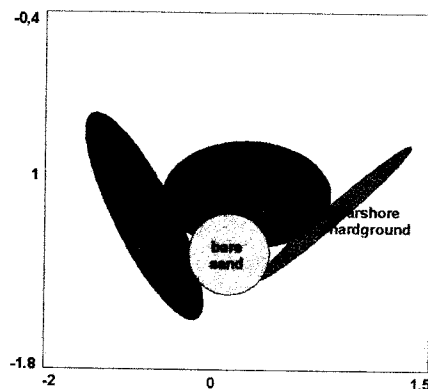


Figure 4: An example of a Principle Components Analysis output. The individual picks are contained within the clusters and color coded. These same colors are then displayed on the map.

Echoplus data are received as a string of univariate indices for roughness (first echo) and hardness (second echo). They can be plotted either against each other (roughness versus hardness), or, if calibration files were collected, they can be coded directly corresponding to the means and variances of the calibration files. Otherwise, they can be subjected to an equivalent analysis as QTC data.

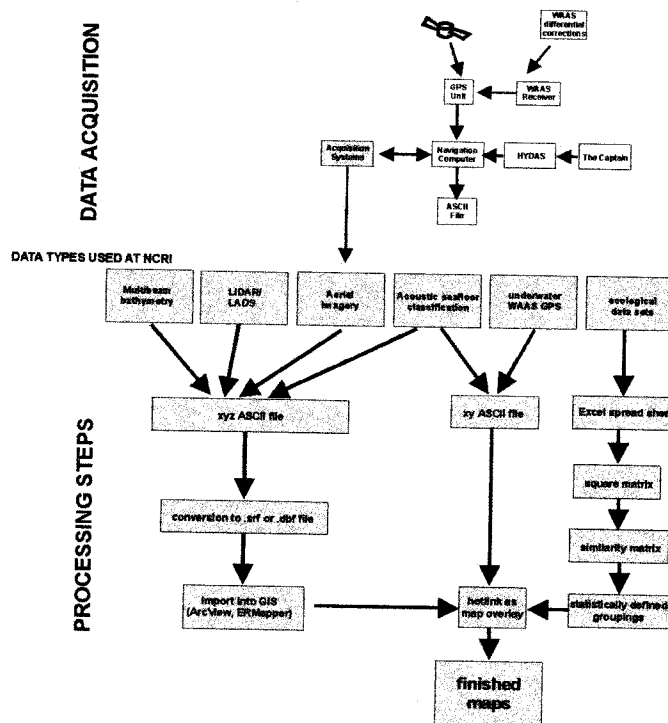


Figure 5: A flow-chart of the work and data flow in the suggested mapping project from acquisition to final product.

Results

The following flight lines of the EAARL Lidar were sailed by the acoustic vessel: 15, 17, 19, 20, 47. Each line was sailed three times in order to produce repetitive data, and a tie line was sailed from line 15 to line 47.

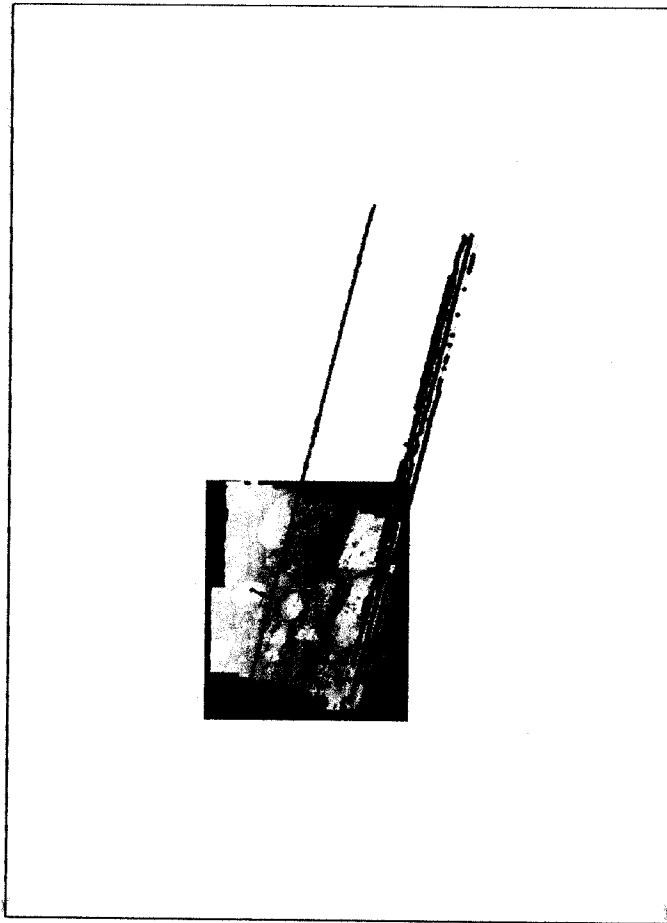


Figure 6: The acoustic survey lines. The image underlying the lines shows Alina Reef in the top left corner.

Acoustic ground discrimination using the OTC system was successful on a basic level in clearly separating patch reefs from surrounding sand. However, some confusion remained between seagrass and algae classes. It is likely that this is due to the large footprint of the 30 KHZ transducer, which did not provide fine enough resolution to discriminate between two classes with similar backscatter values.

Further tests with the system in Sebastian River have shown that the smaller opening angle of a 200 kHz transducer provides increased accuracy of detection and is indeed capable of discriminating between bare sand, algae and seagrasses. Fig. 7 shows the first and second echo received by the Echoplus system plotted against each other. The three separate clusters clearly show that distinct acoustic classes based on differential backscatter strength exist.



Figure 7: The acoustic survey lines. Discrimination between reef (light blue) and seagrass (yellow). It is evident that the sand/seagrass/algae discrimination was only moderately successful. This can be remediated by using a transducer with a smaller footprint.

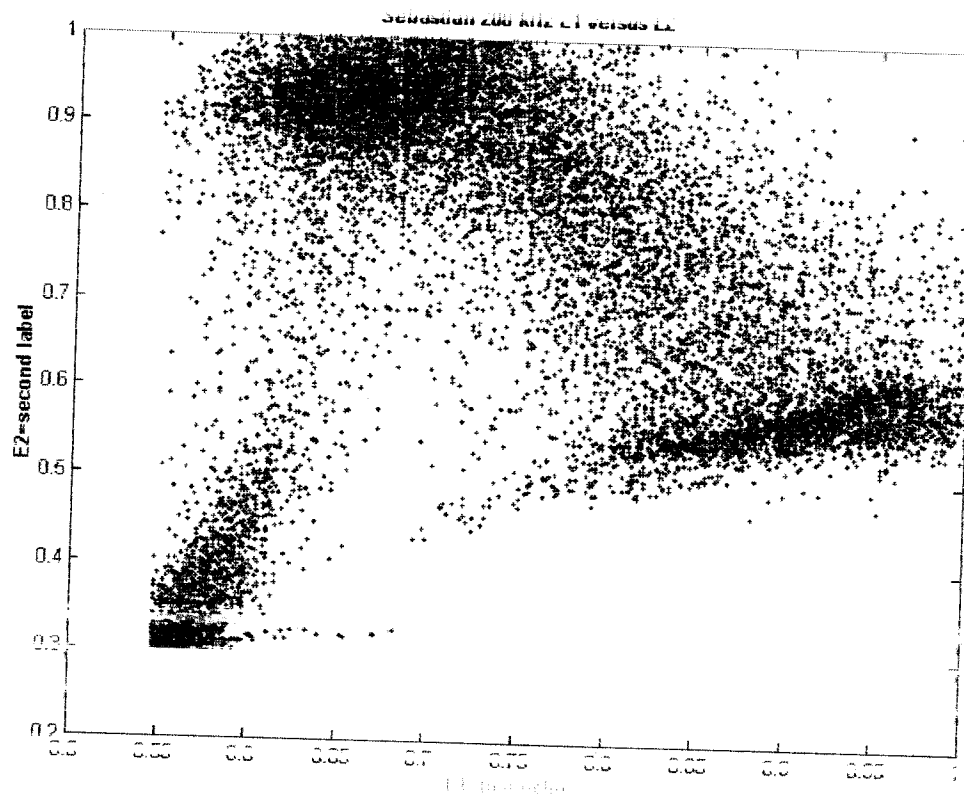


Figure 6. The acoustic survey lines. The image underlying the lines shows Alina Reef in the top left corner.

It is therefore planned to use a 200 kHz transducer in further trials to increase the system's accuracy. This will lead to a smaller footprint, which reduces the ecological grain of the survey. Also, the higher frequency signal is prone to scatter sooner than the longer 50 kHz signal. Since much of the desired information resides in the backscatter portion of the signal, this will also likely enhance ground discrimination.

The development of an acoustic library was not successful. In theory, data from one classification could be used to force a supervised classification on any arbitrary dataset since echo-strengths are normalized to be depth-invariant. While it could be shown that there is indeed depth invariance in the dataset, classification of transects that ran over Pacific Keel was not successful using echo classes that were obtained over Alina's Reef. This shows that the acoustic signals either have too much variability due to system drift (varying output voltages etc.) or that more detailed signal processing is necessary. Further investigations are pending.



Figure 7: Results of a supervised classification of acoustic data obtained over Pacific Reef. The data were trained against a survey performed over Aina's Keel. The results were not successful, which could indicate that either the system was unstable (due to output voltages) or that more signal processing is necessary before meaningful acoustic signal libraries can be produced.

Acknowledgements: NCKI and the project staff deeply appreciate the opportunities provided by NPS staff, their patience and help during fieldwork, and support during the proposal and reporting process.