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Mapping seagrasses for dredging operations

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eagrass beds represent some of the most valuable aquatic habitats within the marine ecosystem. They provide critical refuge and foraging grounds for a diversity of organisms, including crustaceans and other invertebrates, as well as fish. Many of these species are economically important.

Corps of Engineers districts frequently need to assess the character, extent, condition, and potential impacts to seagrass beds within their jurisdiction, particularly in areas where dredging is proposed in the vicinity of existing seagrass beds. Traditional seagrass survey methods are expensive, labor-intensive, and subject to unknown error. The Submersed Aquatic Vegetation Early Warning System (SAVEWS), an integrated sensor/software system consisting of hydroacoustic, global positioning system, and geographic information system components, has the potential to provide rapid, low-cost, near-real time detection and mapping of marine seagrasses.

This article highlights a limited feasibility test conducted in St. Andrews Bay, Florida, during mid-April 1995, early in the growing season. The objectives of this test were to address the technical feasibility of using SAVEWS in the marine environment and to determine its utility for rapid mapping. Conditions encountered during the field effort included short, highly epiphytized seagrasses and relatively high wind and wave action, resulting in what could be considered to be "worst-case" test conditions for SAVEWS. If SAVEWS could be successfully operated in these conditions, it should easily work during peak growth conditions during the calmer summer months.

Seagrass bed (photograph by Dr. William Brostoff)

Site description

The test site, St. Andrews Bay, located near Panama City, Florida (Figure 1), was selected for several reasons. It contained at least three species of seagrasses of differing growth habits and densities; the water clarity was good, which allowed for collection of underwater video data and diver observations, along with hydroacoustic data; and previous studies provided background information (Fonseca, Kenworthy, and Thayer 1987; Grady 1981; Saloman and Naughton 1982).

Three species of subtropical seagrasses can be found in intertidal

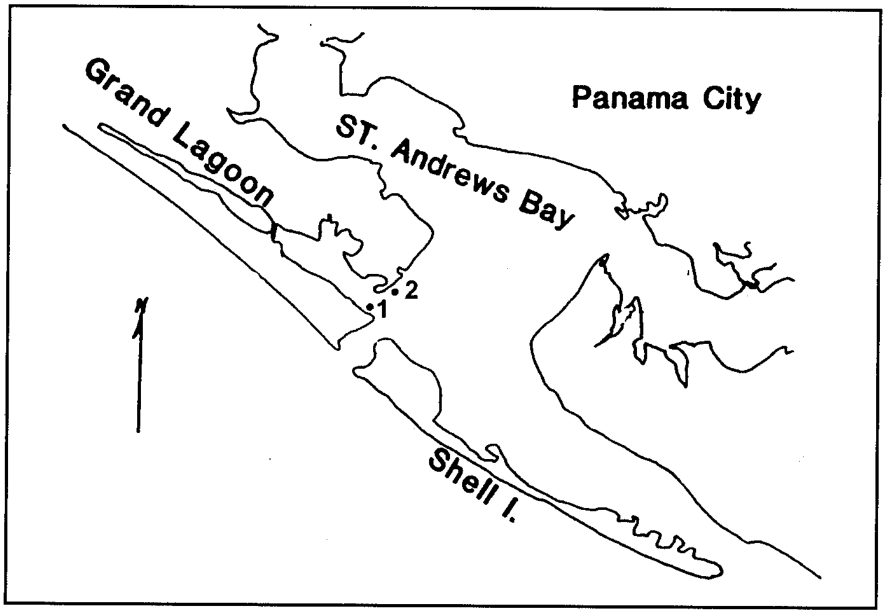

Figure 1. Study area in St. Andrews Bay, Florida, showing location of stationary samples and controlled transect (1) and the large plot survey (2)

and shallow subtidal areas of the bay—*Halodule wrightii* (shoalgrass), *Syringodium filiforme* (manatee grass), and *Thalassia testudinum* (turtle grass).

Halodule wrightii is a relatively short, fine-textured species that occurs primarily at shallow depths (<1 meter) in the intertidal zone. Measurements of blade height and width encountered during this study were 5 to 9 centimeters and 0.1 centimeter, respectively. *Syringodium filiforme* is also fine-textured (mean blade width = 0.1 centimeter), but has a taller growth habit (observed blade length = 10 to 20 centimeters), and was found in slightly deeper water than *Halodule.* The dominant species, *T. testudinum*, presents a much larger surface area (blade height 7 to 15 centimeters, blade width 0.3 to 0.4 centimeter), resulting in a stronger hydroacoustic signal. Hydroacoustical signature data were collected for pure stands of *Thalassia* of various densities, mixed beds of *Thalassia* and *Syringodium*, and pure stands of *Halodule.*

Inventory of seagrass mapping techniques

Active and passive optical techniques (most commonly aerial photography) are routinely used for mapping of submersed aquatic vegetation (SAV) and are particularly efficient for large areas with clear water. Known landmarks that are visible in the photographs make location referencing relatively easy. However, good water clarity is a critical requirement, which limits the use of these techniques in many areas.

Direct observation by divers can provide detailed information on species composition, density, and overall condition of the seagrasses (Mellors 1991), but this method is quite labor intensive, expensive, and covers only a limited sampling area. Diver surveys are also dependent on good water clarity, although to a lesser degree than aerial photographic techniques.

Off-the-shelf hydroacoustic depth profilers (that is, narrow-beam hydroacoustic transducers pointed vertically downward at the bottom, also known as fathometers) have been used to detect freshwater SAV (Maceina and Shireman 1980) and seagrasses (Miner 1993) in the water column before they were visible from the water's surface. The acoustic impedance provided by the plants generates a measurable signature. While this is a powerful tool for vegetation detection, the process of vegetation mapping is still slow and labor intensive, involving manual interpretation of strip chart printouts, measurement and correlation of position data, and spatial interpolation to generate profiles and map products.

Recent developments in the fields of digital signal processing, global positioning systems (GPS), and geographic information systems (GIS) now make it possible to automate the entire process and to generate maps in near-real time. These integrated technologies offer the potential to rapidly detect and map seagrasses, as explored in this article.

SAVEWS

Through support from the Tennessee Valley Authority Joint Agency Guntersville Project, the U.S. Army Engineer Waterways Experiment Station (WES) developed an automated SAV detection and mapping capability consisting of digital hydroacoustic, GPS, and GIS components (Figure 2). An amplitude-based digital hydroacoustic sounder (Biosonics DT4000) with a high-frequency (420-kHz), narrow-beam (6-degree) transducer generates a short pulse and records the echo return from the water column below the boat. A boat-based GPS system collects GPS satellite

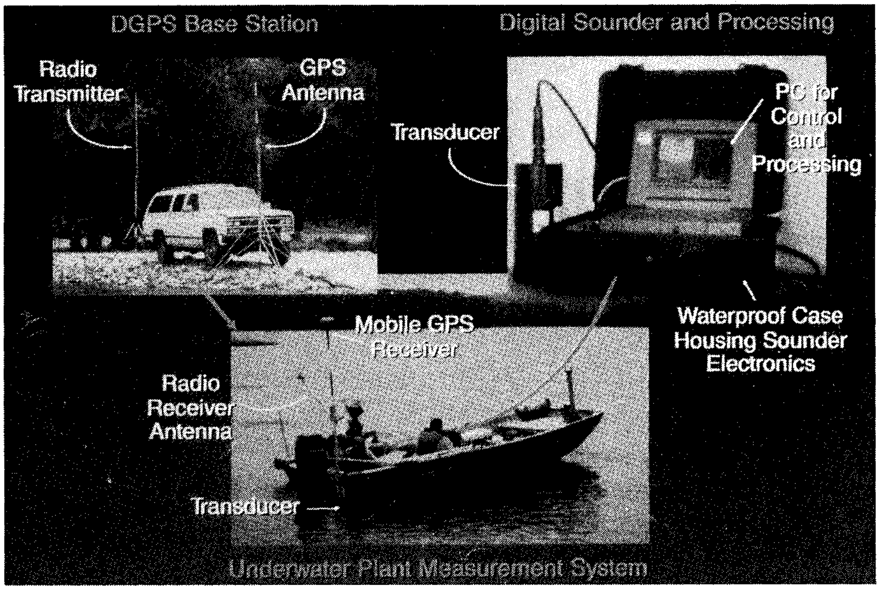

Figure 2. Components of SAVEWS

data and radio-transmitted differential GPS corrections broadcast from a U.S. Coast Guard navigation beacon, or other GPS base station. The real-time differentially corrected GPS position, accurate to within 5 meters horizontally, and the digital hydroacoustic data streams are merged and stored on the hard disk of a 486 notebook PC.

The system can be used from a small boat in which the operator traverses a systematic pattern, guided by a position display on the GPS monitor. Immediately after the pattern is complete, the combined position/hydroacoustic signal file is processed by a WES-developed algorithm. This algorithm uses hydroacoustic signal features characteristic of freshwater SAV-inhabited aquatic environments to determine bottom depth, plant presence, and geometric descriptors of the plant canopy. The processed output is then entered into a mapping package resident on the notebook PC aboard the boat. Spatial interpolation occurs, and maps are generated and displayed on the PC screen within minutes. This system is described in greater detail in Sabol and Melton (1996).

The system was designed for early detection of nuisance freshwater SAV species (such as hydrilla and Eurasian watermilfoil) in lentic environments before they are visible from the surface. Physical/hydroacoustic characteristics of these environments, which are exploited by the SAVEWS classification algorithm, include calm surface conditions and associated low surface noise levels, large canopy-forming plants that are strong acoustic targets and exceed 20 centimeters in height, and gradually changing bottom depths. Tests conducted under these conditions have been highly successful, in part because the signal-processing logic incorporated these features.

This study was conducted to evaluate the performance of SAVEWS for detection and mapping of marine seagrasses under conditions significantly different from those for which the initial processing algorithm was designed. Specific issues that must be resolved to evaluate the usefulness of this system for seagrass detection and mapping include the following:

- What are the hydroacoustic characteristics of the shallow-water seagrass environment, and how do these differ from the lentic freshwater SAV environment?
- What hydroacoustic features must be used in a seagrass classification algorithm?
- What are the operational considerations for effective use of the system in this environment?

Procedures

Several types of measurements were made during the 3-day field test. A set of stationary hydroacoustic signature measurements of plants and bottom conditions were made, followed by observation and sampling by divers (Figure 1, location 1). Hydroacoustic measurements, with coaligned underwater video for "ground truth," were made along several transects. Video-equipped divers also swam transects, recording a close-up view and making notes on species presence, density, and height. Several moving surveys were performed over large areas, some using the coregistered underwater video camera. The stationary samples and a subset of the transect data were used for basic hydroacoustic characterization and algorithm training. The remainder of the data were available for evaluating system performance.

The large-area surveys were used to address questions of coverage rates, transect pattern, and other operational considerations such as coverage rates, effective depths, and transect patterns. This included surveying a large plot (approximately 8 hectares), consisting of a patchwork of vegetated and bare sand areas (location 2 in Figure 1), at various transect densities (ranging from 10- to 100-meter spacing) to determine the minimum transect density needed to obtain suitable map accuracy. The digital data were processed and entered into a GIS package that performed spatial interpolation using the triangulated irregular network procedure. Maps were generated for bathymetry, vegetated areal coverage, and plant height and were visually compared to determine minimum survey density.

Test findings

Typical hydroacoustic conditions are illustrated as echograms (Figure 3). The echogram represents depth along the vertical axis, ping report number (equivalent to time or distance traveled) along the horizontal axis, and the echo return level as a colorization of voltage squared in decibels. (This represents a measure of the acoustic intensity of the echo. It is computed as *Decibel units = 10 * log (Voltage output)*^{2}, where 1.0 volt is the full-scale output of the transducer.) Decibel values close to zero (relatively larger numbers) represent strong echoes, while large negative values (relatively small numbers) represent weak echoes.

In all areas surveyed, the bottom was easily visible by its strong echo return (heavy dark line in Figure 3). The strong return (-47 to -53 decibels) results from the hard sand bottom found throughout the outer bay. The location of the bottom is identified by the depth corresponding to the sharpest rise in voltage squared return—roughly the top edge of the highest return band in Figure 3. In unvegetated areas, a sharp gradient occurs between the bottom and the overlying water column, which typically has echo levels below -80 decibels. In vegetated areas this sharp gradient is not evident.

Other important physical features encountered which affect the hydroacoustic signal include waves, rapidly changing bottom bathymetry, and surface "noise." Waves were considerably higher than those typically encountered during lentic freshwater surveys. Water depth frequently changed rapidly over a very short distance, presumably because the bay is a high-energy environment. Both of these conditions differed from those typical of a freshwater SAV environment. Surface noise, represented as the medium-strength returns (-75 to -55 decibels) emanating from the surface down to depths as great as 1 meter or more, results from small bubbles entrained in the water from surface waves, turbulence, or boat propellers, causing multiple scattering of the signal.

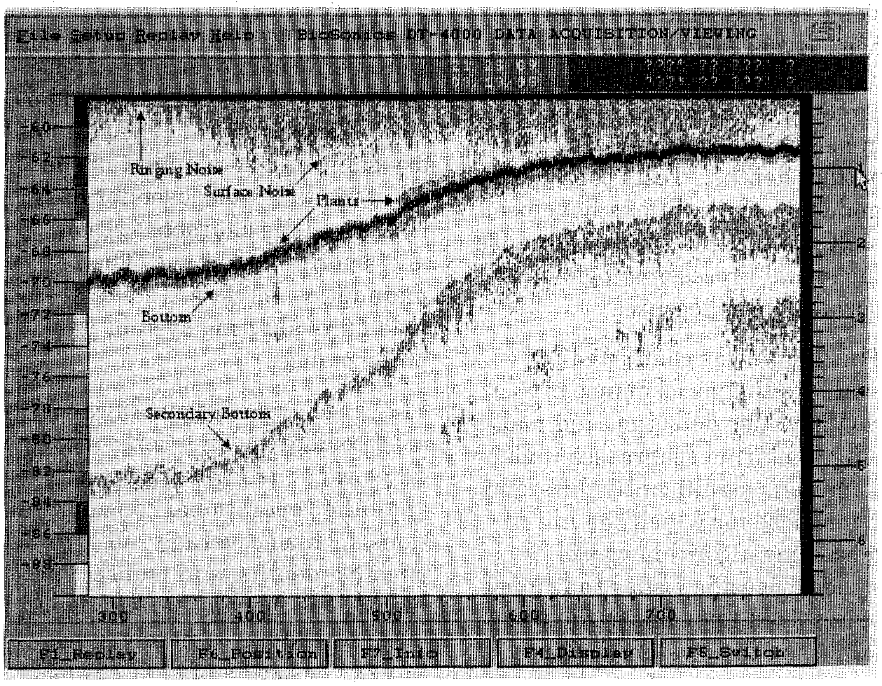

Figure 3. Echogram of transect illustrating typical hydroacoustic features. (The color original was reproduced in black-and-white for this article to minimize publication costs. A color copy can be obtained by contacting the senior author, Mr. Sabol.)

Seagrasses in the echogram typically appeared as a thin layer (5 to 20 centimeters) of medium echo-return levels (-75 to -55 decibels) immediately above the bottom. The more robust *Thalassia* was easily distinguishable in the signal at biomass as low as 80 grams/square meter (dry weight) and heights as short as 10 centimeters. The finer and less dense *Syringodium* and *Halodule* were not consistently detectable. This is at least partially due to the high surface noise occurring in the shallow areas where these species were found.

It quickly became apparent that the plant detection algorithm tailored for lentic freshwater SAV environments would not work well in the St. Andrews Bay environment. This was due to differences in plant growth morphology, bottom conditions, waves, and surface noise. A new set of processing steps was developed to detect and classify plant conditions in the bay environment. This sequence includes bottom detection, surface noise evaluation (rejection of ping reports with excessive noise), vegetation detection, and assignment of vegetation canopy attributes.

Algorithm training was performed using a subset of the hydroacoustic measurements with ground truth measurements. Within the bare sand training set, 98 percent of the pings were correctly classified as bare sand; misclassified pings indicated very short vegetation. For the vegetated training samples, plant height and coverage predictions were in good agreement with actual measurements for denser *Thalassia* samples but tended to underestimate the sparse *Halodule* and *Syringodium* samples. The new algorithm, denoted SEAGRASS 1.0, was implemented for processing the stored digital data on the SAVEWS PC. The processed outputs include position-referenced bottom depth, vegetated areal coverage estimate (percentage), and mean plant height.

The algorithm was tested using several segments of moving surveys (5.5 minutes of data consisting of 3,300 pings covering a distance of approximately 800 meters) with coaligned underwater video. A segment of this transect is illustrated (Figure 4) for an area transitioning from bare sand to plants. Percent cover predicted by the algorithm compares favorably with an observer's visual interpretation of the coregistered video. The algorithm estimated the coverage to be approximately 75 percent of that interpreted by the viewer, with a correlation coefficient of 0.73.

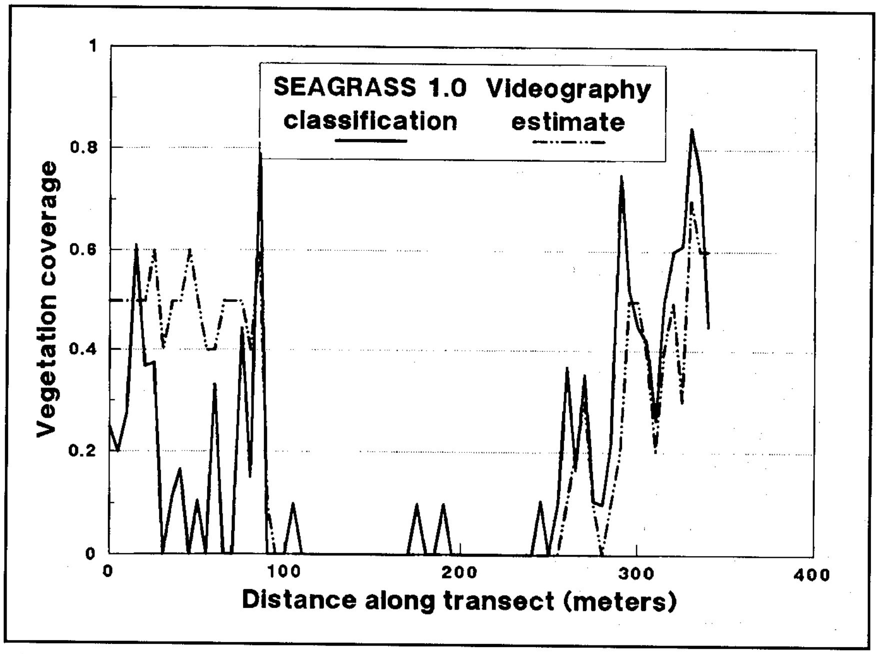

Figure 4. Comparison of SEAGRASS 1.0 algorithm with observer-interpreted coaligned underwater video imagery

Data from the large plot surveyed at different transect spacings were processed with SEAGRASS 1.0 and mapped to display bathymetry and vegetation attributes. A subjective comparison between maps generated from different transect spacing data sets showed visual similarity between maps with transect spacing up to 50 meters. The 50-meter transect-spacing series of maps is presented as Figure 5. At this transect spacing, data for mapping can be acquired at a rate of 0.6 hectare/minute.

Summary

This test has demonstrated the feasibility of using SAVEWS to detect and map seagrasses. Since hydroacoustic conditions encountered in St. Andrews Bay were significantly different from the lentic freshwater SAV environments for which the original SAVEWS algorithm was developed, it was necessary to develop a new algorithm for seagrass detection and classification. This algorithm exhibited good qualitative agreement with visual observations and diver measurements.

Thalassia was easily detected, although the more finely structured *Syringodium* and *Halodule* were not consistently detectable. This is considered due, at least partially, to the low abundance of these species and the high surface noise occurring in the shallow areas where these species are found. It is anticipated that improved detection of these species will be achieved during periods of higher abundance, in the summer months. Surface noise in the shallow areas (<1 meter), caused by waves or the survey boat itself, was the biggest problem. Signal strengths for surface noise were in the same range as vegetation signal strengths, masking the vegetation when the two overlapped. If it is necessary to survey shallow areas, it may be necessary to wait for calm conditions and high tide.

This system has the potential for highly cost-effective detection and mapping of seagrasses. Its greatest utility would probably be for mapping medium-scale projects, particularly where poor water clarity limits the effectiveness of optical mapping methods. Variable density sampling indicated that, for this particular environment, reasonable spatial accuracy can be obtained with a maximum transect spacing of 50 meters (corresponding mapping coverage rate of 0.6 hectare/minute).

SAVEWS is currently operational for detection and mapping of freshwater SAV and seagrasses. Developmental efforts continue in the areas of vegetation quantification, species discrimination, and sediment classification. The SAVEWS developers are actively seeking study sites, so that additional data can be acquired for further system development. The system is available through WES to support Corps of Engineers divisions or districts and other government agencies that need vegetation mapping.

For additional information about SAVEWS, contact

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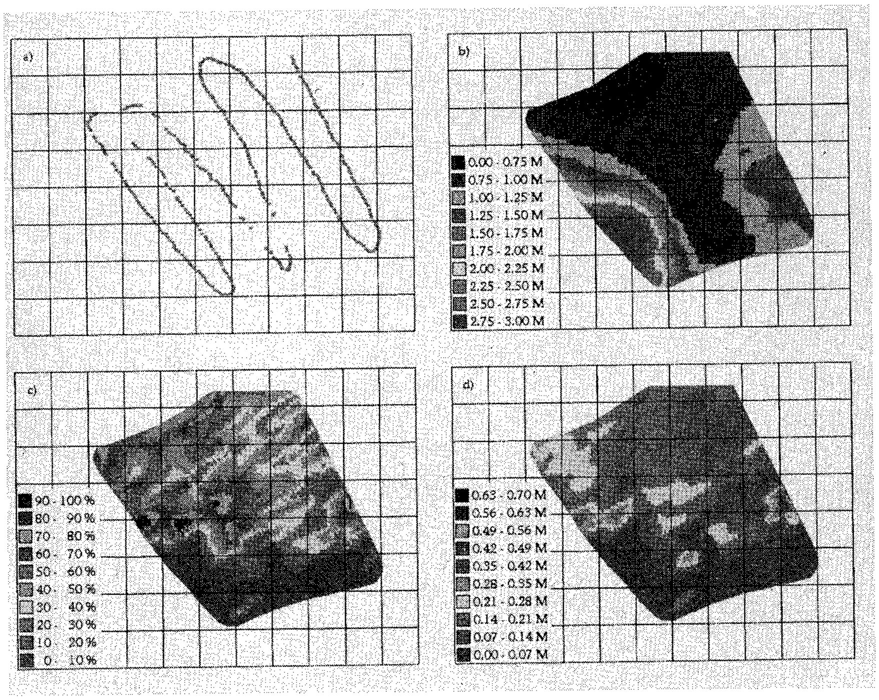

Figure 5. Maps of test plot (overlain with 50-meter grid for reference) generated from 50-meter transect spacing data: a, survey path; b, bathymetry; c, vegetated areal coverage; and d, plant height. (The color original was reproduced in black-and-white for this article to minimize publication costs. A color copy can be obtained by contacting the senior author, Mr. Sabol.)

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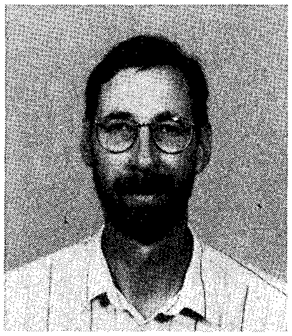

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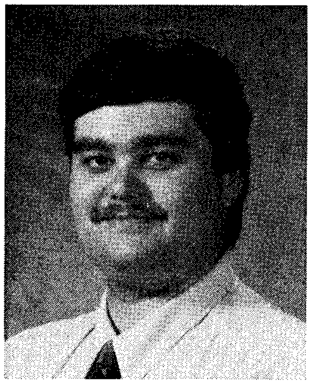

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New coastal ecology course offered

A new course focusing on state-of-the-art marine ecological methods will be offered next year (April 19-23, 1997) in Charleston, South Carolina. The course will consider such topics as habitat assessment techniques appropriate to coastal ecosystems, experimental design, sensitive/endangered species, applications of sediment profiling imagery, and basic concepts in marine and estuarine ecology. Class size is limited to 20 students, to enhance the hands-on field and laboratory instruction.

To register or to obtain further information, see your training officer and request Corps PROSPECT Course 263, or call Mr. John Buckley, U.S. Army Engineer Division, Huntsville, (205) 722-5898.

Calendar of Dredging-Related Events

May 20-22, 1996	**Tri-Service Environmental Workshop**, Hershey, PA **POC**: Keith Hicks, (804) 865-8721
June 11-14, 1996	**WEDA XVII (Western Dredging Association)**, “Improvements in Dredge Technology” and Exhibition, Marriot Hotel, New Orleans, LA, **POC**: Larry Patella, (503) 285-5521; fax (360) 750-1445

EEDP

This issue reports on a portable measurement system that integrates hydroacoustic and global positioning system technologies to detect and map aquatic vegetation. Low-density seagrasses were successfully detected and mapped during a field test. Capabilities, limitations, enhancements, and availability of the system are discussed.

ENVIRONMENTAL EFFECTS OF DREDGING

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the Waterways Experiment Station. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program managed by the Environmental Effects of Dredging Programs. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Contributions of pertinent information are solicited from all sources and will be considered for publication. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Communciations are welcomed and should be addressed to the Environmental Laboratory, ATTN: Dr. Robert M. Engler, U.S. Army Engineer Waterways Experiment Station (CEWES-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call AC 601/634-3624.

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