A National Oceanographic Partnership Program Award

Development of an Autonomous Sampling Network for Plankton, Hydrography and Currents. Phase I. Incorporation of Plankton Imaging Capability into Autonomous Underwater Vehicles

Cabell Davis, Scott Gallager, and Robert Goldsborough
Departments of Biology and Applied Ocean Physics and Engineering
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543-1052
Phone: (508) 289-2333 FAX: (508) 457-2134 E-mail: cdavis@whoi.edu

Award Number: OCE-0000580
http://science.whoi.edu/users/cdavis/vpr-remus/FrameSet.htm

Long-term goals

The single biggest challenge in Biological Oceanography over the next two decades is development of predictive capability. At present, this capability is limited by the sparseness of our data. We are unable to sample with high enough resolution in time and space to capture episodic events and features that control population size of marine species. In the present project we are developing an autonomous high-resolution sampler by merging plankton-imaging technology with autonomous underwater vehicle (AUV) technology. We consider this project Phase I of a 3-phase long term effort. In this first phase, we are integrating the Video Plankton Recorder (VPR) into the REMUS AUV and testing it at sea. Future funding will be sought to complete the remaining two phases, which will involve autonomous daily sampling across the mouth of a coastal embayment (Phase II) and use of multiple VPR/REMUS vehicles for autonomous daily mapping of an open ocean region (Phase III).

Objectives

Our objectives for this first phase have been to: 1) modify the design of the VPR to make it compact and autonomous in terms of power and data recording capability, and its ability to be carried by the REMUS vehicle and other AUVs, 2) to insert the new modular VPR into REMUS, and 3) to test the REMUS in coastal waters off Woods Hole and in longer deployments across the mouth of Cape Cod Bay and on Georges Bank

Approach

- Design a modified VPR system to make it compact and autonomous
- Build the mechanical and electronic components of the new VPR
- Design the REMUS interface components for easy insertion and removal of the VPR module.
- Develop software for controlling the VPR module including power cycling and data acquisition.
- Test the completed VPR-REMUS system in nearby coastal waters.

Work Completed

- Design and construction of a new modular VPR system for insertion into the REMUS vehicle.
- Modifications to REMUS system for controlling the VPR.
- Software development allowing: 1) acquisition of digital video and hydrographic data autonomously, 2) control of the VPR power cycling and data I/O via ethernet.
- Initial testing in coastal waters off Woods Hole.
- Long continuous deployment across the mouth of Cape Cod Bay from Provincetown to Plymouth.

Results

We have successfully completed the design tasks, fabricated the mechanical and electronic components of the new VPR, completed initial software development, conducted an initial at-sea test deployment of the new VPR/REMUS system, modified software and hardware components to improve data quality, and a more extensive field trial. The development work has involved: 1) repackaging the VPR camera and strobe, together with their optical components, into small lightweight pressure housings that attach to a modular VPR control housing inserted into the REMUS vehicle, 2) assembling a data recorder electronics package (essentially a digital VCR) that accepts the video signal from the VPR, stores up to 20 hours of video on a hard disk, while fitting into the modular VPR control housing. A compact wavelet based compressed video recorder was used as the digital VCR and was installed in the VPR control housing, which then was inserted into the REMUS vehicle. This self-contained video recorder consists of a PC-104 single board computer, a commercial wavelet compression board and a high capacity hard drive. Together these components were mounted on a carrier board that contains power supplies and a control interface. A software program was also developed to control the recorder and collect ancillary data to be recorded along with the video data.

The completed prototype VPR/REMUS was initially tested successfully in the coastal waters off Woods Hole (Figures 1).

Figure 1. Deployment of VPR-REMUS in coastal waters off Woods Hole.

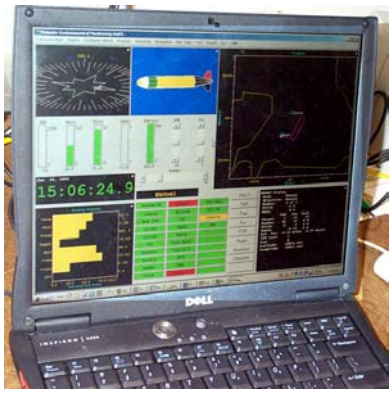

Figure 2. Remus data display.

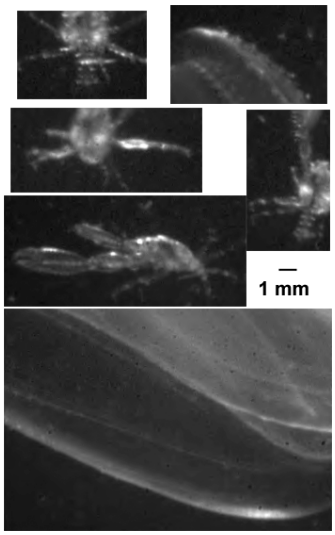

Figure 3. Images of crab larvae and ctenophores taken using VPR-REMUS.

The REMUS vehicle was programmed to sample at 2 meters depth along two track lines parallel to two transponder buoys. The data collected during the initial test was analyzed and provided needed information for further field tests.

In FY2002, our primary effort involved field testing, improvement to the optical system, and use of GPS navigation. After further testing in local waters near Woods Hole, we conducted an extensive uninterrupted 40 km deployment of the VPR-REMUS system across the mouth of Cape Cod Bay. The system operated autonomously, undulating between the surface and 10 m off the bottom as it swam across the bay. The system paused at the surface at regular intervals to obtain a GPS fix and then would to continue on its preprogrammed mission toward Plymouth Harbor. We followed the system aboard the R/V *Asterias* (WHOI's 45' research vessel). We subsequently have examined the images from this deployment and found that further hardware and software modifications to the imaging system are needed. We have subsequently focused on modifying the video acquisition compression/decompression (CODEC) method and the optical alignments to improve the image quality. We are preparing to conduct an extensive deployment of the system on a cruise to Georges Bank in March 2003.

Impact and Applications

Development of the VPR/REMUS system will allow high-resolution robotic sampling of plankton and environmental variables coastal and open ocean regions. Such high-resolution data is crucial for meaningful predictions of the impact of environmental change, including global climate change, aquatic pollution, and over-harvesting, on marine populations.

National Security

Robotic sampling of plankton and environmental variables in freshwater and coastal marine systems of the United States may provide early warning of potential harmful or deadly contaminants introduced to these systems.

Economic Development

The compact and autonomous design of the new VPR system has been incorporated into a new mini-VPR system that is commercially available for general aquatic sampling through Seascan Inc., Falmouth, MA.

Quality of Life

Once the robotic sampling networks are established in coastal waters and aquatic environments, the data can be used to better quantify effects of pollution and overfishing.

Science Education and Communication

The data from such a sampling network can be transmitted to public venues for educating students and the general public in the area of aquatic ecology.

Transitions

Economic Development

As mentioned above the basic concepts and designs the VPR module developed for REMUS have been incorporated into a new mini-VPR system that is now commercially available to aquatic researchers worldwide through Seascan, Inc,, Falmouth, MA.

Quality of Life

We plan to develop as part of Phase II and III, an autonomous sampling network of robotic plankton/hydrographic samplers to provide realtime data that can be used by managers (fisheries and water quality) in deciding policy regarding coastal waters.

Science Education and Communication

Data from the above mentioned network will be available on the web for display in museums and marine sanctuary facilities for education of the K-!2 and the general public.

Related projects

We have developed other VPR sampling systems for real-time rapid ocean surveys and moored applications. (See http://seal.whoi.edu/)

Publications

Davis, C. S., S. M. Gallager, X. Tang, L. Vincent, and C. J. Ashjian, H. Qiao. Real-time visualization of taxa-specific plankton distributions. *Mar. Ecol. Prog. Ser* (submitted).

Davis, C. S., F. T. Thwaites, R. G. Goldsborough, Q. Hu, and S. M. Gallager. 2002. New Developments in Imaging and Deployment of the Video Plankton Recorder. AGU/ASLO Ocean.

Davis, C. S. 2002. New Technological Developments. Invited short article for International GLOBEC brochure. 2pp. (in press).

A National Oceanographic Partnership Program Award