NOAA-Fisheries Advanced Sampling Technology Working Group (ASTWG) FY 08 Annual Report

EXECUTIVE SUMMARY

The long-term goals of the Advanced Sampling Technology Working Group (ASTWG) are to improve the accuracy and precision of living marine resource assessments by identifying information needs for existing and new stock assessments, identifying new and innovative uses of sampling technologies, and facilitating and conducting research to advance our understanding of the marine environment.

This year the May meeting of the ASTWG was held in conjunction with the National Stock Assessment Workshop (NSAW) with a session dedicated for interaction between the ASTWG and stock assessment scientists. Priorities for the ASTWG in FY08 were to continue development of an alternative sampling platform (AUV), to improve acquisition and analyses of underwater images, to improve accuracy and precision of acoustic estimates, and evaluation of the ME70/MS70 hydro-acoustic system. Many of these projects are supported through the ASTWG competitive grants program that funds projects to address identified knowledge gaps in assessments of living marine resources.

This document consolidates the annual reports of each of the Science Centers to highlight accomplishments from ASTWG funding. Also appended in the back of the report are progress reports of technology projects supported by the ASTWG grants program.

Regional Support of FY08 ASTWG: Northeast Fisheries Science Center

(Representatives: Michael Jech, 508-495-2353, Michael.Jech@noaa.gov; Joseph Godlewski, 508-495-2039, Joseph.Godlewski@noaa.gov)

GOALS

The goal of ASTWG supported efforts at the Northeast Fisheries Science Center (NEFSC) is to implement advanced sampling technologies to improve survey operations with integrated sensor deployment and analytical tools to obtain more accurate, precise, cost-effective, and synoptic measurements for monitoring our nation's living marine resources and their habitat using ecosystem-based management approaches.

PRIORITIES

Priorities during FY08 were to develop the technical infrastructure required to improve fish stock assessments, participate in ASTWG national initiatives, complete the ASTWG-supported research FY07 projects 1) "Multibeam (Simrad ME70/MS70) users workshop for fisheries applications", 2) "Workshop on modeling fish and zooplankton acoustic scattering" and 3) "Remote detection and identification of marine animals to improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON)".

A FY08 priority for the NEFSC Advanced Sampling Technologies group was the continued field testing of the Advanced Fisheries Tow Vehicle (AFTV) which provides our agency with a unique horizontally-stable towfish platform that readily integrates and deploys new technologies in support of efforts to improve NOAA's Stock Assessment Improvement Plan (SAIP), Essential Fish Habitat (EFH), and Integrated Coastal and Ocean Mapping (ICOM) research.

APPROACH

Our approach for developing NEFSC's advanced sampling technologies has been to develop collaborative efforts for research, evaluation, and implementation of new technologies aboard existing Atlantic Herring Acoustic Surveys, Bottom Trawl Surveys, and Gear Performance Studies. This collaborative effort also included mentorship for academic students through NOAA's Undergraduate Scholarship Program and Education Partnership Program.

WORK COMPLETED

The Electronics Engineer hired with the ASTWG Center funds has provided engineering support for various advanced sampling technology projects; fisheries acoustics, seafloor and habitat mapping, underwater video, and survey gear performance.

We have continued development of seafloor mapping capabilities with the Kongsberg EM3002 300 kHz multibeam system. The EM3002 is a shared resource among the NEFSC, Massachusetts Department of Marine Fisheries, and NOAA Costal Survey and is deployed on the FRV GLORIA MICHELLE at the NEFSC.

Effort was devoted to developing NEFSC's acoustic capabilities aboard the FSV H B BIGELOW. The capabilities include split-beam scientific echo sounders (EK60) and multibeam (ME70) sonar.

We are developing and completing three manuscripts as a result of the "**Workshop on modeling fish and zooplankton acoustic scattering"**. The first manuscript describes theoretical models and standard targets (e.g., sphere, cylinder, prolate spheroid, and shelled). The second and third manuscripts describe theoretical models as applied to fish with swimbladders (Atlantic herring and Atlantic cod) and zooplankton (euphausiid).

The NEFSC is continuing its efforts at field testing of the Advanced Fisheries Tow Vehicle (AFTV) system (Fig. 1). The AFTV is presently configured for verifying acoustic targets in the water column with underwater cameras and video capability and for collecting acoustic data with a 38-kHz EK60 deepwater split-beam transducer. In addition, we have incorporated a Dual-Frequency Identification Sonar (DIDSON) in the nose of the AFTV to quantify fish behavior in conjunction with the ASTWG funded project "**Remote detection and identification of marine animals to improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON)**". Future plans are to configure the AFTV for video mosaics and acoustic seabed classification for assessing scallop populations and habitat.

Figure 1. The AFTV being deployed on the NOAA ship FRV DELAWARE II during the annual Atlantic herring acoustic survey in the Gulf of Maine during September 2008. Note the DIDSON unit and the underwater camera in the forward section.

We have also participated in meetings to discuss progress on the ME70 as part of the ASTWG funded project: "**Multibeam (Simrad ME70/MS70) users workshop for fisheries applications**". The objectives of these meetings are to maintain communication among the Science Centers and the manufacturer on development of the ME70 multibeam and initiate collaborations among the Science Centers and academia.

RESULTS

The DIDSON sonar was deployed on the northern flank of Georges Bank during the first two weeks of the NEFSC's annual acoustic survey of Atlantic herring in September 2008. These deployments were the first on Atlantic herring in the Gulf of Maine. We are initiating efforts to utilize the DIDSON sonar for identification and classification of acoustic backscatter, length measurements, and behavioral observations. The DIDSON has high spatial resolution and can be used to detect fish near the bottom (Fig. 2).

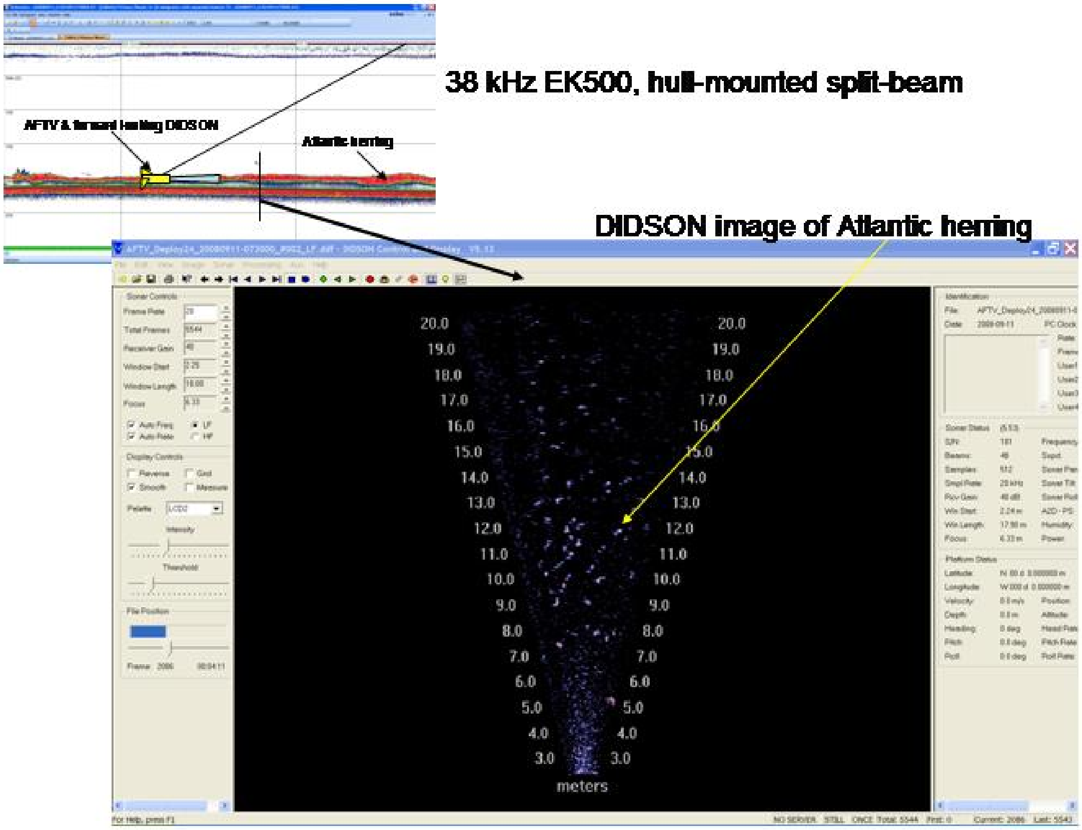


Figure 2. Echogram of 38 kHz, hull-mounted split-beam data (upper left panel) and an echogram of a single transmission from a Dual-frequency IDentification SONar (DIDSON) (lower panel). The 38 kHz echogram shows a dense layer of Atlantic herring, *Clupea harengus* (confirmed with a pelagic trawl haul). The DIDSON was set in the AFTV looking horizontally forward and the AFTV was towed through the dense herring layer. The DIDSON was operating at 1.1 MHz, with 48 0.4^{o} by 12.0^{o} beams and 7 cm range resolution. Data were collected in the Georges Bank region of the Gulf of Maine in September 2008. The bright spots are herring. From this image we can measure the inter-fish spacing and sizes. From the time series of successive transmissions, we can measure the behavior of the herring.

IMPACT/APPLICATIONS

NEFSC efforts in support of the national ASTWG initiatives and regional projects will improve our ability to monitor economically and ecologically important living marine resources in a more accurate and cost-effective manner. Support has also fostered increased collaboration with academic partners and other governmental agencies.

TRANSITIONS

The development and continued improvement of our electronics support to the NEFSC has allowed the advanced sampling technology group to augment our acoustic sampling as well has enhance and further our efforts towards optical measurements and implementing advanced technologies for improving gear mensuration and on-board fish measurements.

RELATED PROJECTS

The ASTWG funded three projects in FY07

- Multibeam (Simrad ME70/MS70) users workshop for fisheries applications by D. Demer (SWFSC), Chris Wilson (AFSC) and M. Jech (NEFSC)
- Workshop on modeling fish and zooplankton acoustic scattering by M. Jech (NEFSC) and J. Horne (U. Washington), and
- Remote detection and identification of marine animals to improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON) by C. Wilson (AFSC) and others from the Science Centers.

Progress reports for these projects are provided as separate documents.

PUBLICATIONS

Weber, T. C., H. Peña, and J. M. Jech. Acoustic observations of Atlantic herring schooling behavior in the northwest Atlantic. (*Accepted to ICES J. Mar. Sci.*)

Gurshin, C. W. D, J. M. Jech, W. H. Howell, T. C. Weber, and L. A. Mayer. Acoustic backscatter and density measurements of captive Atlantic cod using a 300-kHz multibeam sonar synchronized with a 120-kHz split-beam echosounder. (*Accepted to ICES J. Mar. Sci.*)

PRESENTATIONS

Expenditures [$135K]

The Northeast Fisheries Science Center (NEFSC) was allocated **$135K** in FY06 to support the FTE position and ASTWG participation. The FTE salary and overhead costs totaled **$110K**. An additional tax was imposed on the $135K by the NEFSC (**$25K**) for a total salary and tax reduction of **$135K**.

Regional Support of FY08 ASTWG:
Southeast Fisheries Science Center

(Representatives: Charles Thompson, 228-688-2097, charles.h.thompson@noaa.gov ; Joe Serafy, 305-361-4255 x255, joe.serafy@noaa.gov)

GOALS

The goal is to develop the infrastructure for developing and deploying advanced sampling technologies required to improve stock assessments.

PRIORITIES

Priorities of the SEFSC include improving fishery-independent data on reef fish stocks, determining large-scale movement patterns of highly migratory species, and improving estimates of catchability (particularly for highly migratory species on longline gear) and natural mortality within the US Gulf of Mexico, South Atlantic, and Caribbean regions.

APPROACH

FY08 activities addressed improving reef fish assessments. Fishery-independent surveys for reef fish are typically conducted using non-extractive visual methods, either by divers or video cameras, to estimate fish density and community structure. The value of these surveys can be improved through the use of stereo imaging systems to obtain accurate measurements of fish length without the necessity of capture. A camera system has been developed that incorporates both video and stereo still cameras to image reef fish. Analysis of data from video surveys is both time consuming and labor intensive. These issues can be addressed by computer automation of the analysis. A project was begun in FY08 to develop algorithms necessary to automatically detect, track, and count fish in video or still image sequences.

Figure 1. Combined stereo/video camera systems.

WORK COMPLETED AND RESULTS

Development of stereo video camera systems was continued during FY08. The system is composed of color video and stereo monochrome still cameras controlled by a PC104+ computer and installed in an underwater housing. In FY08, four completed camera systems were fielded for the duration of the SEFSC reef fish survey. Vision Metrology System (VMS) software is being used to measure fish lengths in images from the stereo cameras. Analysis of the stereo images from FY08 is still underway and is providing length-frequency distributions for observed species where previous video surveys provided, at best, a rough estimate of size range. An experiment was conducted to characterize precision of length measurements produced from stereo images as a function of object size, range from camera, and aspect angle, by photographing and measuring known objects in a tank. Effort is also being spent to quantify errors, bias, and repeatability of length measurements by different analysts.

Figure 2. Single frame from underwater image sequence with two fish present (left) and result after application of automated detection algorithms currently under development (right.)

Figure 2. Single frame from underwater image sequence with two fish present (left) and result after application of automated detection algorithms currently under development (right.)

Efforts to develop automated image processing produced preliminary algorithms to detect moving objects in underwater image sequences. Details on this ASTWG funded project are attached as a separate report. ASTWG funds were also used for collaboration with SWFSC on development of the NMFS AUV. This effort was directed at debugging and modifying AUV navigation software and resulted in the first autonomous multi-leg missions executed by the AUV.

IMPACT / APPLICATIONS

Stereo camera systems represent a significant advance in SEFSC's ability to assess reef fish stocks. These systems will provide accurate length measurements on a greater number of individual fish than was possible with previous techniques (paired laser arrays or viewer estimation). Efforts to automate analysis of images collected with these systems will reduce both the time required and the cost to produce survey results.

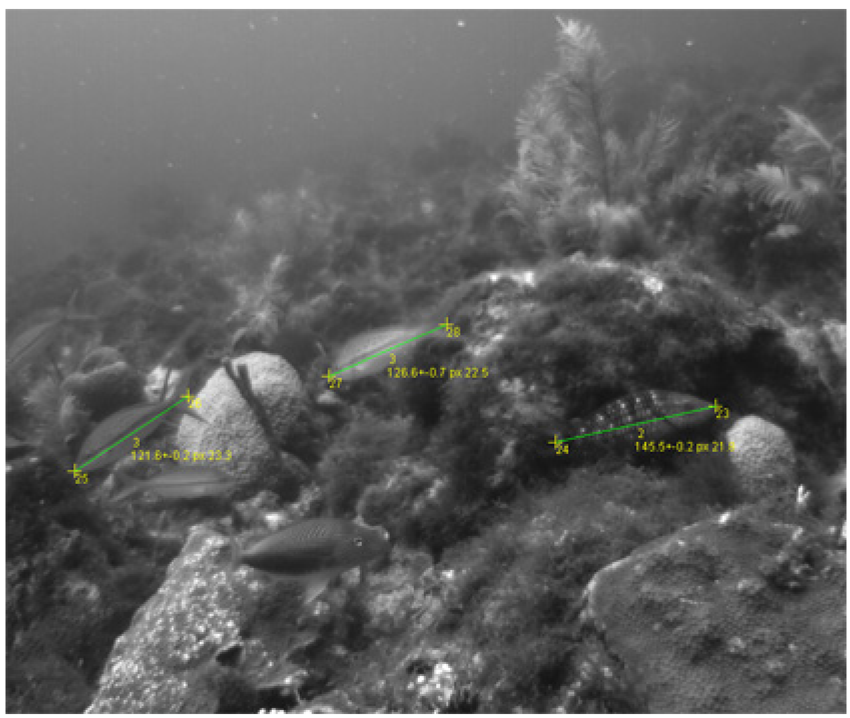


Figure 3. Image from stereo camera showing graphic display of length measurements on three fish using VMS software.

TRANSITIONS

Four additional stereo video camera systems with the same design as the SEFSC's but slightly different hardware were constructed for the Florida Fish and Wildlife Conservation Commission for use in their reef fish research.

RELATED PROGRAMS
Development of the stereo camera system is expected to benefit several programs, including on-going monitoring of reef fish communities in Marine Protected Areas (MPAs) in the NE Gulf of Mexico and in the South Atlantic Bight as well as the newly implemented State-Federal West Florida Shelf reef fish survey. Each of these programs requires more accurate methods to measure the size of animals captured or observed.

RELATION TO NATIONAL PROJECTS
Stereo camera development will support the effort to survey within boundary areas (near-surface, near-bottom, irregular topography) using the NMFS AUV or ROVs.

PRESENTATIONS
No presentations were made during FY08.

EXPENDITURES
The Southeast Fisheries Science Center was allocated $135K in FY07 to support the FTE position and ASTWG participation and used $6.6K of funds allocated to SWFSC for collaborative work on the ASTWG AUV. SEFSC also received a $62.2K grant to work on automated image analysis as described in the attached project report.

Regional Support of FY08 ASTWG: Southwest Fisheries Science Center

(Representatives: David Demer, 858-546-5603, David.Demer@noaa.gov; and Randy Cutter, 858-546-7691, George.Cutter@noaa.gov)

GOALS

The Advanced Survey Technologies Group (AST) in the Fisheries Resources Division (FRD) at the Southwest Fisheries Science Center (SWFSC) supports ecosystem-based fisheries management through new and innovative uses of sampling technologies.

PRIORITIES

During FY08, the priorities of AST were manifold. The group:

- Identified new, promising topics for research within the SWFSC and with collaborators;
- Conducted research and development on advanced technologies for improving the accuracies, precisions and efficiencies of fisheries surveys;
- Analyzed, interpreted and reported data and results from research and development pertaining to advance survey technologies and their applications;
- Communicated research results in various professional venues such as presentations at professional meetings and publications in peer reviewed journals;
- Provided service and leadership outside of NOAA and served on domestic and international scientific working groups, advisory panels, formal and ad hoc groups; and
- Provided professional and scientific expertise through manuscript reviews, scientific editing, and participation in formal academic teaching.

APPROACH

AST characterizes measurement and sampling uncertainties, defines gaps in existing data, and develops, refines, and employs advanced survey technologies to improve the accuracies, precisions and efficiencies of fisheries surveys and thus resulting stock assessments. To maintain an emphasis on the scientific objectives, rather than on the instrument or instrument platform being developed, AST also conducts fisheries research and surveys using the instrumentation and methods it develops. Examples of advanced survey technologies being developed by AST include: an autonomous underwater vehicle (AUV); micro-echosounders; a deep-water echosounder for measuring *in situ* target strengths; a multi-frequency sidescan and multibeam method for surveying epipelagic fish and jellyfish; a towed stereo camera system for visually identifying acoustic targets and estimating their lengths and orientations; an acoustical-optical technique for surveying demersal fish; a passive-acoustic method for monitoring fish; an acoustic method for detecting and enumerating salmon in streams and rivers; and a split-beam method for accurately detecting seafloor range, slope, hardness and roughness using data from EK60 or ME70 systems.

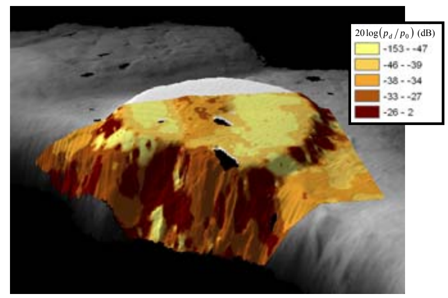
WORK COMPLETED

During FY08, AST has:

- Tested and refined NOAA Fisheries AUV to precisely navigate at prescribed depth and speed. Made necessary hardware and software modifications and prepared for operational deployments;

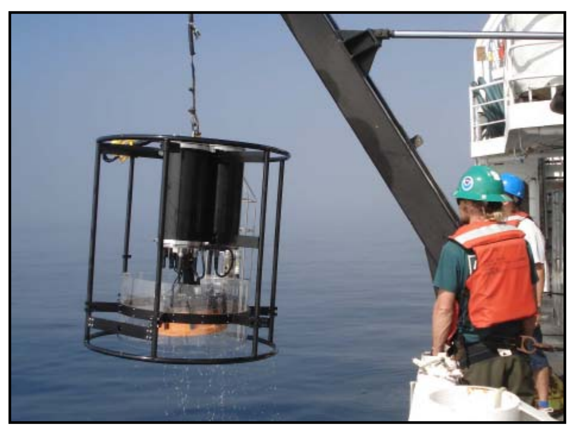
EchoTag configured for an autonomous, one-year deployment on a Scripps Institution of Oceanography buoy.

- Designed, constructed and deployed a micro echosounder (EchoTag) for deployment on buoys, drifters, gliders and marine animals;
- Planned and conducted second Collaborative Optically-assisted Acoustical Survey Technique Survey of the rockfish in the Southern California Bight (COAST07/08), from NOAA Ship David Starr Jordan and CPFV Outer Limits;
- Surveyed coastal pelagic species off the west coast of the United States;
- Developed and tested a novel multi-frequency sidescan-multibeam technique for surveying epipelagic fish and jellyfish;



Seafloor classification based on novel methods for processing multi-frequency split-beam echosounder data. The methods are applicable to the ME70.

- Developed and tested a statistical-spectral technique for acoustic target identification;
- Developed and tested a technique for quantifying the acoustic ‘Dead Zone’;
- Developed and tested a split-beam technique for measuring the within-beam seafloor slope;
- Developed and tested a technique for estimating seafloor hardness and roughness, independent of seafloor slope and detection range;
- Designed, constructed and deployed an underwater stereo camera system;
- Designed, constructed and deployed a deepwater echosounder (DropTS);
- Outfitted UNOLS’ ship “New Horizon” with a five-frequency EK60 system, hull-mounted transducers, and data collection and processing equipment;
- Designed, constructed and installed a portable four-frequency echosounder array for Scripps Institution of Oceanography to use on CalCOFI and other surveys including sampling of mid-trophic levels.
- Collaborated with colleagues from IFREMER aboard the French research vessel “Thallassa”; worked on the development and application of the new Simrad ME70 broad bandwidth multi-beam sonar for fisheries surveys; and developed a specification for ME70 data processing;
- Coordinated the acoustic calibration, data collection and analysis for two California Current Ecosystem Surveys of coastal pelagic species, particularly sardine, from NOAA ships “David Starr Jordan” and “Miller Freeman”.



Deep-water echosounder (DropTS) for accurately measuring target strengths of *in situ* fish. The 38 kHz transducer is mounted on a novel gimbal system.

- Coordinated the acoustic calibration, data collection and analysis for the Leatherback Use of Temperate Habitat (LUTH08) survey of jellyfish and CPS circa Monterey Bay, from NOAA ships "David Starr Jordan" and "Miller Freeman".
- Made total target strength measurements of juvenile salmon and tested a novel method for remote detections and enumerations.

RESULTS

Progress reports for projects funded by ASTWG are provided as separate documents. Results of other AST projects are documented in Publications below.

IMPACT/APPLICATIONS

Fisheries resources must be understood and managed in the context of ecosystems. NOAA Fisheries and its Advanced Sampling Technologies Working Group aim to meet this challenge with development and increased use of instrumented small craft, buoys, satellites and autonomous underwater vehicles as critical components of our nation's ocean observation system.

TRANSITIONS

AST served on NOAA/NMFS teams, task forces, and *ad hoc* groups:

- SWFSC Representative to NMFS Working Group on Advanced Survey Technologies;
- NMFS Representative to the NOAA Working Group on Autonomous Underwater Vehicles;
- Committee member for the SWFSC Ocean Ecosystem Observing Task;
- WG and SG member for the ICES WG on Fisheries Acoustic Science and Technology; and
- Co-Convener for the 2008 International Council for the Exploration of the Sea (ICES) Symposium on Fisheries Acoustics Science and Technology, Bergen, Norway.

AST refereed manuscripts for: Marine Ecology Progress Series, ICES Journal of Marine Science, Fisheries Research, and others.

AST advised researchers and students including:

- Post-Doctoral Advisor to Ana Sirovic, Ph.D., Oceanography, UCSD / Scripps Institution of Oceanography.
- Post-Doctoral Advisor to Juan Zwolinsky, Ph.D., Portuguese Fisheries Research Institute - IPIMAR / University of Aveiro, Portugal.
- Masters Student Advisor to Tanya Graham, Moss Landing Marine Lab

RELATED PROJECTS

AST applied for and received funding from the ASTWG for the following projects:

- D. Demer and J. Renfree, Measurements of the temperature-dependent performance of electro-acoustical transducers and the longitudinal and tranverse sound speeds of Cu and WC calibration spheres, $39.5k
- J. Butler *et al.*, The use of stereo-camera technology to improve accuracy for optically-assisted acoustic rockfish abundance and habitat surveys, $49.1k.
- Cutter *et al.*, Acoustic identification and enumeration of epipelagic fish and jellyfish, $92.54.
- D.A. Demer and G.R. Cutter, Jr., "Autonomous Underwater Vehicle Development," NOAA/NMFS/ASTWG, $100k

PUBLICATIONS

Papers published and submitted for peer-reviewed publication in FY08:

- G.R. Cutter Jr. and D.A. Demer, (2007) "Accounting for scattering directivity and fish behavior in multibeam-echosounder surveys," ICES J. Mar. Sci., 64(9): 1664-1674.
- D.A. Demer and J. Renfree, (2008) "Temperature dependent performance of echo sounder transducers," ICES J. Mar. Sci. 65: 1021–1035.
- C.S. Reiss, A.M. Cossio, V. Loeb, and D.A. Demer, (2008) "Variation in the biomass of Antarctic krill, (*Euphausia superba*), around the South Shetland Islands from 1996 to 2006," ICES J. Mar. Sci.
- J.D. Warren, J. A. Santora and D. A. Demer, (in press) "Response of avian and pinniped predators to changes in the submesoscale distribution of Antarctic krill before and after a near gale." Marine Biology.
- M.J. Cox, J.D.Warren, D.A. Demer, G.R. Cutter, and A.S. Brierley, (in press) "Three dimensional observations of Antarctic krill (*Euphausia superba*) swarms using a multi-beam echosounder." Deep Sea Res. II., Special Issue.
- M.J. Cox, D.A. Demer, J.D. Warren, G.R. Cutter, and A.S. Brierley (in press) "Multibeam echosounder observations of Antarctic krill (*Euphausia superba*) swarms and interactions between krill and air breathing predators." Mar. Ecol. Prog. Ser.
- A. Širović, G.R. Cutter, J.L. Butler and D.A. Demer, (in press) "Using sounds of rockfishes to monitor their populations in the Southern California Bight," Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- George R. Cutter, Josiah S. Renfree, M. Cox, A. Brierley and D.A. Demer, (in press) "Estimating orientations of Antarctic krill using multibeam sonar," Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- D.A. Demer, G.R. Cutter, J.S. Renfree and J.L. Butler, (in press) "A statistical-spectral approach to echo classification," Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- J.S. Renfree, S. Hayes, and D.A. Demer, (in press) "Sound-scattering spectra of steelhead (*Oncorhynchus mykiss)*, coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids," Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- A. Širović and D.A. Demer, "Sounds of captive rockfishes," Copeia (submitted).
- D.A. Demer, A.M. Cossio and C.S. Reiss, "CCAMLR 2000 Revisited," *CCAMLR Science*, (submitted).

Published Abstracts:

- D.A. Demer, J. Butler, G.R. Cutter, S. Mau, A. Sirovic, D. Murfin, J. Renfree, and T.S. Sessions, "The Collaborative Optically-assisted Acoustic Survey Technique for estimating rockfish dispersion and abundance in the Southern California Bight, 2007," 2008 Western Groundfish Conference, Santa Cruz, CA.
- G. R. Cutter, Jr., J. Butler, D. Murfin, S. Mau, and D.A. Demer, "Possible associations between submesoscale rockfish dispersion and bathymetric features," 2008 Western Groundfish Conference, Santa Cruz, CA.

- Ana Širović and D.A. Demer, “Rockfish sounds in aquaria and the ocean,” 2008 Western Groundfish Conference, Santa Cruz, CA.
- D.A. Demer, “Uncertainty in acoustical surveys of Antarctic krill,” 6-8 May 2008, National Stock Assessment Workshop, Port Townsend, Washington.
- D.A. Demer, G.R. Cutter, and Josiah Renfree, “A statistical-spectral approach to echo classification,” The Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- A. Širović, G.R. Cutter, J.L. Butler and D.A. Demer, “Using sounds of rockfishes to monitor their populations in the Southern California Bight,” Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- George R. Cutter, Josiah S. Renfree, Martin Cox, Andrew Brierley and D.A. Demer, “Estimating orientations of Antarctic krill using multibeam sonar,” Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- Josiah Renfree, Sean Hayes and D.A. Demer, “Broad bandwidth characterization of juvenile salmon,” Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.
- D.A. Demer, R. Cutter, S. Sessions, J. Renfree, D. Needham, M. Paterson, D. Detlor, M. Jech, W. Karp, W. Michaels, F. Parrish, M. Seki, P. Sheridan, A. Shimada, D. Somerton, C. Thompson, and C. Wilson, “Surveying with a sound and sight sensing submarine,” Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.

PRESENTATIONS

AST participated in the following presentations:

- D.A. Demer, J. Butler, G.R. Cutter, S. Mau, A. Sirovic, D. Murfin, J. Renfree, and T.S. Sessions, “The Collaborative Optically-assisted Acoustic Survey Technique for estimating rockfish dispersion and abundance in the Southern California Bight, 2007,” 2008 Western Groundfish Conference, Santa Cruz, CA.
- G. R. Cutter, Jr., J. Butler, D. Murfin, S. Mau, and D. Demer, “Possible associations between submesoscale rockfish dispersion and bathymetric features,” 2008 Western Groundfish Conference, Santa Cruz, CA.
- Ana Širović and D.A., “Rockfish sounds in aquaria and the ocean,” 2008 Western Groundfish Conference, Santa Cruz, CA.
- D.A. Demer and D.N. Maclennan, Report on the ICES SEAFACTS Symposium and Proceedings to the ICES Fisheries Technology Committee, Halifax, Nova Scotia, Canada, September 2008.
- D.A. Demer, R. Cutter, S. Sessions, J. Renfree, D. Needham, M. Paterson, D. Detlor, M. Jech, W. Karp, W. Michaels, F. Parrish, M. Seki, P. Sheridan, A. Shimada, D. Somerton, C. Thompson, and C. Wilson, “Surveying with a sound and sight sensing submarine,” Proceedings of the Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies, Bergen, Norway, 16-20 June 2008.

AST was invited to speak at the following forum:

- Invited Speaker at 12 March 2008 Meeting of the Pacific Fishery Management Council, Sacramento, CA; presented “The Collaborative Optically-assisted Acoustic Survey Technique for estimating rockfish dispersion and abundance in the Southern California Bight, 2007.”

EXPENDITURES

In addition to the grant moneys from ASTWG, the SWFSC was allocated $135K in FY08 to support one FTE position (G.R. Cutter)

Regional Support of FY08 ASTWG:
Northwest Fisheries Science Center

(Representatives: Dezhang Chu, 206-861-7602, dezhang.chu@noaa.gov; Rick Brodeur, 541-867-0336, rick.brodeur@noaa.gov

GOALS:

The goals of the Northwest Fisheries Science Center (NWFSC) are to work in concert with the ASTWG to improve the accuracy and precision of living marine resource assessments and expand the information gathered for use in integrated ecosystem assessments (IEAs). These goals will be accomplished by identifying information and technology needs for existing and new assessments, improving these assessments, and advancing our understanding of the marine environment. By identifying new and innovative uses of sampling technologies and advancing these technologies, we will facilitate acquiring the necessary information for ecosystem-based management decisions.

PRIORITIES:

Priorities during FY08 included participation in ASTWG national initiatives, attending the ASTWG semi-annual meeting, improving a portable and autonomous GPS logger for use by groundfish Observers, and developing a prototype of an automated acoustic calibration system.

APPROACH:

Our approach was to develop and employ state-of-art technologies to improve and expand data collected on existing surveys and to develop new technologies that could be used to initiate new surveys for monitoring groundfish.

WORK COMPLETED:

Upgrade of the Portable and Autonomous GPS Logger:

Vessel Monitoring Systems (VMS) that are required on all groundfish vessels provide only a rough estimate of fishing location and effort since the data are transmitted only every 30 to 60 minutes. There is a need to capture independent and accurate tow track information aboard commercial trawl vessels operating off the west coast. Fisheries observers can collect this information but captains on the fishing vessels are reluctant to allow scientific observers to directly obtain the digital GPS data from the vessel owned equipment. Over the summer and winter of 2007, a prototype GPS logger, a "black box" which can autonomously log high resolution ship track information during a trawling event, was developed for use by groundfish observers. The GPS logger is designed to be carried to a vessel by a groundfish observer, easily mounted above the wheelhouse and operated remotely from deck to activate the logging of the ship's track during trawling. This device will give a more detailing picture of trawling activity than is recorded either in logbooks and or by VMS and may be useful for the analysis of bycatch “hotspots”.

During the 2007 pilot study, a number of issues of the GPS Logger were identified and have been solved in the current upgraded version. The upgrades include: 1) improvements in battery power consumption were made to allow for a longer time deployment (up to 30 days); 2) addition of a USB drive port to the GPS Logger. This gives the Logger virtually unlimited storage space and allows the Observers to remove and replace the USB drive with minimized down time; 3) increase in on board flash memory from 256 Kbytes to 2 MB, an increase by a factor of 8, to increase buffering for the added USB drive port; 4) upgrade of the handheld remote control unit radio and the GPS Logger radio to decrease response time for logger control (Fig. 1a); 5) construction of a redesigned GPS Logger packaging that has a tubular canister shape which would be easier to mount on a vertical rail or mast (Fig. 1b).

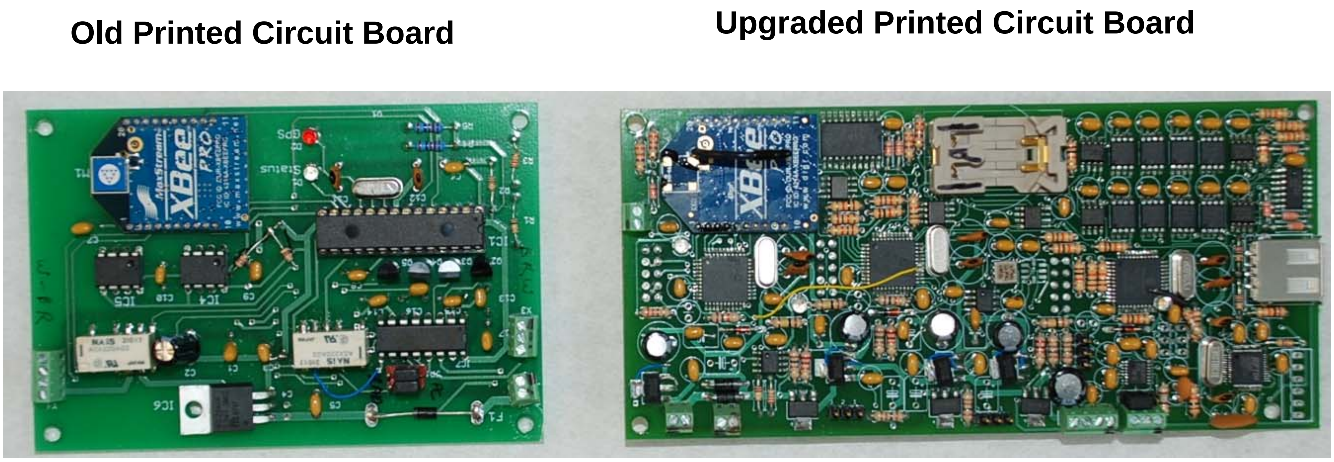


Figure 1a. Comparison of the layout between old and upgraded Printed Circuit Board (PCB). The upgraded PCB contains power switching circuitry in a multi-tasking design.

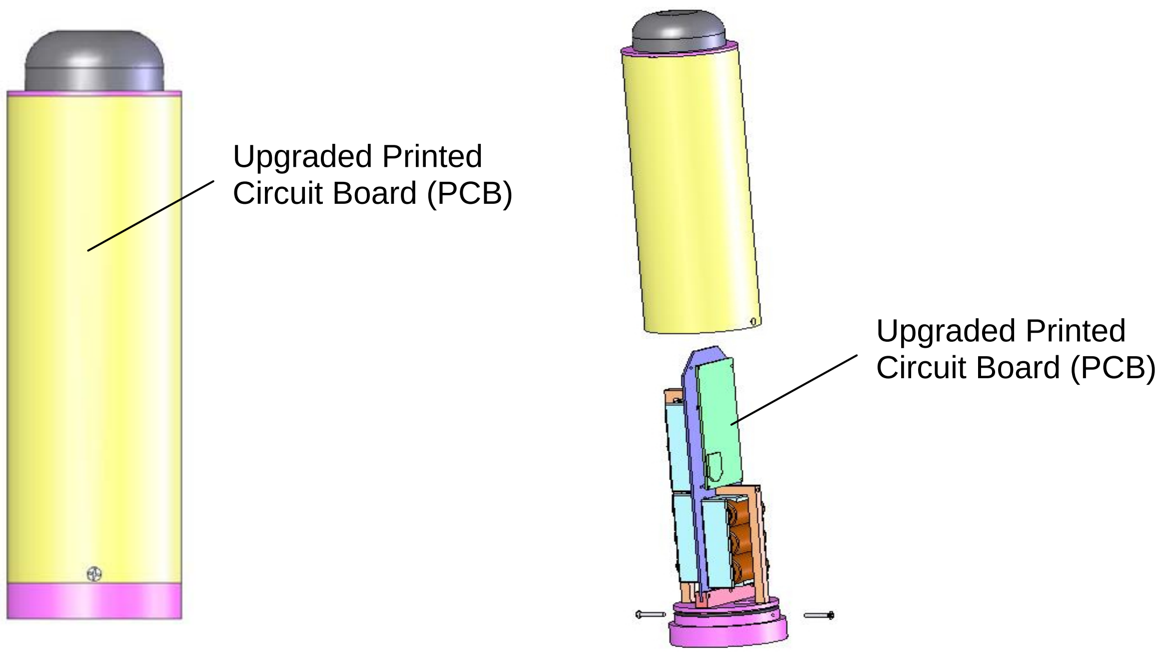


Figure 1b. New GPS Logger housing and exploded view

Prototype of the Automated Acoustic Calibration System

To effectively conduct the acoustic system calibration at sea, an automated mechanical system has been built. This system is controlled by computer software in Matlab with an easy-to-use Graphic User Interface (GUI). The software can control motors driving three individual downriggers independently. The standard spheres used in the calibration can be tethered with combination of spectra and monofilament lines fed through downriggers. The locations of the sphere can be determined by software so that spheres can be moved to anywhere locations in 3D: horizontal and vertical movement. The software allows the spheres move in a number of ways including moving along a straight line in an arbitrary direction and moving with a certain pattern (multiple parallel lines). Even the whole 2D beampattern mapping can be completed by a single click. (Fig. 2)

Advantages of such an automated system include:

- Easy-to-use. It does not require an experienced operator(s);
- Better position control and repeatability. It allows the sphere(s) maintain approximately the same depth, or much less depth fluctuation compared to the conventional manual operation;
- More efficient and uniform coverage for beampattern mapping. It reduces the chance of overlapping in one region and no or less coverage in other regions.

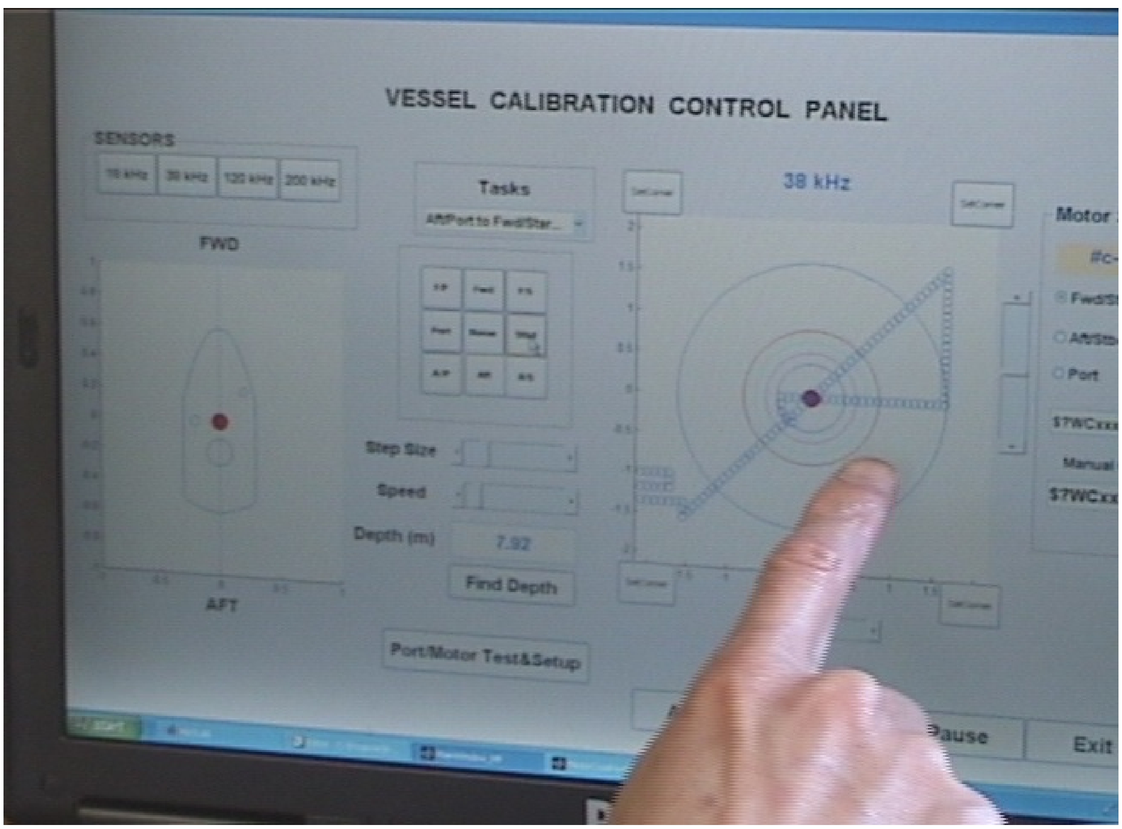


Figure 2. Graphic User Interface (GUI) of the control panel of the Automated Acoustic Calibration System.

RESULTS

Portable and Autonomous GPS Logger

The upgraded GPS logger was deployed several times with a senior observer on a pilot basis. The sea test was conducted in November 2008 onboard F/V Piky off the coast of Oregon. Obviously, the GPS logged vessel positions were not on a straight track line, which was assumed trawl line previously (Fig. 3). The maximum deviation was about 3.5 minutes (lat), or roughly 3.5 nmi and the actual trawl distance or sample volume was about twice as that for trawling along a hypothetical straight track line.

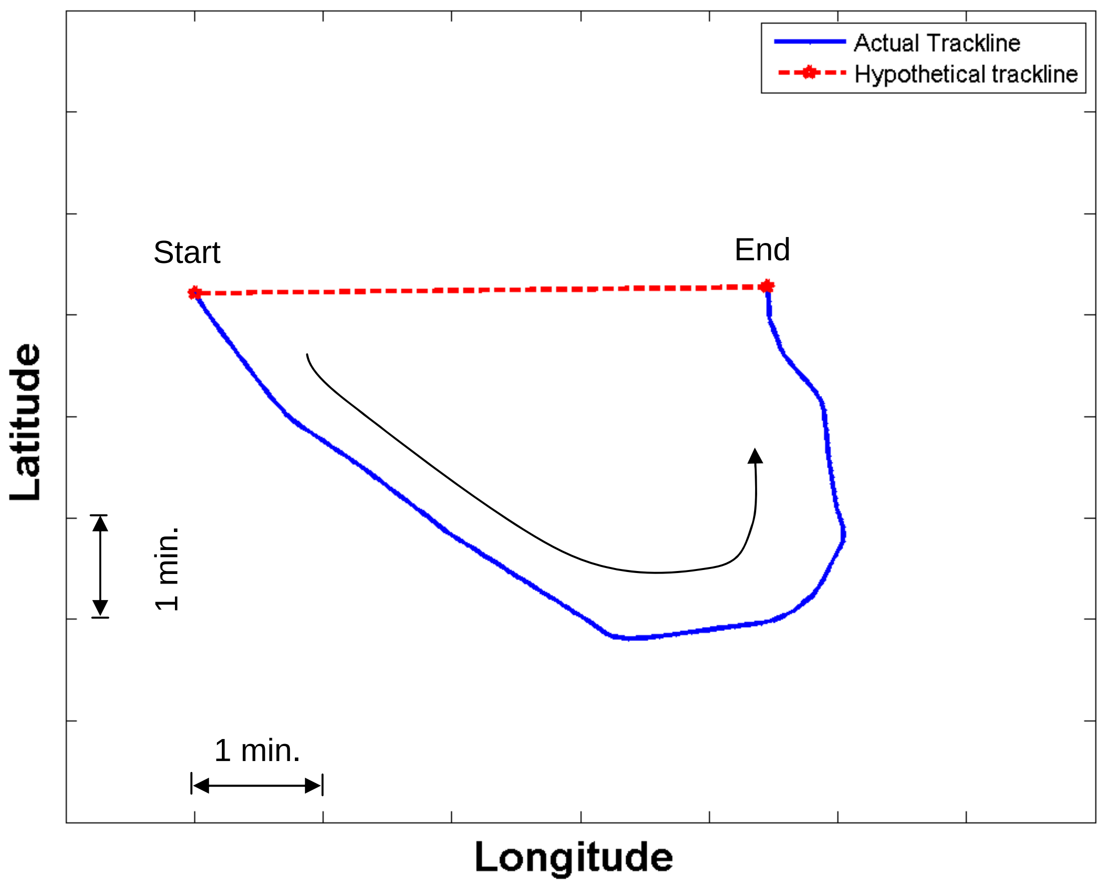


Figure 3. Trackline of the F/V Piky recorded with the upgraded Portable GPS Logger during a trawling event in December 2008.

Automated Acoustic Calibration System

The system was tested at the NWFSC between the main and south buildings. One downrigger was mounted on the roof of the south building (starboard side), and two downriggers were mounted on the second floor of the main building (port side) (Fig. 4a). The sphere was tethered with spectra lines (Fig. 4b) and was moved at a designated depth (roughly about 1 foot above the ground) within a region with similar horizontal (along- and athwart- ship) dimensions to those in field operation. The test was successful. The system was also tested on two NOAA ships, Miller Freeman and Oscar Dyson, during the 2008 hake Inter-Vessel Calibration (IVC) cruise. The system worked fairly well except when line tensions were too tight or too loose, which fouled the line.

Our next step is to upgrade the automated downriggers by adding a new wire tension sensing apparatus. This will allow for keeping wire tension within desired limits and prevent line from fouling.

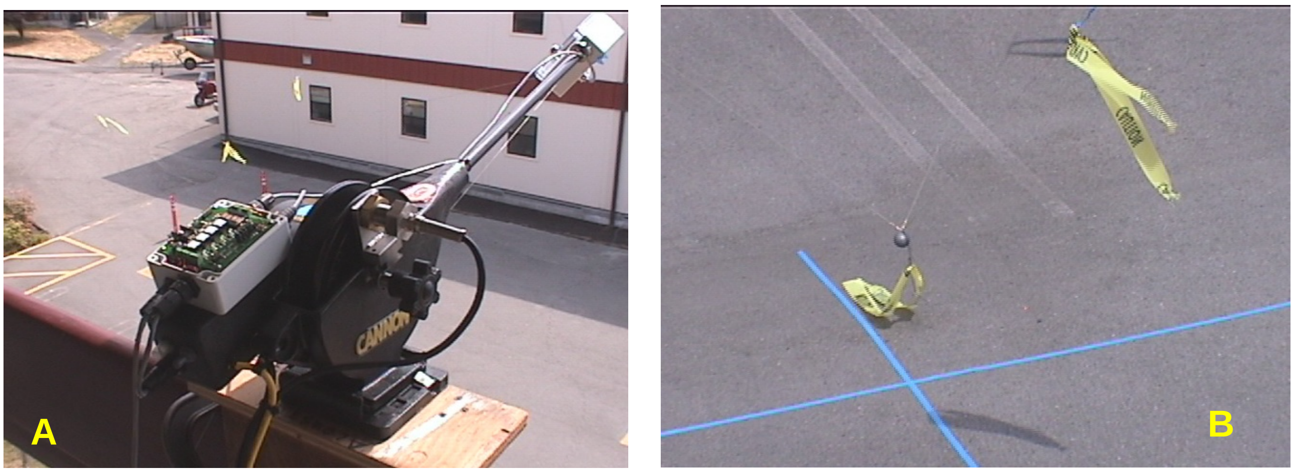


Figure 4. Prototype of the Automated Acoustic Calibration System. (a) Motor control box attached to the downrigger which is mounted on the second floor of the main building at the NWFSC; (b) Sphere tethered with three spectra lines hanging above the center position of the hypothetical center of the centerboard.

IMPACT / APPLICATIONS

Our efforts on improving the GPS Logger will enhance the amount of the data collected during trawls with observers and expand the data collection activities in a cost effective way. This work is a collaborative effort with the fishing industry and will improve the data quality recorded through Observer Program.

The prototype of the Automated Acoustic Calibration System will increase the efficiency, accuracy, and repeatability of the acoustic system calibration on board the ship using standard sphere. Such system will be very useful once multibeam sonar system, such as ME70, becomes a standard data acquisition system of echoes from both water column and seafloor.

TRANSITIONS

The GPS tracking of trawling patterns will be used to further define areas where bycatch of over-fished groundfish is high and will provide more detailed scientific advice to implement rockfish conservation areas. The upgraded Portable and Autonomous GPS Loggers were tested in November 2008 and the initial results were very promising. The technologies can be easily shared with other Observer Programs within NMFS.

The Automated Acoustic Calibration System, once the tension detection apparatus is completed and tested, can be used as a standard calibration system not only for the acoustics team of the NWFSC but also the acoustics teams of the other centers within NMFS, or even beyond NOAA/NMFS. This system is also easy to build and is a low-cost system, especially when the calibration of the more complex multibeam sonar system is involved.

EXPENDITURES

The Northwest Fisheries Science Center (NWFSC) was allocated $135K in FY08 to support the FTE position and ASTWG participation. Salary and travel costs for this FTE exceeded 135K and were supplemented from other Groundfish research funds. The FTE supported has assisted in these projects described above.

Regional Support of FY08 ASTWG:
Alaska Fisheries Science Center

(Representatives: Chris Wilson, 206-526-6435, Chris.Wilson@noaa.gov; David Somerton, 206-526-4116, David.Somerton@noaa.gov)

GOALS

The goals of the Alaska Fisheries Science Center (AFSC) are to work in concert with the ASTWG to improve the accuracy and precision of living marine resource assessments by identifying information needs for existing and new stock assessments, identifying new and innovative uses of existing sampling technologies, and facilitating and conducting research to advance our understanding of the marine environment.

PRIORITIES

The FY08 priorities for AFSC projects, which involved some ASTWG-support were: 1) continue research with ASTWG DIDSON imaging sonar and a large midwater trawl to investigate net selectivity of walleye pollock to this trawl, and 2) continue development of an autonomous lowered echosounding system to refine estimates of walleye pollock *in situ* TS.

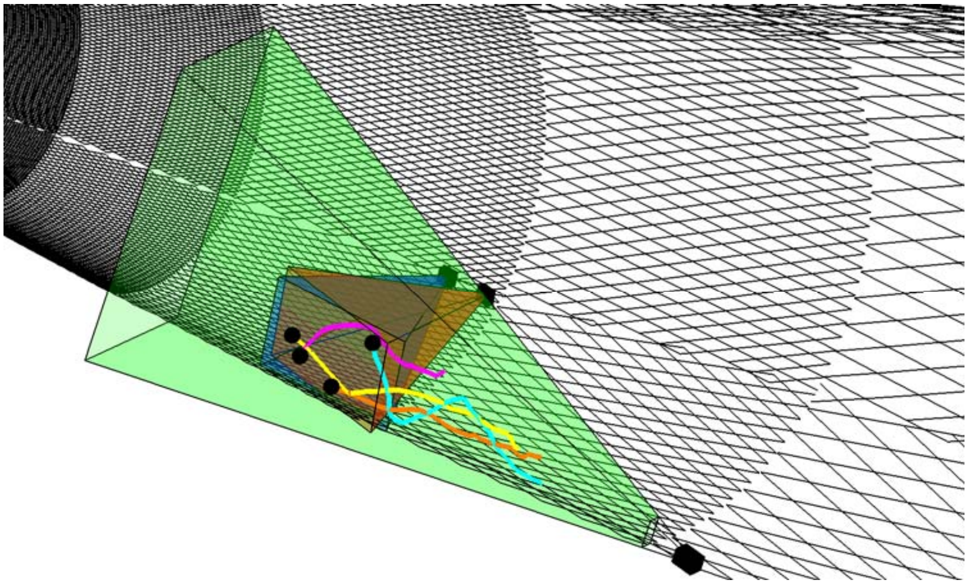
APPROACH

Our approach in developing AFSC's advanced sampling technologies has been to allocate efforts for research, evaluation, and implementation of new technologies during the course of routine survey operations. The approaches involve either collaborative (e.g., lowered echosounding system) or individual efforts (e.g., net selectivity) although in all cases, the products will have widespread applications within NOAA and elsewhere.

WORK COMPLETED AND RESULTS

Net selectivity based on stereo camera system and DIDSON imaging sonar

The DIDSON was used to observe fish escapement behavior in survey trawl gear during acoustic abundance surveys for walleye pollock conducted in winter and summer of 2007. A stereo-camera system was simultaneously deployed to identify DIDSON targets and provide fish length measurements during the summer survey. Both instruments were placed inside the trawl at the location of maximum fish escapement (Figure 1). DIDSON data were processed using automated tracking application (Handegard and Williams, 2008) to provide information on fish movements relative to the lower trawl panel (Figure 2). Fish lengths and identification were estimated from stereo-images using a customized computer application for deriving measurements developed using Matlab software and the camera calibration toolbox (Figure 3; Jean-Yves Bouguet, California Institute of Technology). The DIDSON enabled high-rate unbiased sampling of fish positions without the need for continuous lighting, which can bias fish behavior. Periodic sampling using the stereo-camera provided target specific data not resolvable using the DIDSON data. The simultaneous use of both the Didson and stereo camera systems provide a more complete picture of the interaction between the fish and the trawl as part of the investigation to assess the selectivity of walleye pollock to large midwater trawls.



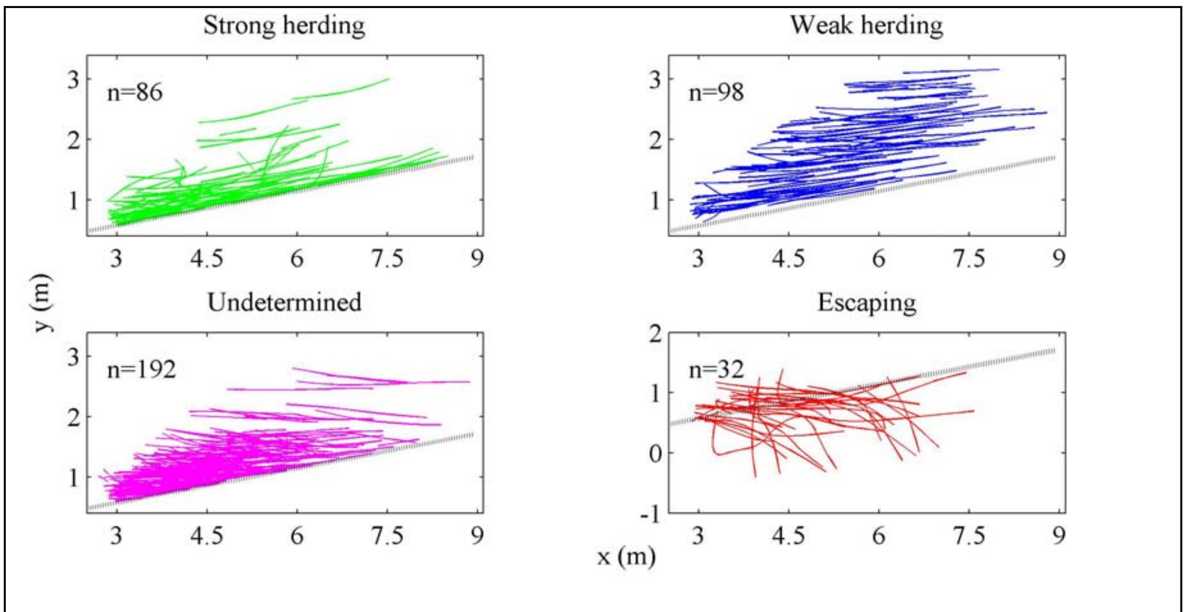


Figure 2. Four observed types of fish responses relative to the trawl panel from tracks based on DIDSON data. The tracks were aggregated over 5 deployments taken during the summer 2007 eastern Bering Sea acoustic survey of walleye pollock.

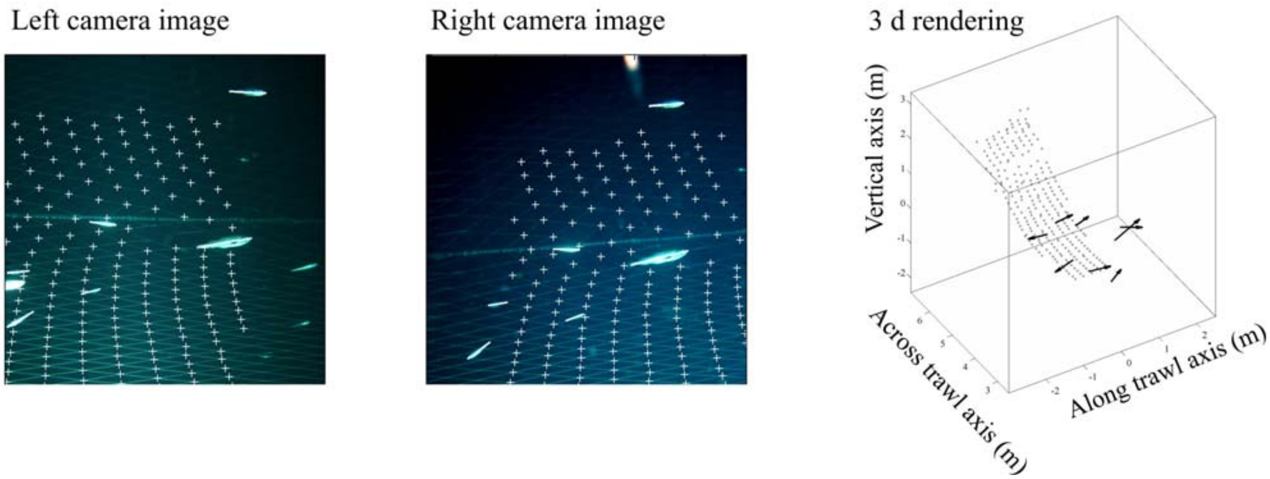


Figure 3. Stereo-camera image analysis of pollock with the AFSC midwater survey trawl. Equivalent points in both images are manually indicated, and stereo-based calculations are then used to estimate three dimensional positions. Fish length, position, and orientation are estimated by selecting the snout and tail of the fish in both images.

Lowered echosounding system

Figure 4. Lowered echosounding system includes gimbal-mounted 38 kHz splitbeam transducer.

The lowered echosounding system (Figure 4) is a collaborative effort between SWFSC and AFSC. Researchers at SWFSC completed phase 1 of the project in 2007, which included the design, manufacture, and initial testing of the system. The 315 kg system can operate to a maximum depth of 500 m autonomously and logs data internally. Alternatively, the system can be connected to a Cat5 Ethernet cable for long-range control and communications. Work on the device in 2008 primarily focused on developing the software applications used for the remote monitoring and control of the instrument. This included the dtsSerialServer application that runs on the device PC, the dtsSerialClient application that runs on a topside PC, and a number of software components that glue the system together. The Client/Server applications are written in Python. The dtsSerialServer application running on the device PC integrates data streams from the EK60 and other sensors on the device, processes them, and then sends these data via an underwater modem to the surface. The dtsSerialClient application running on the shipboard computer receives the data and displays them in an intuitive manner (Figure 5). The client application offers the ability to start and stop pinging, adjust the ping interval, start and stop the recording of raw data, and full control over the display of echogram and single target histogram data. Select sensor information is also provided allowing the user to monitor battery status and instrument attitude data. The applications were designed with flexibility and expandability in mind to accommodate future expansion of the system.

These applications are built on a number of key software libraries that enable their operation. The server application interfaces with the Simrad ER60 software using the pySimrad software library, the first and only full implementation of the Simrad remote control and data subscription interface. The server application also relies on the pySensorLogger library that provides a simple and flexible interface for logging and monitoring of serial based sensors. The acoustic modem messaging protocol provides an efficient, fault-tolerant communication link optimized for the low bandwidth half-duplex connection provided by the modems.

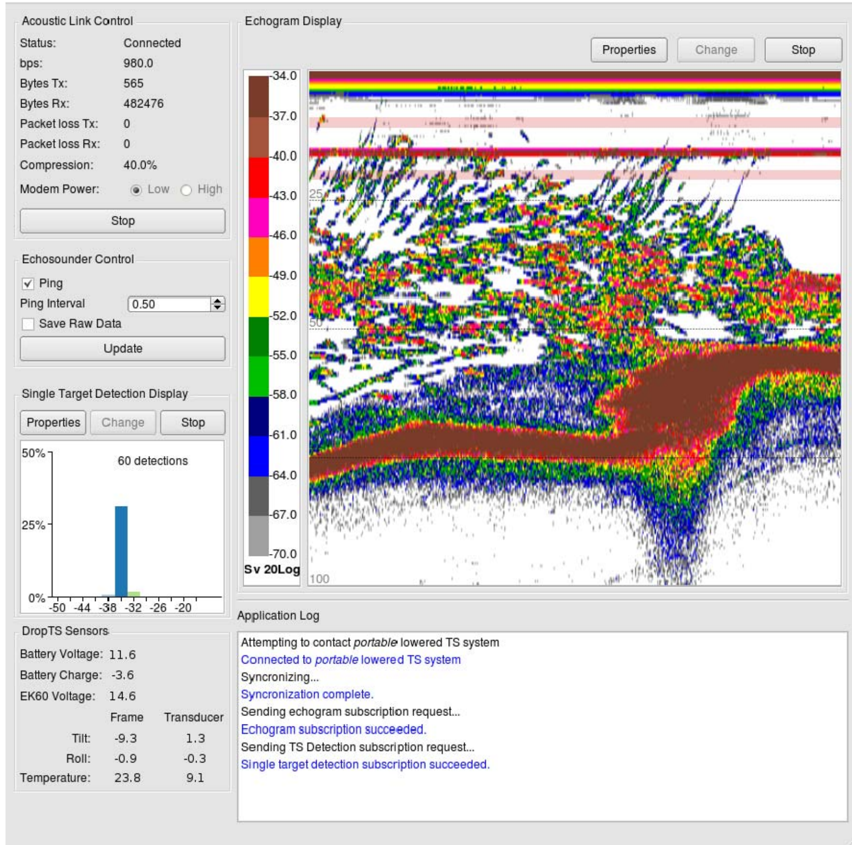


Figure 6. Screen grab of lowered echosounding system software used to remotely monitor and control the system. Target detection depth intervals (pink lines) are easily set so, for example, returns from a calibration sphere (red line) above fish scattering are summarized in the single target detection window. This illustrates one of the many features readily controllable by the software.

Field tests of the lowered echosounding system to evaluate the communications software and overall performance of the device were conducted this year aboard the NOAA ship *Oscar Dyson* in January (Puget Sound, WA) and February (Shumagin Islands, AK). The system was successfully deployed to a maximum depth of 450 m. The communication linked performed well over all depths. Additional testing is underway to confirm the attitude measurements of the frame and transducer during deployment, to refine the rigging system used to decouple the motion of the vessel from the device, and to understand and possibly reduce the relatively high noise level that appears in the first 20 m of the data when the system is deployed deeper than about 150 m. Plans are underway to conduct these tests and to use the system to collect *in situ* target strength measurements on pre-spawning walleye pollock during the March 2008 AFSC Shelikof Strait acoustic survey.

IMPACT/APPLICATIONS

The projects described above are designed to improve survey estimates of abundance by quantifying and reducing sources of bias and uncertainty. This is accomplished in two ways. First, by providing methodological and technological advances to acoustic survey efforts, and secondly by testing assumptions inherent in acoustic survey methodologies.

TRANSITIONS

The goal for many of the technological developments that AFSC staff worked on is to incorporate these developments into the routine stock assessment survey efforts conducted at AFSC (e.g., MACE Program) as well as at other Science Centers. Incorporation can occur over the short term as in the electronic measuring board and trigger-jigger instrument control box (see ASTWG FY07 Annual Report). Alternatively, the transition period for other projects is more long term (e.g., net selectivity and lowered echosounding system projects described above) but the results of these studies will also be used to refine and improve the stock assessment efforts when appropriate.

PUBLICATIONS

Handegard, NO and Williams, K. 2008. Automated tracking of fish in trawls using the DIDSON (Dual frequency IDentification SONar). ICES J. Mar. Sci. 65:636-644.

PRESENTATIONS

Towler, R. Processing fisheries acoustic data in MATLAB using the EchoLab tool kit: case study with commercial fishing vessel data. June 2008. ICES Fisheries Acoustics Symposium (SEAFACTS). Norway.

HONORS/AWARDS

None at this time.

EXPENDITURES [$170.5K]

The Alaska Fisheries Science Center (AFSC) continued to use the **$135K** that was permanently allocated to support the FTE position. In addition, $15.5k was used to purchase the Hermes software license for use with the Simrad multibeam sonar (ME70) and $20k was used to purchase upgraded servers for the ME70 aboard the Dyson.

Regional Support of FY08 ASTWG:
Pacific Islands Fisheries Science Center

(Representatives: Frank Parrish frank.parrish@noaa.gov and Mike Seki michael.seki@noaa.gov)

GOALS

The goal of ASTWG supported efforts at the Pacific Islands Fisheries Science Center (PIFSC) is to develop hydroacoustic and other sampling capabilities for the assessment of both pelagic and demersal species. The focus is on both ship and smallcraft-based technologies to obtain a cost-effective means for monitoring the region's living marine resources and their habitat for ecosystem-based management approaches.

PRIORITIES

Priorities in FY08 included 1) "Development of a fisheries independent method of biomass estimation of bigeye tuna at Cross Seamount, 2) "Assessment of juvenile pink snapper (*Pristipomoides filamentosus*) population at a Hawaiian nursing ground", 3) "Acoustic Characterization of the Mesopelagic Community off the Leeward Coast of Oahu" and 4) **"**Assessment of the effects of Bottomfish Restricted Fishing Areas on populations at Penguin Banks." Each of these projects are detailed below under the work completed section.

APPROACH

The PIFSC approach for developing advanced sampling technologies has been to use the resources provided by ASTWG to develop staff expertise and hydroacoustic infrastructure which is then used in collaborative research projects. Funds from other programs provide ship time and resources to field the sampling effort and assist with the development of technology. Leveraged funds have come from the University of Hawaii Joint Institute of Marine and Atmospheric Research, National Center for Coast and Ocean Sciences, and others.

WORK COMPLETED

Project 1) Development of a fisheries independent method of biomass estimation of bigeye tuna (*Thunnus obesus*) at Cross Seamount, Hawaii

During FY08, a third cruise was conducted to Cross Seamount, located 250 km south of Oahu within the Hawaiian archipelago. The cruise is a part of a project focused on developing an acoustic method to estimate bigeye tuna biomass at the seamount, a population heavily targeted by local fishermen. In addition to biomass, the study is aimed at investigating the movement patterns and distribution of bigeye tuna and its forage, micronekton, as well as estimating the composition of micronekton in the seamount environment relative to those in pelagic environments nearby. In addition to bioacoustic data, the physical, chemical, and biological environment were sampled to study the seamount environment and to investigate its effects on bigeye tuna and its forage, micronekton. The survey was conducted on board the NOAA ship *Oscar Elton Sette*, equipped with a hull-mounted, split-beam Simrad EK acoustic system, operating at 38, 70, and 120 kHz frequencies. Acoustic data were groundtruthed by handline fishing and micronekton sampling using a midwater trawl. Environmental data were collected by an Acoustic Doppler Current Profiler (ADCP), operating at 75 kHz frequency, while temperature, salinity, dissolved oxygen, and chloropigments were measured with a CTD rosette.

Survey strategy and design were optimized for the FY08 cruise by using data from literature, experimental and commercial fishing data, and data obtained during the first two cruises which were conduced in 2005 and 2007. Preliminary results from the FY08 shipboard survey show increased bigeye tuna and micronekton biomass at the seamount, consistent with previous observations. Further, the seamount has an effect on the vertical distribution of micronekton over the plateau and at its flanks. Over the plateau, several layers of micronekton occupy the depths of 200-400 m (Figure 1), a layer that is devoid of organisms away from the plateau. The deep scattering layer is thicker and extends vertically at the flanks. Micronekton is observed to be actively swimming against the currents during their diel vertical migratory periods (Figure 1) and their composition is different at the seamount than away from it. These facts indicate that the Seamount is likely to be occupied by some resident species of micronekton. While the effects of the Seamount on micronekton extend to slopes that are at 800-1000 m deep, bigeye tuna are tightly associated with the plateau or slopes not deeper than about 500 m. Bigeye tuna appear at dawn at the upcurrent, southwest edge of the plateau to feed on specific micronekton layers which are migrating downward from the shallow scattering layer (Figure 2). At this time, bigeye are tightly concentrated in a small area, highly mobile, and form very loose aggregations. During the early morning hours, bigeye spread and occupy the southwest end of the plateau, still feeding. By late morning, they are spread over the plateau area south of the summit. During the afternoon and early evening, bigeye occupy the entire area of the plateau and tend to form thicker aggregations. At around sunset, bigeye start dispersing and seemingly leave the plateau, to appear next dawn again at the upcurrent edge. As opposed to bigeye tuna, large, thick aggregations of fish, likely to be lustrous pomfret (*Eumegistus illustris*), appear after sunset and occupy the entire area of the plateau, not farther than 50 m off the seafloor. At sunrise they descend along the flanks, predominantly on the upcurrent side of the plateau, and occupy depths of the deep scattering layer at 500-750 m.

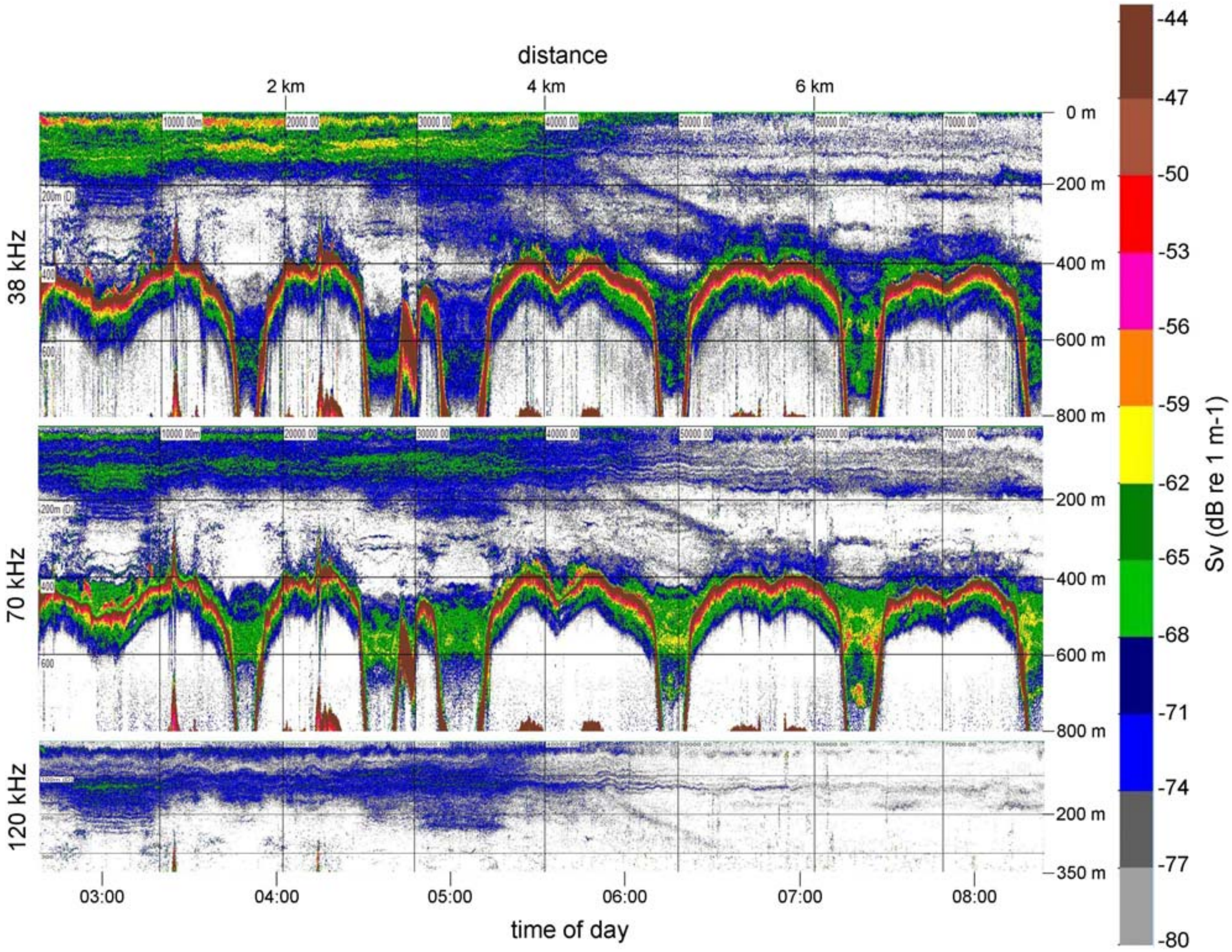


Figure 1. Echograms showing the shallow (SSL) and deep (DSL) micronekton scattering layers over the plateau and flanks of Cross Seamount, including a nighttime (left) to daytime (right) transition period. The very high S_v (> -44 dB) are backscatter from the plateau floor. Note the differences in backscatter properties of micronekton at the 38 kHz (top), 70 kHz (middle) and 120 kHz (bottom) frequencies, the micronektonic layers between 200 and 400 m depths (absent away from the plateau), and the presence of large aggregations of fish over the plateau floor during night and at the flanks during day. Micronekton is shown to descend to the deep scattering layer along both downcurrent (at ~06:00-06:30) and upcurrent (at ~07:00-07:03) flanks. Bigeye tuna is seen after 06:00, most noticeable on the 120 kHz echogram (see Figure 2).

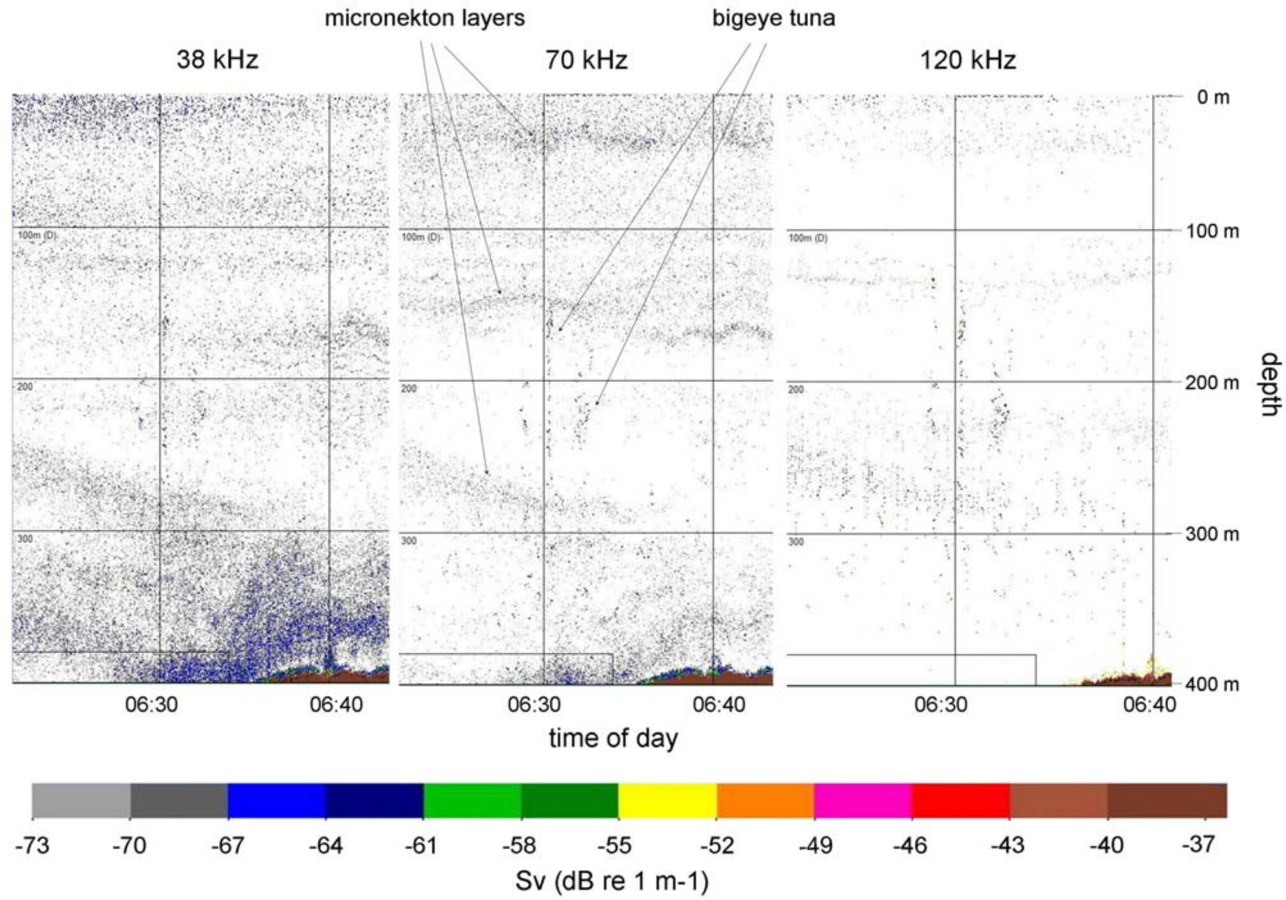


Figure 2. Loose aggregations of bigeye tuna foraging on descending micronekton layers after dawn at the upcurrent flank of the Seamount. Note that as opposed to micronekton, tuna backscatter is similar at all three frequencies. This image is a portion of Figure 1 from 6:22 to 6:43 am.

Project 2) Assessment of juvenile pink snapper (*Pristipomoides filamentosus*) population at a Hawaiian nursing ground

As part of a project to develop an acoustic method to monitor stocks of juvenile pink snappers in their nursery grounds, acoustic surveys are being continued in a known nursery ground off the east coast of Oahu, in about 70-100 m deep waters and gently sloping bathymetry. The purpose of the surveys is to estimate relative biomass of juvenile pink snappers using bioacoustic data and, eventually, develop a timeseries to monitor changes in their biomass. During FY08, a total of 9 surveys were conducted over a predetermined grid, increasing the total number of surveys from 17 to 26. All surveys were conducted with the equipment used in previous years: a side-mounted, split-beam Simrad EK60 system on aboard the small (~ 7 m long) NOAA boat, *Kumu*, operating with up to 3 transducers at 38, 120, and 200 kHz frequencies.

Analyses results of data collected thus far show temporal variability in the number of fish tracks – with acoustic descriptors consistent with those of juvenile pink snappers – at scales from less than an hour to months (Figure. 3a). However, the mean Target Strength (TS) of tracks remain relatively constant (Figure 3b) and consistent with those of juvenile pink snappers with the expected 13-15 cm fork lengths, as measured during *in situ* TS observations in FY06. During the July, October, and January surveys, fish tracks were generally detected at deeper depths and in deeper waters then during the February surveys (Figure 3c and d). Previous research indicates the presence of two recruitment classes during fall, with larger individuals (16-18 cm FL) leaving and smaller ones (11-13 cm FL) arriving, with the number of small ones peaking early spring. The very low number of detections in January might be due to the failure of the new recruitment class to arrive in high enough numbers, with the larger fish gone. It could also be possible that the newly arriving, small snappers tend to stay very close to the bottom, reducing or even preventing their acoustic detection. The deeper tracks and water depths during July, October, and January could indicate that the older, larger snappers tend to occupy the deeper, offshore part of the nursery ground, with the smaller ones staying in shallower waters. However, the mean TS values do not reflect large enough differences in values between the months, although the highest and lowest values in January and February, respectively, could be explained by the presence of larger and smaller individuals during those months.

During FY09, acoustic surveys of the nursery grounds will continue, with the addition of a stereo video system installed on the *Kumu*. The addition of the camera system will allow for simultaneous acoustic and camera observation, groundtruthing the acoustic data. Further, more simultaneous *in situ* video and TS measurements, taken at various frequencies, will be conducted on juvenile pink snappers with known sizes at the depths of the snappers' observed highest concentrations (80-90 m) to fine tune their acoustic identification in the field. In addition, TS measurements of a species of puffers, *Torquigener florealis,* with know sizes will be conducted in the nursery grounds. *Torquigener florealis* is the only other fish found in significant numbers in the depth range that is consistent with those of pink snappers within the nursery ground. *In situ* TS measurements of *Pristipomoides filamentosus* and *Torquigener florealis* with know sizes were already conducted during earlier stages of this study. While results of these experiments indicate that the TS of pink snappers are significantly higher than those of puffers of the same size, more measurements are necessary to fine tune our ability to distinguish between the two species and reduce the margin of error in identifying pink snapper tracks.

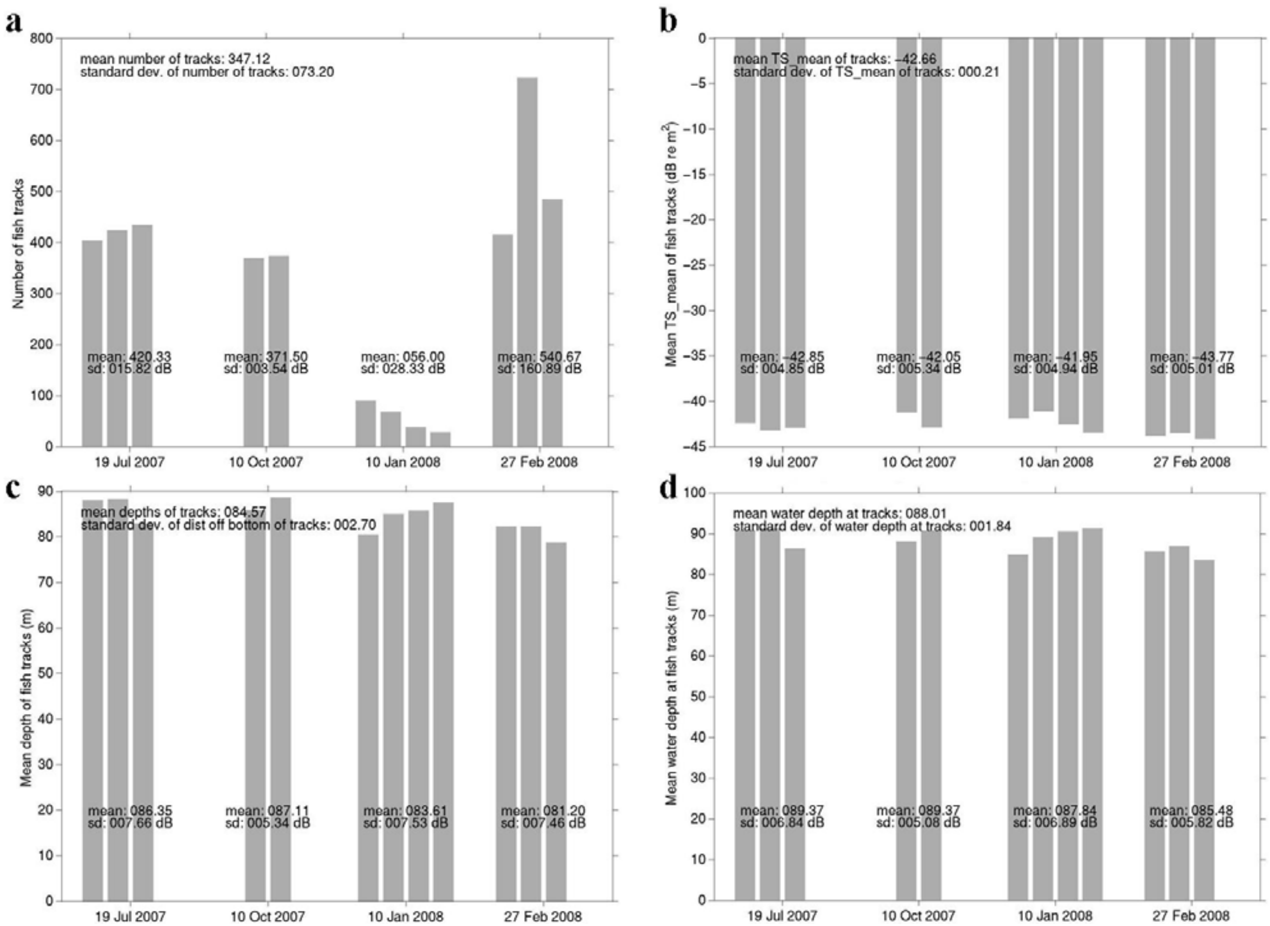


Figure 3. Number of fish tracks detected (a) with acoustic descriptors consistent with those of juvenile pink snapper (b), their depths (c), and the mean water depth at the tracks (d). Columns correspond to each survey conducted, organized by the day of the survey. Each survey took about 45 minutes to complete, with the next survey starting immediately at the completion of the previous one. Means and standard deviations on the bars indicate variability within the day, while the mean and standard deviation displayed in the top left indicate variability between the four days of the surveys.

Project 3) Acoustic Characterization of the Mesopelagic Community off the Leeward Coast of Oahu

The purpose of this project is to use active acoustic methods to describe the mesopelagic community off the west coast of Oahu. This community is an important food source of higher trophic level organisms that are targeted by the local fishery. Acoustic data for this project were collected during a week in October 2004 on board the NOAA ship *Oscar Elton Sette*, equipped with a hull-mounted, split-beam Simrad EK60 system. Surveys were conducted at the 38 kHz and 120 kHz frequencies, in waters typically 800 – 1300 m deep. The cruise was part of the Micronekton Inter-calibration Experiment (MIE – part of a PICES working group) focusing on establishing the efficacy of different micronekton sampling gears as results of net trawl sampling highly depend on the type of gear used. Traditionally, micronekton trawl sampling is utilized to groundtruth acoustic data collected to study micronekton; however, the bias resulting from the selectivity of sampling gear likely transfers into the acoustic results and introduces large margins of error in biomass and composition estimates. Thus, results of the acoustics data obtained during the MIE cruise and samples of three different kinds of trawling gear were compared to each other to obtain information on the performance of the gears for micronekton relative to those of the acoustics.

Acoustic data obtained during this study show that the shallow scattering layer (SSL) generally occupies the upper 200 m of the water column, while the deep scattering layer (DSL) is found at the depths of 450 m and 750 m (Figure 4). Both layers exhibit dynamic and complex features and are composed of several thin layers with structures that vary both in space and time. While the SSL was observed to be considerably denser during nighttime than daytime due to the diel vertical movements of migratory micronekton, the DSL is a permanent feature (Figure 4) likely reflecting the presence of non-migratory organisms and/or organisms that migrate from deeper waters during the night. Daytime the water column is devoid of organisms between ~200 m and ~400 m, while organisms are more dispersed vertically during night. Areas of shallower than ~800 m topography are associated with denser and deeper DSL. Acoustic data indicate that the daytime DSL contain the highest relative biomass, followed by nighttime SSL then daytime DSL, with the daytime SSL showing the lowest values. Differences in the strength of backscatter at the two frequencies in the upper 200 m indicate higher percentages of fish with swimbladder and possibly other gas-bubble-containing organisms in the SSL during nighttime than daytime, suggesting that these organisms make up the majority of micronekton that migrate from the DSL to the SSL during the night.

Results of all three sampling gears are generally inconsistent with those of the acoustics data. While acoustic results indicate that the densest layer is the nighttime SSL, followed by the daytime DSL then the nighttime DSL, biomass in the trawl samples only with the largest mouth opening showed the same trend. The relative compositions of organisms caught by any of the trawls in any of the scattering layers are inconsistent with those of the acoustic results. Percentages of trawl samples collected in the DSL during day- and nighttime, and in the nighttime SSL indicate that organisms that scatter higher at the higher frequency dominate the vertically migratory micronekton; opposite of the acoustics results. Further, the percentage of catch of organisms that scatter higher at the lower frequency relative to those that scatter higher at the higher frequency in the nighttime SSL are inconsistent with δS_v values, defined as 120 kHz – 38 kHz S_v. Although inconsistent, the composition of samples from the net with the largest mouth opening shows the highest agreement with those of the acoustics results. This fining is not surprising since highly mobile micronekton – which tend to be larger and likely contain high percentages of fish with swimbladder – are presumably able to evade the net, the more so with smaller and smaller nets. Further, the results of this study indicate that a significant portion of the discrepancy between acoustic and net trawl results can be explained by the failure of the nets to adequately sample the scattering layers, especially the DSL, even though the depth of the nets and the scattering layers were continuously monitored during each trawl.

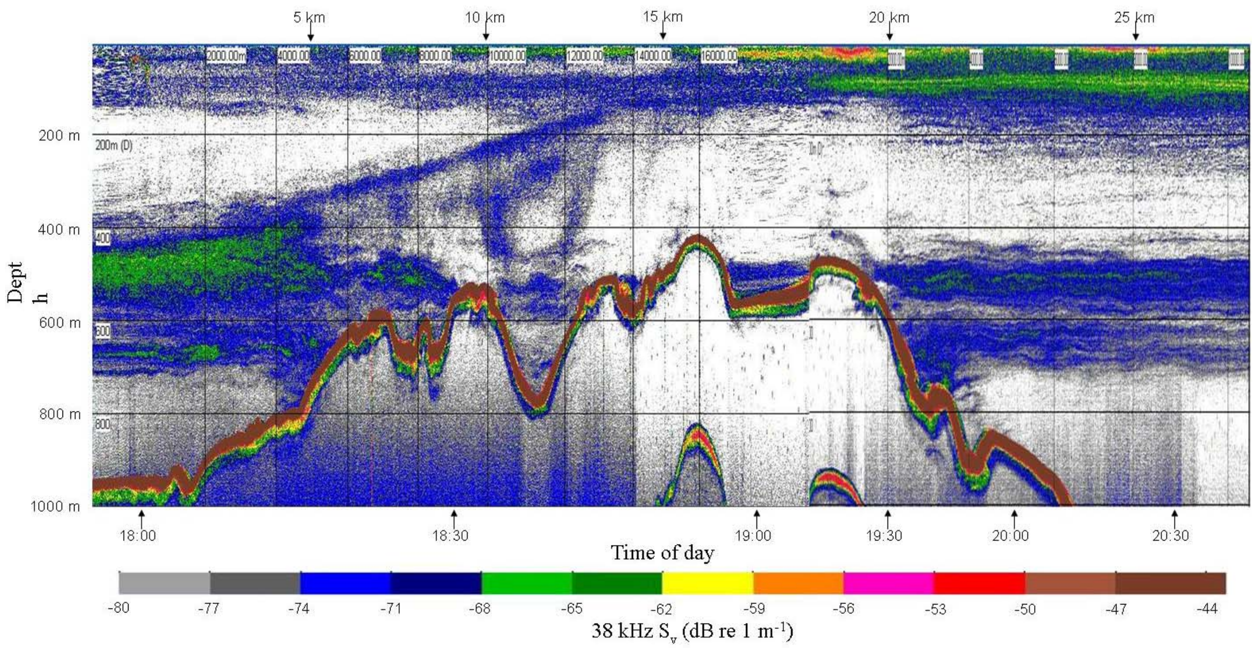


Figure 4. Echogram illustrating the structure of the SSL and DSL during daytime (left) and nighttime (right), separated by the evening vertical migratory period. The very high S_v (> -44 dB) are backscatter from the seafloor. Note that the DSL extends vertically at the slopes.

Project 4) Assessment of the effects of Bottomfish Restricted Fishing Areas on populations at Penguin Banks

The Hawaii local fishery heavily targets several species of bottomfish in the Hawaiian archipelago, mostly at seamounts and at shallow banks. Of the five most important target species (4 snapper and 1 endemic grouper), two have been federally listed as overfished, prompting the establishment of several Bottomfish Restricted Fishing Areas (BRFAs) in 1998. However, a 2005 review concluded that the established BRFAs include only 5% of high-relief, hard-substrate areas in the 100-400 m depth range, found to be preferred habitat of most of the targeted species. This finding resulted in the creation of a new system of BRFAs that took effect on July 1, 2007. The focus of this project is to assess the effectiveness of the new BRFAs by developing an acoustic method of estimating bottomfish biomass and monitor changes at closed, recently-closed, and open areas.

For this project, the heavily fished “Three Fingers” area at the south slope of Penguin Banks was selected – a shallow (50 m) bank extending approximately 35 km west-southwest off the island of Molokai, Hawaii. This region is ideal for the development of an acoustic method to monitor bottomfish densities as it is in the relative vicinity of the Pacific Islands Fisheries Science Center and its home port in Pearl Harbor, and it includes a BRFA established in 1998 (BRFA 10, over Finger 3), an area established in 2007 overlapping BFRA 10 (BRFA F, over Fingers 3 and 2), and an area open to fishing (Finger 1). Further, there has been an extended amount of BOTCAM work conducted in recent years to study the commercially important bottomfish in this area.

During May 2007, 2 days of surveys were conducted to establish "base-line" acoustic recordings of the Three Fingers area of Penguin Banks before the closure of the new BFRA F. The cruise was conducted on the *Oscar Elton Sette*, equipped with a hull-mounted, split-beam Simrad EK60 system, operating at the 38 and 120 kHz frequencies. Data recorded during this cruise show loosely aggregated bottomfish or bottomfish forming small, thicker aggregations. Backscatter characteristics of these recordings are consistent with theoretical TS values of the expected sizes of bottomfish (approx 60 cm FL) the in the area.

Plans for the next fiscal year include a second cruise to collect acoustic data for 5 days at the Three Fingers region of Penguin Banks. The cruise will be conducted on the NOAA ship *Oscar Elton Sette*, equipped with an additional 70 kHz transducer, increasing the available frequencies from two to three. During acoustic recordings, video recordings of bottomfish with a lowlight camera will be conducted to groundtruth the acoustic data and to estimate mean Target Strength of specific size fish and to learn to possibly distinguish bottomfish species by differences in their TS values, aggregative structure, depth, relief type, or other potential descriptors.

PRESENTATIONS:

Domokos, R., Pakhomov, E., Seki, M.P., and Jeffrey J. Polovina, J.J. Acoustic characterization of the mesopelagic community off the leeward coast of Oahu. PICES XVI Annual Meeting, Victoria, British Columbia, October 26 – November 5, 2007.

Domokos, R., Pakhomov, E., Seki, M.P., and Jeffrey J. Polovina, J.J. Acoustic characterization of the mesopelagic community off the leeward coast of Oahu. Ecosystems and Oceanography Working Group of PIFS Meeting, Honolulu, Hawaii, November 7, 2007.

Domokos, R., and Polovina, J.J. Oceanographic influences on albacore forage in the American Samoa longline fishing grounds. Pelagic Fisheries Research Program PI meeting, Honolulu, Hawaii, Nov 13 – 14, 2007.

Domokos, R., and Polovina, J.J. Environmental Effects on Forage and Longline Fishery Performance for Albacore Tuna in the American Samoa EEZ. 59th International Tuna Conference, Lake Arrowhead, California, May 19 – 22, 2008.

Domokos, R., and Polovina, J.J. Bigeye tuna and its forage base at Cross Seamount 98th Meeting of the Scientific and Statistical Committee, Honolulu, Hawaii, June 10 – 12, 2008.

Domokos, R., and Polovina, J.J. Environmental Effects on Forage and Longline Fishery Performance for Albacore (*Thunnus alalunga*) in the American Samoa Exclusive Economic Zone. ICES 6th Symposium in Acoustics (SEAFACS), Bergen, Norway, June 16 – 20, 2008

NOAA-Fisheries Advanced Sampling Technology Working Group (ASTWG) Grant Progress Reports

List of project progress reports:

-Development of the NOAA Fisheries Autonomous Underwater Vehicle

-Automated Recognition and Tracking of Fish in Underwater Video

-The use of stereo-camera technology to improve accuracy for optically-assisted acoustic rockfish abundance and habitat surveys

-Acoustic identification and enumeration of epipelagic fish and jellyfish

-Development and evaluation of new technology for the remote identification and enumeration of larval fish.

-Remote Detection and Identification of Marine Animals to Improve Fish and Habitat Assessment, and Reduce By-Catch using the ASTWG Dual Frequency Identification Sonar (DIDSON)

-Development of GSM remote receiving stations for the enhancement of ecological assessments of protected species.

Advanced Sampling Technology Working Group
Progress report to
The Office of Science and Technology

TITLE: Development of the NOAA Fisheries Autonomous Underwater Vehicle

INVESTIGATORS:

Dr. Randy Cutter[1]
George.Cutter@noaa.gov
858 546-7691

Dr. David Demer[1]
David.Demer@noaa.gov
858 546-5603

Charles Thompson[2]
Charles.H.Thompson@noaa.gov
228-688-2097

Steve Sessions[1]
Steve.Sessions@noaa.gov
858 546-7104

Josiah Renfree[1]
Josiah.Renfree@noaa.gov
858 546-7104

[1] NOAA Fisheries
Southwest Fisheries Science Center
Fisheries Resources Division
8604 La Jolla Shores Dr.
La Jolla, CA 92037

[2] NOAA Fisheries
Southeast Fisheries Science Center
Mississippi Laboratories
Building 1103 Rm 218
Stennis Space Center, MS 39529

GOALS

The NOAA Fisheries AUV (Figure 1) is designed to conduct ecosystem-based fish stock assessments, autonomously. This project's principal goal is to make the AUV operational for surveys. In FY2008, funds were provided via ASTWG for maintenance and supplies, contracted labor, transportation, travel and training.

Figure 1. NOAA Fisheries AUV prepared for deployment.

PRIORITIES

The goals for the NMFS AUV Program were refined by the ASTWG during its meeting in the Fall of 2007. These goals includ swimming at faster speeds, conducting missions with longer durations, following terrain, operating the stereo camera system, and accurate acquisition of waypoints. Particular emphasis was placed on accomplishing multi-leg missions with autonomous navigation..

APPROACH

During FY2008, a significant amount of time was devoted by the AST group at SWFSC to pursue the aforementioned goals. Deficiencies in the AUV design and control software were identified and fixed via bench and tank testing, and field trials in the ocean. Collaboration between Science Centers was established and led to the accomplishment of several milestones.

WORK COMPLETED

Work completed on the AUV during FY2008 included improvements to the mechanical system; debugging and revision of the control code; calibration of the stereo camera system; ocean-deployments of the AUV; operational use of the echosounder, stereo camera, DVL and CT sensors; and conduct of test surveys. The list of milestones accomplished during FY2008 is presented in Table 1. In addition to the milestone accomplishments, we acquired the spare parts from a nearly identical Fetch 3.5 AUV from the University of Delaware that had sunk and flooded. The spare parts included intact hull sections, internal framework, deployment apparatus, propellers, fins, nose and tail sections and all non-electrical components from the UDel AUV. The hull sections are identical to SWFSC hulls and would have been very expensive to reproduce, as would most of the other parts because they were all custom designed and fabricated. As we deployed the SWFSC AUV, it became clear that whenever repairs and replacement parts were needed, the process was time consumptive, expensive, and caused cessation of AUV operations and development for typically a week to months. Hence, the acquisition of these parts can limit interruption to AUV development that might occur if some critical part is damaged during field operations.

Table 1. NOAA Fisheries AUV (Fetch 3.5) milestones for FY2008. Symbol ~ indicates work underway, ✓ indicates achieved, ~/✓indicates recurrence of issue and solution under different conditions, gray shading indicates proposed timeline.

AUV Milestone	Sep 2007	Oct 2007	Nov 2007	Dec 2007	Jan 2008	Feb 2008	Mar 2008	Apr 2008	May 2008	Jun 2008	Jul 2008	Aug 2008	Sep 2008	First Achieved	Comments
Single-leg missions with longer duration	✓													8/2007	
Depth-holding	✓	✓								~/✓	~/✓	~/✓		8/2007	Reliably stable up to 600 RPM (avg. 1.4 m/s).
Faster speeds (1.5 m/s)	✓													12/ 2007	
Terrain-following					✓									1/2008	
Computer systems backup						~	~	~	✓					5/2008	Disk images of full systems.
Stereo cameras					~	~	~	~	~	✓				6/2008	Calibrated.
Strobe					~	~	~	~	~						Troubleshooting .
Waypoint acquisition									~	~	✓			7/2008	Achieved 1st in simulations, then in ocean.
Multi-leg missions (and “multi-depth, single-leg missions”)				~	~	~	~	~	~	~	~	✓		8/2008	Achieved ML with surface and underwater waypoint-finding and for various depths.
Replace existing foam with syntactic foam							~	~	~	~					Acquired foam. Postponed fabrication in favor of fieldwork.
Faster speeds (2.5 m/s)										~	~	✓*		8/2008	*Max. speed recorded = 1.98 m/s; (> 2.5 m/s was observed, not recorded).
Dive to deeper depths															Not attempted b/c of concerns.
Hollings Scholar / Intern project						~	~	~							Intern declined the opportunity.
Adaptive sampling (grad. student thesis)					~	~									Student declined the opportunity.
Collaboration with other NMFS & ASTWG investigators										✓	✓	✓		6/2008 – 8/2008	Collaborative work between SWFSC & SEFSC.

Details: The average speed of the AUV on leg 4 of multi-leg mission #6 (ML6) on 13 Aug. 2008 was 1.80 m s-1, or 3.59 knots, with a maximum speed of 3.85 knots (1.98 m s-1).

RESULTS

Mechanical system repairs and improvements

Mechanical improvements were made to the AUV's stereo camera housing, GPS/radio antenna, and dive planes. Syntactic foam was acquired to replace the existing foam in the external fairings, nosecone, and tailfin ring. After one deployment in January 2008, a small amount of water (~ 5 ml) was found inside the stereo camera housing. It was determined that each camera port had only single, axial o-ring. Engineering and fabrication services (STS) were contracted to modify the port design so that there would be an additional face-sealing o-ring behind the port (Figure 2).

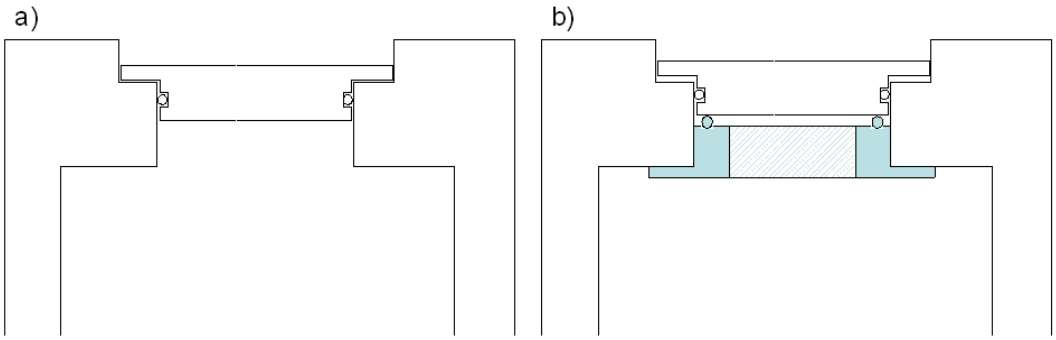


Figure 2. AUV stereo camera housing (a) original design, and (b) modified design.

Control code development

Debugging and revision of the AUV control code on the flight computer focused on autonomous navigation and dive control. Constant probing of several variables and conditions during all states of AUV code execution was implemented as a subprogram that can be inserted and called from anywhere in the control code, and a log file is generated for each deployment that provides details critical to debugging AUV behaviors. Problems were identified and solved by a collaborative effort involving detailed inspection and review of code, debugging, bench test simulations and collection of mission log files, and revisions were made to several portions of code controlling navigation and waypoint-finding, resulting in accurate autonomous navigation and achievement of the ultimate goal of multi-leg mission capability. Code revisions were made that accomplished underwater navigation by DVL-assisted dead reckoning. Some code revisions were made during deployments while the AUV was in the ocean to address problems. For example, after dead-reckoning was implemented, the error between the realized and planned course was high, and it was determined that the course-over-ground data from the DVL was inaccurate, and modifications had to be made to use DVL heading data for the dead reckoning. Subsequently, DR solutions were quite good. Also, it was apparent that occasionally the DVL returned false zero values that the AUV would detect and respond to by bailing out. Code to handle this condition was revised during a deployment, and remedied bailouts on false zero detections. Bailouts on strong targets in the water column sensed by the DVL can still occur, and will be addressed by further code revisions that involve simultaneous processing of the DVL and EK60 bottom-detection data.

Camera calibration

Images of a standard checkerboard target were collected with the AUV's stereo cameras in a tank at SIO on 25 and 30 June 2008. AUV stereo cameras were calibrated using stereo pair images of the target with 30-mm grid cells that was held at various angles and ranges from the cameras (Figure 3). The Camera Calibration Toolbox for Matlab (Bouguet; http://www.vision.caltech.edu/bouguetj/calib_doc) was used to estimate calibration parameter values. Images of a dead sardine that had been measured in the lab were collected for comparison with the length estimated using the stereo images. The images in Figure 3 are from the AUV's stereo camera system and indicate the quality of imagery possible under good lighting conditions. The sardine is 19.2 cm (forklength), 20.7 cm (total length) and held at approximately 0.5 to 1 m from the cameras.

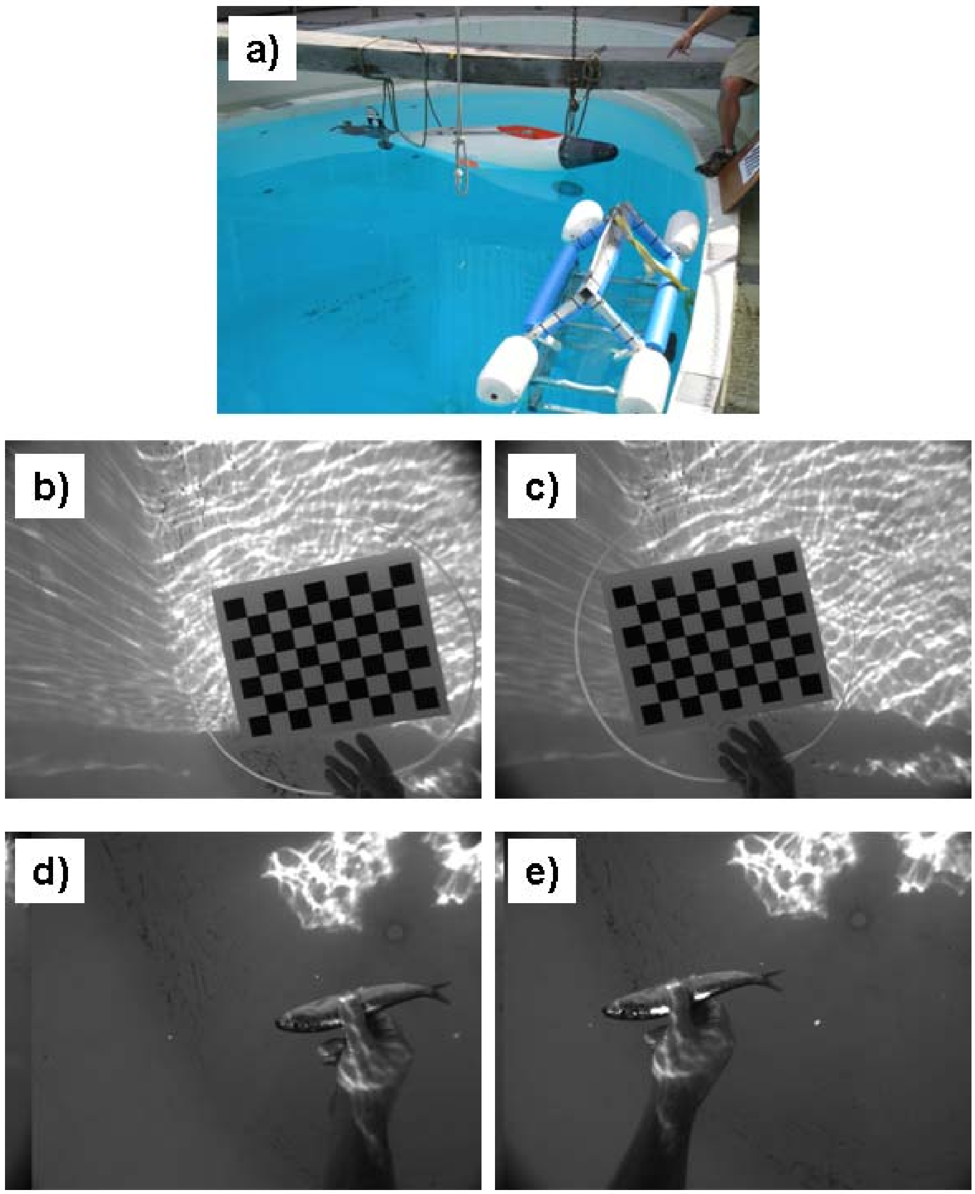


Figure 3. AUV stereo camera calibration. (a) AUV suspended in tank; (b) left and (c) right stereo pair images of the standard target; and a stereo pair, (d) and (e), of a Pacific sardine.

Ocean Deployments

During FY2008, ten ocean deployment days were planned, and nine deployment days were completed. Deployments were designed to test and troubleshoot various behaviors, provide data for debugging code, and collect survey data. Missions were conducted on 20 Dec. 2007, and on 17 Jan., 11 Jun., 9 July, 18 July, 24 July, 6 Aug., and 13 Aug. 2008 A scheduled survey deployment on 8 Aug. 2008 had to be aborted. Each of these were full single day deployments operating the AUV from SIO Pier or the NOAA *R/V D.V. Holliday*. Generally, four or five people are required for safe deployment and recovery and chase-boat operations.

Multi-leg missions

Multi-leg missions were successfully completed on 06 and 13 August, 2008 by the NOAA Fisheries AUV in the vicinity of Scripps Canyon, off La Jolla, California. Accomplishment of this important milestone was a result of a collaborative effort between SWFSC and SEFSC researchers: G. Cutter (SW), C. Thompson (SE), D. Demer (SW), T. Sessions (SW), and J. Renfree (SW).

The sequence of events during the AUV's multi-leg missions is depicted in Figure 4, based on results of multi-leg mission #5 from 13 Aug. 2008 (ML5), and is described here. (A) The AUV receives remote command to begin mission; (B) the AUV swims at the surface to the initial waypoint (WP0); (C) the AUV arrives within the error radius (40 m) of WP0 and dives on first leg; (D) underwater navigation from WP0 to WP1, on mission with survey instrumentation operating; (E) dead reckoning indicates arrival within GPS error circle of destination WP; (F) position fix acquired by AUV after surfacing; (G) the AUV swims at the surface to WP1, then dives on Leg 2 and conducts mission to WP2. Steps C-G are repeated for each survey leg, except when underwater waypoint-finding is active. During underwater waypoint-finding mode, the AUV does not surface to obtain a GPS fix at the waypoint, but, instead relies on dead-reckoned fix underwater.

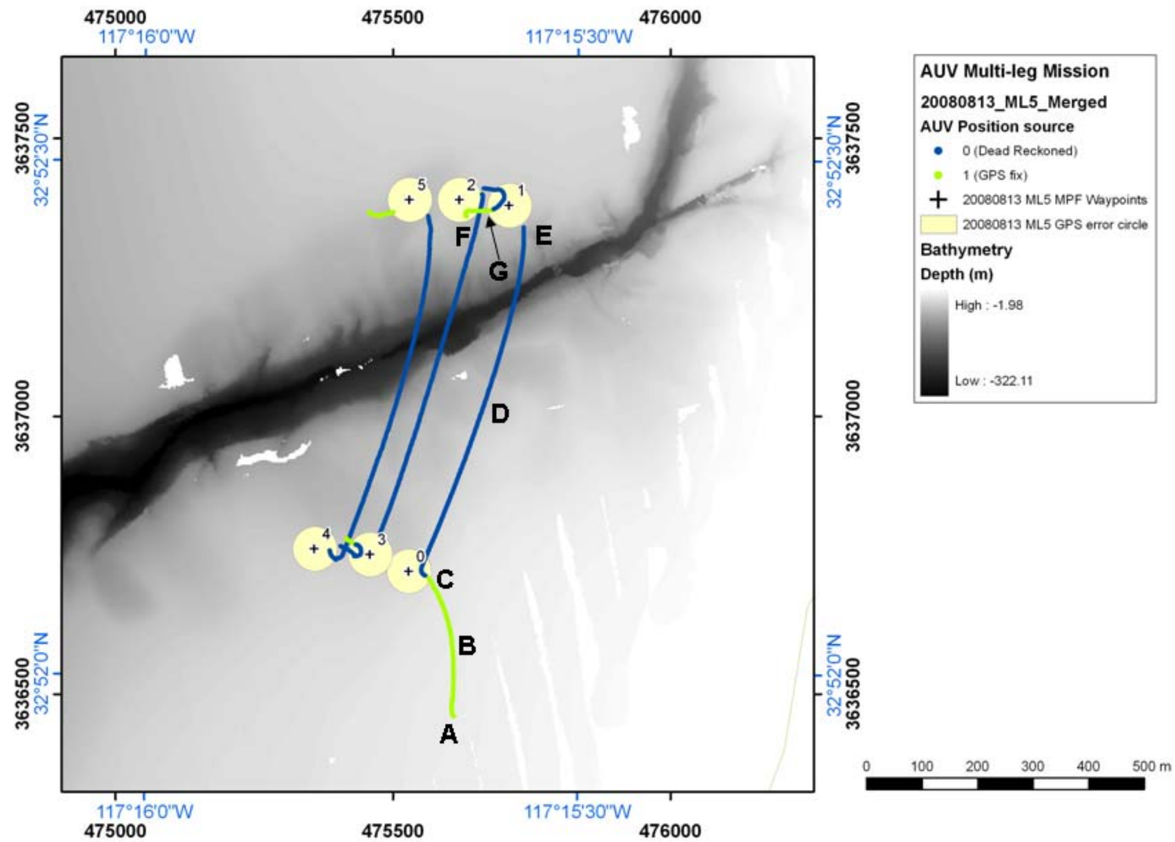


Figure 4. AUV multi-leg mission tracklines from ML5 on 13 August 2008. See text for details.

The error of dead reckoned (DR) positions during autonomous underwater navigation was low when the heading data from the DVL was used for the solution. For cases where the AUV successfully completed the leg (and did not bail-out or time-out) and DVL course-over-ground (COG) data was used for dead reckoning (DR), the DR solution indicated that the AUV was within 44 m and 43 m from the destination waypoint, but the AUV actual positions upon surfacing were 115 m and 408 m away. When DVL heading was used, the DR solution indicated that the AUV was within 43 to 46 m, and the realized distances were from 26 m to 80 m away, on legs with lengths from 63 to 684 m. The absolute difference between the distance from the waypoint estimated by DR and GPS fix ranged from 1 m to 35 m. Hence, when using the DVL heading data for DR, the AUV surfaced within 35 m or less of its intended destination during multi-leg missions (Table 2).

Table 2. Distance from waypoints achieved during autonomous DR on ML missions. Leg Dist is the length of the leg; DRdist is the distance to the waypoint estimated by dead reckoning; FixDist is the distance to the waypoint from GPS fix; dDist is the difference between DR and GPS distances to waypoint; COG is course-over-ground from DVL; Heading is heading from DVL.

Date	Mission	Leg	Leg Dist (m)	DRdist (m)	FixDist (m)	dDist (m)	Status (*)	Heading Source	Comment
20080806	ML1	1	609	143*	375*		Bailout	COG	
20080806	ML1	2	376	44	159	115	Complete	COG	Inaccurate COG
20080806	ML1	3	575	43	448	408	Complete	COG	Inaccurate COG
20080806	ML2	1	390	332*	297*		Bailout	Heading	Speed
20080806	ML2	2	226	217*	211*		Bailout	Heading	Speed
20080806	ML3	1	264	45	44	-1	Complete	Heading	
20080806	ML3	2	267	43	46	3	Complete	Heading	
20080806	ML3	3	312	45	60	15	Complete	Heading	
20080813	ML1	1	332	344*	337*		Bailout	Heading	
20080813	ML2	1	315	86*	79*		Bailout	Heading	
20080813	ML3	1	99	46	26	-20	Complete	Heading	
20080813	ML3	2	845	822*	808*		Bailout	Heading	
20080813	ML4	1	838	293*	242*		Timeout	Heading	
20080813	ML5	1	684	45	80	35	Complete	Heading	
20080813	ML5	2	63	45	38	-7	Complete	Heading	
20080813	ML5	3	680	43	54	11	Complete	Heading	
20080813	ML5	4	74	44	26	-18	Complete	Heading	
20080813	ML5	5	649	44	78	34	Complete	Heading	

Note: Negative dDist values indicate the AUV was closer to the waypoint than expected.

During multi-leg mission ML5 on 13 Aug. 2008 the magnitude and direction of the DR-error appears to be related to an offshore current associated with the canyon (Figure 5).

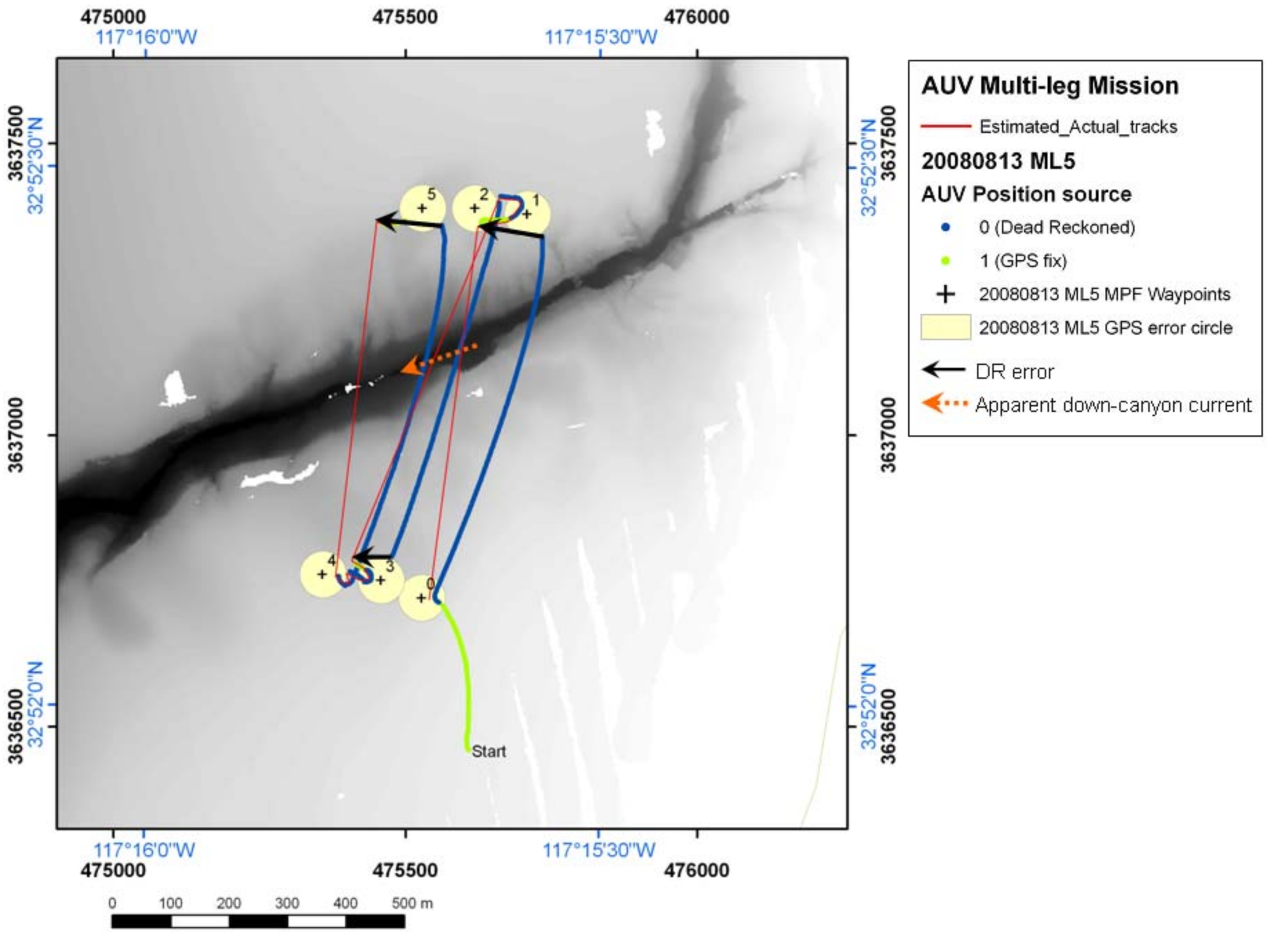


Figure 5. AUV multi-leg mission (ML5, 13 Aug. 2008) dead-reckoned (DR) positions (blue) ; straight lines joining actual position fixes (red); cumulative DR error vectors (black arrows); and apparent down-canyon current, assumed responsible for most of the DR error.

Echosounder data and stereo camera data collection

During single- and multi-leg missions, the AUV collected data from its 38-kHz Simrad EK60 echosounder. The EK60 echogram collected by the AUV during Leg 1 of ML5 (Figures 4 & 5) on 13 Aug. 2008 is presented in Figure 6, showing seafloor data including a south-to-north profile of Scripps Canyon, and water column scattering from plankton and fish in a layer to 25 m. The slightly edited sounder-detected bottom line is shown as the green line.

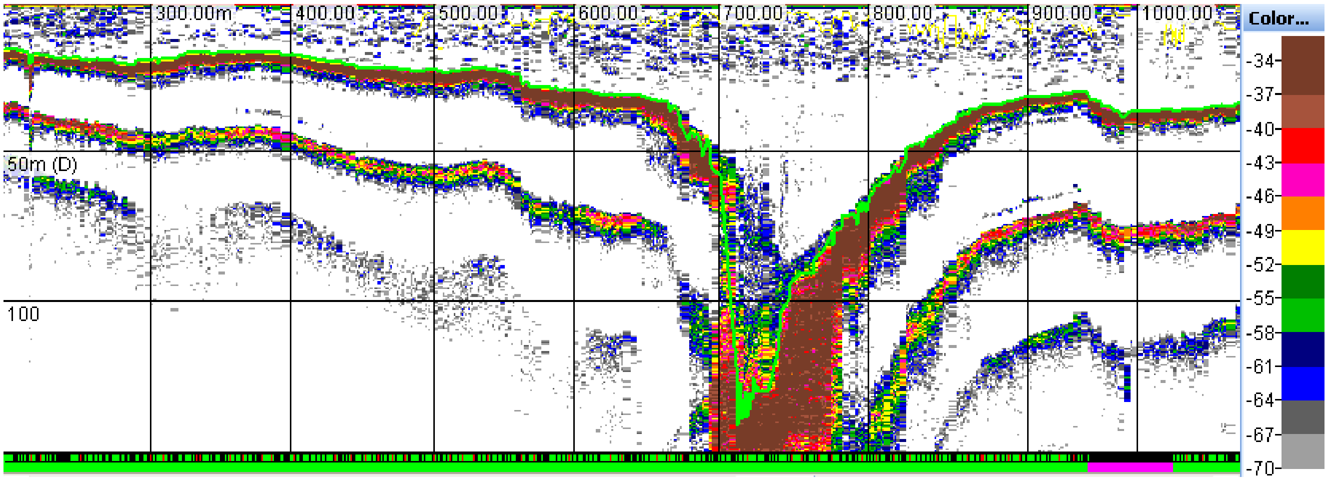


Figure 6. Echogram collected by the AUV from the 38-kHz EK60, during ML5 on 13 Aug. 2008.

<u>Stereo camera data</u>

Stereo image pairs were collected during many of the missions. Often, the camera system would have a delayed acquisition, such that the acquisition interval was ~ 30 sec. Debugging of the camera control code is underway, and the delay is supposed to be related to a memory buffer. Images of small coastal pelagic fish species were collected by the AUV during a deployment off La Jolla, CA in July 2008 (Figure 7). The quality of the images was poor due to over-exposure, however portions of dense schools of fish were evident after some image post-processing; only the left-side images are shown because right-side images were too washed out.

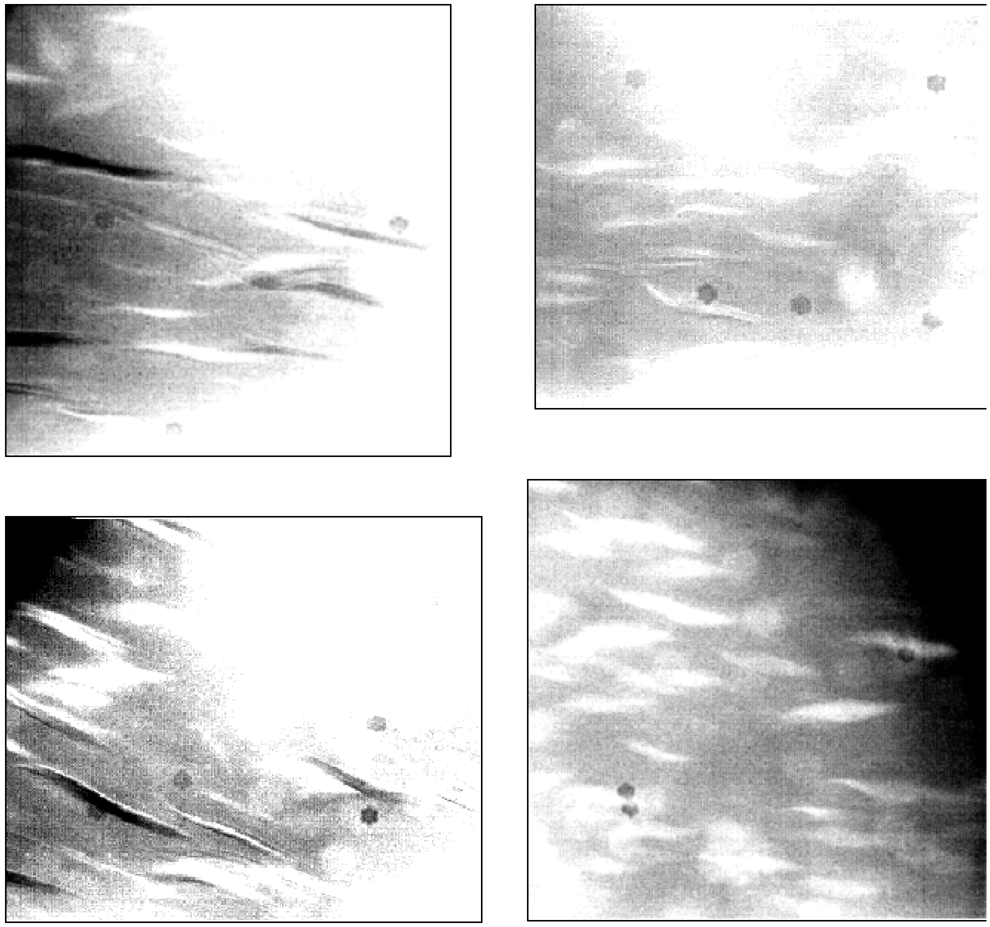


Figure 7. Images of coastal pelagic fish schools collected by the AUV in July 2008.

AUV speed

The AUV achieved a maximum recorded speed of 3.85 knots (1.98 m s^{-1}) during a multi-leg mission (ML6) on 13 August, 2008 (Figure 8). The AUV was observed moving much faster during a period when the RPM went far higher than programmed, during a short burst of unusual behavior. However, those data were not recorded. A typical speed at which tuned dive control parameters reliably produce precise depth-holding is approximately 2.5 knots (~ 1.3 m s^{-1}).

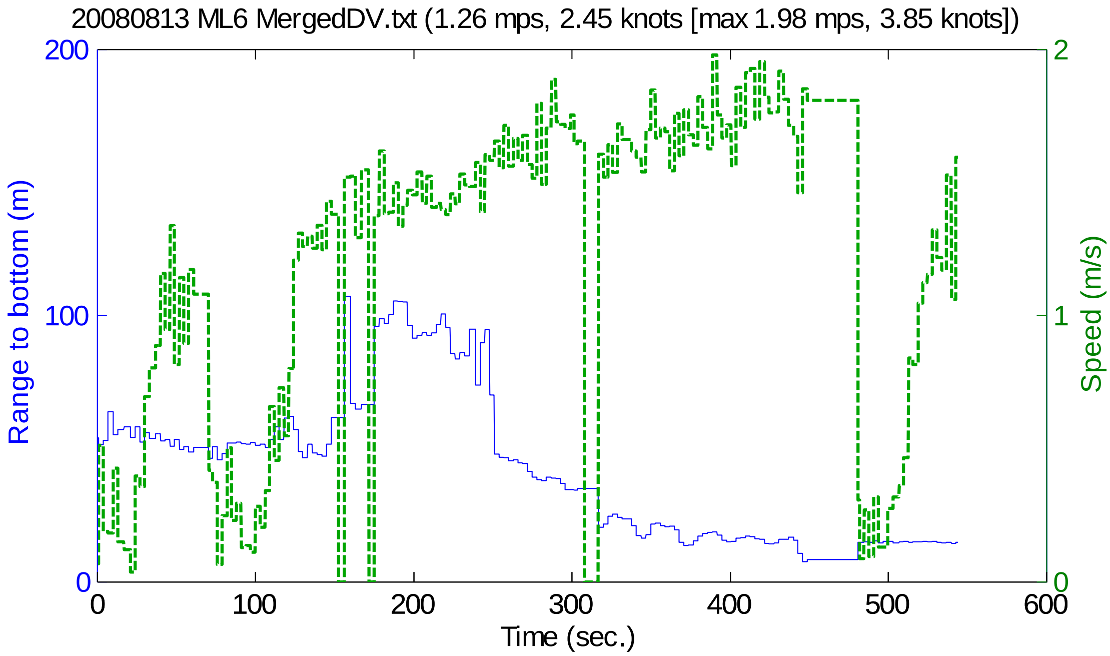


Figure 8. AUV speed and range-to-bottom data from ML6 (all legs, merged) on 13 Aug. 2008, when the AUV reached 3.85 knots, its current maximum recorded speed.

<u>Depth-holding</u>

Precise depth-holding, where the AUV dive depth during a mission is within close range to the target depth, was accomplished in Sep. and Oct. 2007, for a propeller speed of 550 RPM (Figure 9). Retuning of depth control parameters has been underway for variations in dive planes and for faster speeds, and depth-holding has been achieved at speeds up to 750 RPM. Depth-holding is generally reliable and reproducible at RPMs up to 600, and can occur up to 900 RPM, but more control parameter tuning must be done to make the behavior reliable at higher speeds.

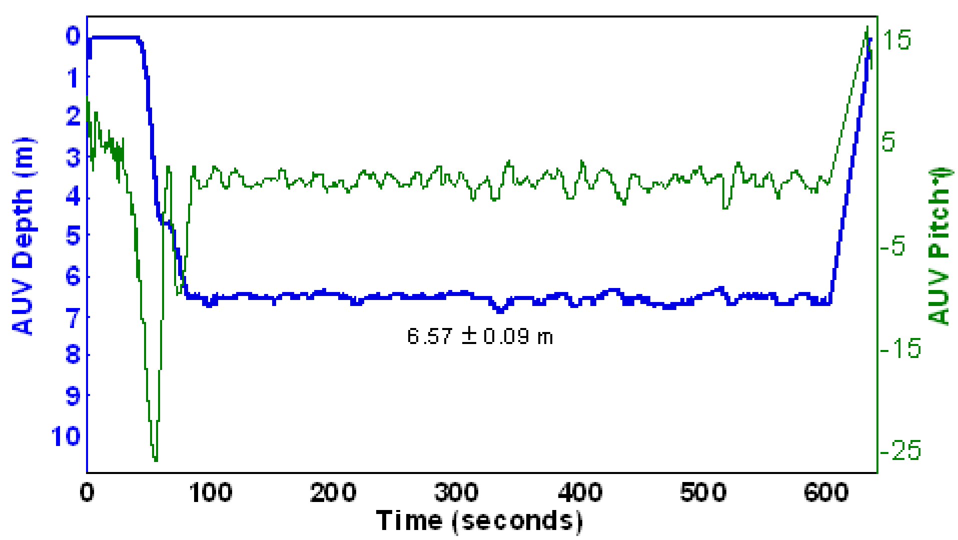


Figure 9. Precise depth-holding dive control during a mission.

Terrain-following

Terrain-following behavior during missions was accomplished beginning in Jan. 2008 (Figure 10), and has been reproduced on several deployments.

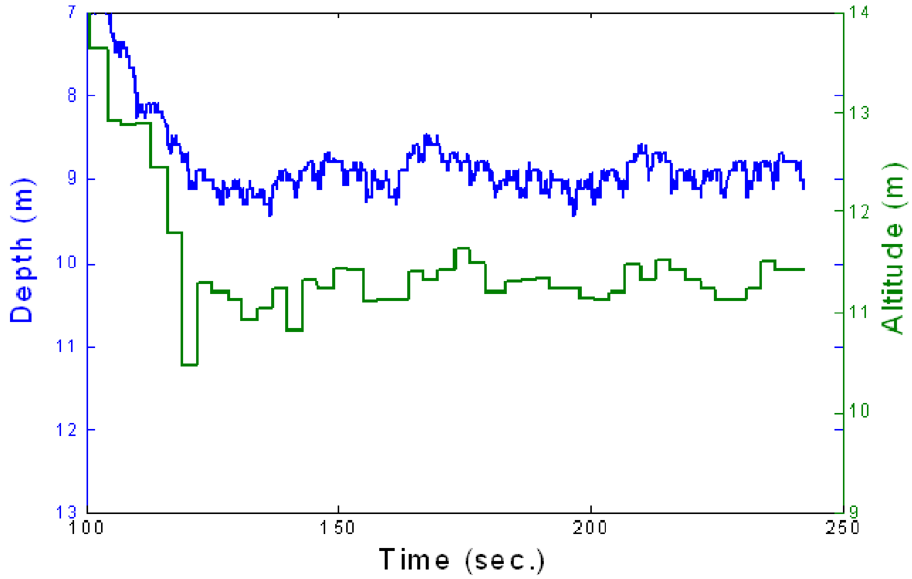


Figure 10. Terrain-following dive control during a mission.

Problems encountered

Navigation

Course-over-ground data from the DVL on the AUV are generally at a constant offset from the DVL Heading values, by approximately -45°, except for occasional periods with large fluctuations of course-over-ground data that are not evident in the DVL heading data (Figure 11).

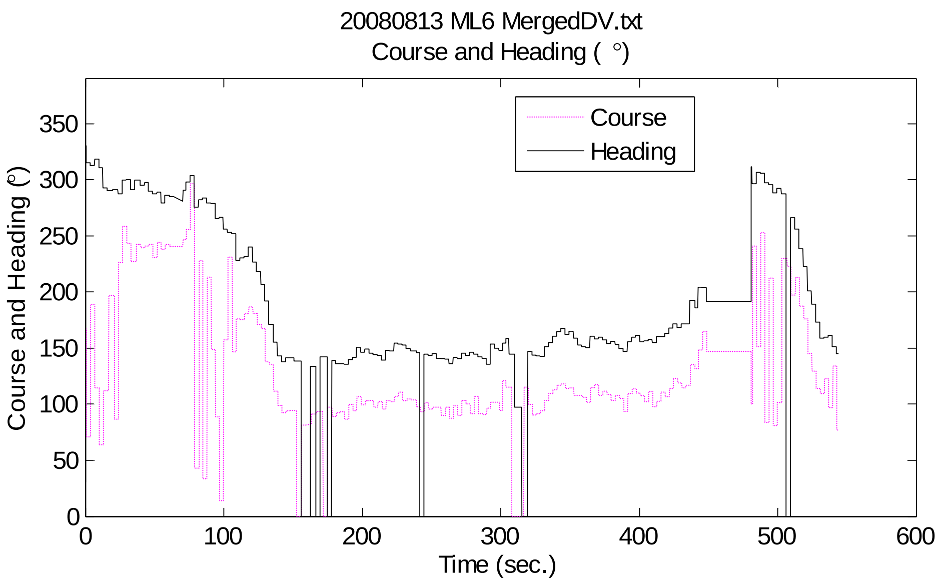


Figure 11. Course and heading data from the DVL on the AUV for multi-leg mission 6 (ML6) on 13 August, 2008.

During the first multi-leg mission on 06 Aug. 2008, the AUV used course-over-ground in the dead reckoning algorithm. By comparing the realized track of the AUV to its dead reckoned positions, it was determined that the course over ground data were inaccurate. Dead reckoning was done subsequently using heading data from the DVL, and realized courses were far more accurate.

Damage and Repairs

On 08 August, 2008, the NOAA Fisheries AUV was loaded onto the R/V D.V. Holliday at Mission Bay marina for a deployment planned on Mission Beach Reef to complete an AUV acoustic survey of rockfish (Sebastes spp.).

Deployment of the AUV was aborted because of a deck incident: sudden slack to the winch cable used to transfer the AUV from the deck to the water caused AUV deployment frame to be dropped on boat deck. The impact caused separation of the AUV aft hull section from the mid-section and two fasteners pulled-through holes, leaving no way to secure the sections for a safe deployment. Later, upon inspection in the laboratory, it was found that the internal chassis frame in the aft section was bent by the impact. No other damage was apparent. Hull, sensors, fins, propeller and internal devices were not harmed.

Repairs were made to the chassis and fastening system, and the AUV was reassembled and tested in the laboratory for two days. Pressure tests were applied, and no leakage was detected. Bench tests indicated normal operation and mechanical integrity after repairs.

Post-damage deployments

The AUV operated normally and reliably during a deployment conducted after repairs for the damage incurred on 08 Aug. The AUV maintained telemetry, operated payloads, surface swam, and completed single- and multi-leg missions successfully. There were anomalously high values of RPM & speed control voltage for missions ML1, ML2, ML4, ML5, and ML6 on 13 Aug. 2008 (Figure 12). It is suspected that this effect could be minor damage to one of the controller boards due to the incident on 08 Aug. 2008, and it is scheduled to be replaced.

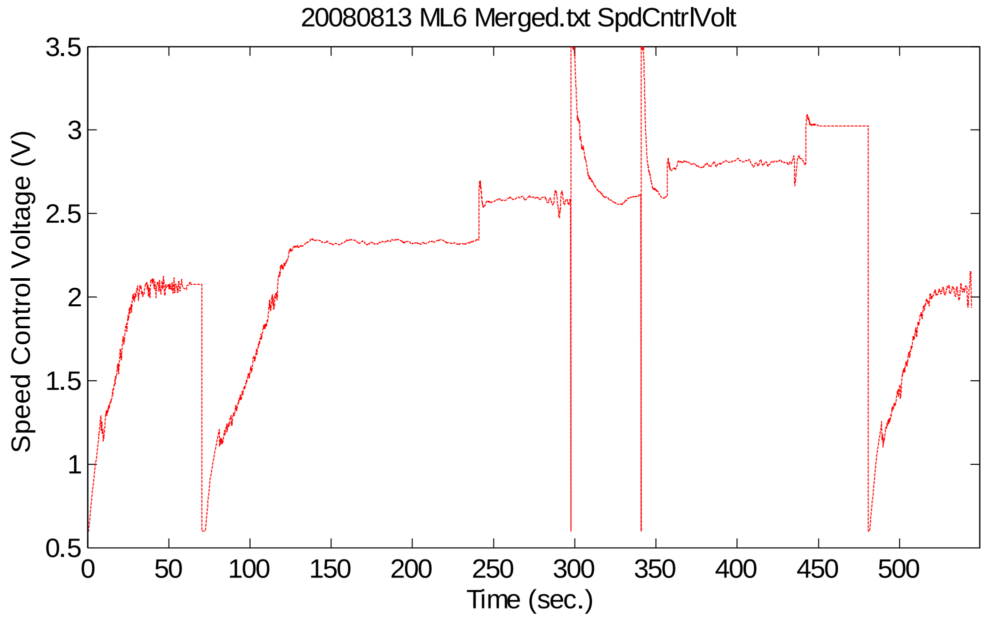


Figure 12. AUV Speed-control voltage (V DC).

Despite the spikes in RPM, the AUV continues to successfully complete multi-leg missions since the damaging incident, and we are confident that the AUV is operational and that the RPM spikes can be eliminated by code revision or replacing the speed-controller board.

IMPACT/APPLICATIONS

The NOAA Fisheries AUV is now operational for fully autonomous single-leg and multi-leg missions collecting echosounder data and stereo-camera images. Field trials indicate that the AUV is ready to perform fisheries acoustic survey work, collecting echosounder, DVL, CT, and stereo image data on multi-leg missions with reliable performance at up to 3 knots for shallow (~ 10 m) dive depths.

The on-site collaboration between researchers from SWFSC and SEFSC was instrumental to the major accomplishments and was made possible by ASTWG support for the AUV.

TRANSITIONS

Constant regular attention and basic maintenance are required to keep the AUV operational and to keep personnel proficient in its operation. Plans for continued development include: troubleshooting and repairing the strobe; fabricating the syntactic foam; completing dives with precise depth or altitude control at even faster speeds; developing and implementing adaptive sampling algorithms; and completing deeper dives. The AUV is now ready for conducting autonomous survey operations in the open ocean, but does require supervision of a team of experienced personnel. Because the AUV is a custom-designed and unique device, and is a complicated system with many moving parts and fragile pieces, that is intended for field service in the ocean, it is beneficial to have personnel capable of rapidly interpreting results and troubleshooting. Also, it is prudent and sometimes necessary to have engineering, design and fabrication services available after any deployment.

RELATED PROJECTS

NPRB Proposal: "Assessment of Rockfish Species in Untrawlable Habitat Using Advanced Acoustic, Optical and Trawl Technologies," Chris Rooper, AFSC; Tom Weber, UNH; and D.A. Demer, SWFSC.

PRESENTATIONS

Presentation to Under Secretary Lautenbacher and staff during their visit to the Southwest Fisheries Science Center, 13 June 2008.

Poster presentation at the stock assessment workshop (NSAW), Port Townsend, WA.

Demer, D.A., Cutter, G.R., Sessions, T.S., Renfree, J.R., Needham, D., Paterson, M., Detlor, D. Jech, M., Karp, W., Michaels, W., Parrish, F., Seki, M., Sheridan, P., Shimada, A., Somerton, D., Thompson, C., and Wilson, C. Surveying with a Sound and Sight Sensing Submarine. Poster presentation at the International Symposium on Ecosystem Approach with Fisheries Acoustics and Complementary Technologies (SEAFACTS), Bergen, Norway, 16-20 June, 2008.

REFERENCES

Bouguet J. Y. Camera Calibration toolbox for Matlab. www.vision.caltech.edu/bouguetj.

Advanced Sampling Technology Working Group
Progress Report to
The Office of Science and Technology

TITLE:

Automated Recognition and Tracking of Fish in Underwater Video

INVESTIGATORS:

Charles H. Thompson
charles.h.thompson@noaa.gov
NOAA NMFS
Southeast Fisheries Science Center
Bldg 1103 Rm 218
Stennis Space Center, MS 39529
228-688-2097

George Ioup
geioup@uno.edu
Juliette Ioup
jioup@uno.edu
Department of Physics
University of New Orleans
New Orleans, LA 70148
504-280-6715

Hazem Kanfar
hkkanfa@uno.edu
Dimitrios Charalampidis
dcharala@uno.edu
Department of Electrical Engineering
University of New Orleans
New Orleans, LA 70148
504-280-7415

GOALS

Underwater imaging systems are used by many programs within NMFS with the objective of identifying and quantifying living marine resources. Manual analysis of the recordings by humans is both time consuming and labor intensive. The goal of this project is to begin development of tools to automate the image analysis to produce results more quickly and cost effectively.

PRIORITIES

The first step in automating analysis of underwater video is to develop algorithms that will detect the presence of fish in the images and track their movement through time. This will allow for counting the number of fish present in a given time period and exporting information for further analysis. The priorities for this project are to develop methods to detect and track the motion of fish imaged by horizontal-view cameras that are used by SEFSC to survey reef fish.

APPROACH

Camera systems used by SEFSC to survey reef fish are deployed on the bottom and typically record images for 20 minutes before being retrieved. During this time, the background and illumination are relatively fixed while fish swim through the sampled volume. Sequences of images will be averaged to produce a background image that can be used to discriminate moving objects. An adaptive process will be used to remove moving object contributions to the background estimation. Division of each frame by the background, followed by a thresholding operation, will separate any image pixels that differ significantly from the background. A region-growing algorithm and edge-detection algorithm will then be applied to group pixels that make up an object. Temporal correlations and analysis of detected object features such as texture, geometric, and photometric characteristics will be used to track objects from frame to frame.

WORK COMPLETED

A framework for the process was developed and preliminary algorithms to calculate background images and perform object discrimination and region growing, were applied to selected image sequences. Due to delays in the funding process and contracting requirements, work on this project did not begin until late in FY08 and most of the work will take place in FY09.

RESULTS

Working algorithms were developed to successfully discriminate moving objects from stationary background. The following example illustrates the process.

Figure1 shows the background image calculated from 200 frames of an image sequence recorded with a grayscale digital camera.

Figure 2 shows a single frame of the sequence at a time when two fish are in view.

Figure 3 shows the division of the image by the background, scaled so that pixels matching the background are white and darker pixels are increasingly different from the background.

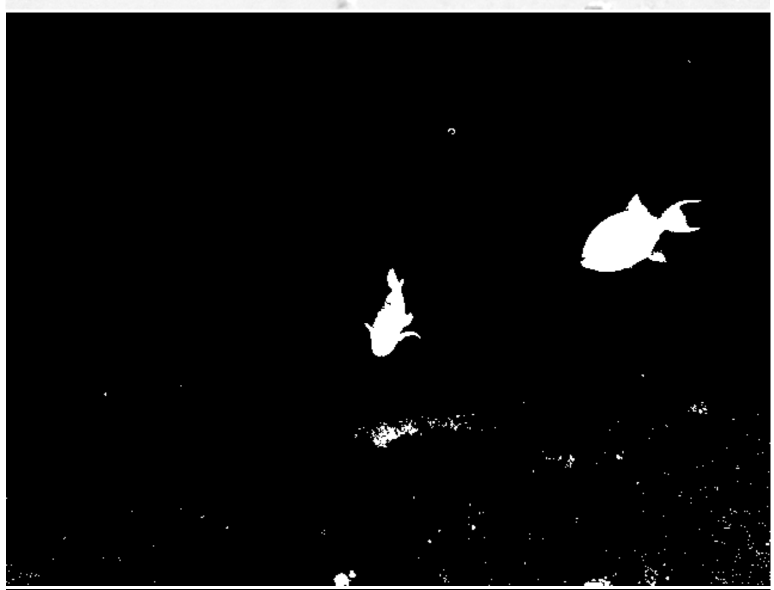


Figure 4. A threshold process generates a binary image where background pixels are set to 0 and remaining pixels to 1.

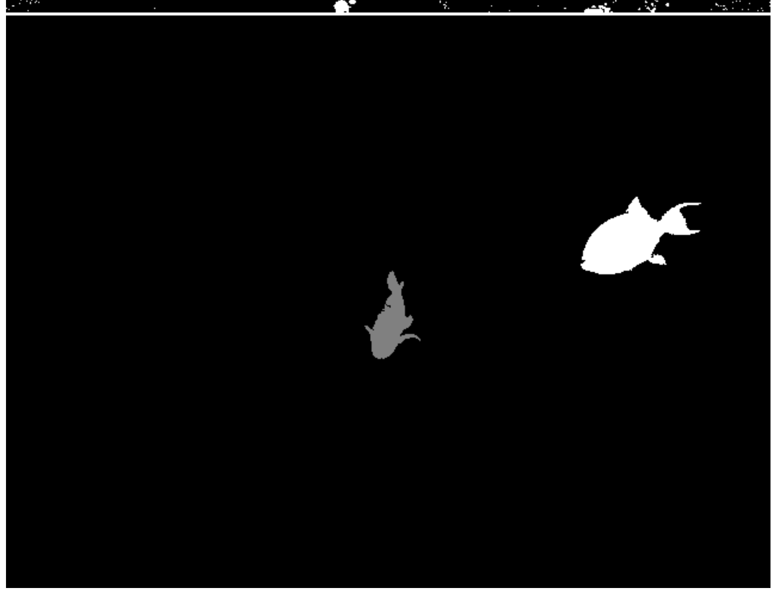


Figure 5. Application of a region-growing algorithm and elimination of regions smaller than a certain threshold produces two objects corresponding to fish in the original frame.

At the end of FY08, work is focused on 1) Adaptively improving the background image by removing contributions from pixels which are part of fish detected in the individual frames used for the background. This will make threshold choice easier and eliminate some of the noise in the binary image. For example, the patch of white pixels below the fish in the center of Figure 4 is caused by a fish that was in part of the background sequence but not in the particular frame analyzed here. 2) Automatic determination of the optimum thresholds for generating the binary image and minimum region size.

Although not necessary in the above example, a complementary technique of edge detection on images at the state shown in Figure 3 followed by region growing constrained to remain within detected edges may also be used to better complete object shapes. Currently, an individual fish can be detected as more than one object, and sometimes multiple fish, very close together or overlapping in an image, are detected as single objects. Tracking object properties from frame to frame is expected to solve these problems since the true number of fish will only change when a new object enters or a tracked object leaves the camera view.

IMPACT/APPLICATIONS

Techniques developed in this project will be applicable to video and image sequences collected with other stationary camera systems and will be made available to other researchers with NMFS. This work is an initial step toward automation of analysis of this type of fisheries data and will be followed by further auomation.

TRANSITIONS

None at this time.

RELATED PROJECTS

This project is closely related to, and is making use of images collected with, stereo camera systems developed by previous ASTWG projects.

PUBLICATIONS

None at this time.

PRESENTATIONS

None at this time.

EXPENDITURES

Grant total = $62,200

Advanced Sampling Technology Working Group
Progress Report to
The Office of Science and Technology

The use of stereo-camera technology to improve accuracy for optically-assisted acoustic rockfish abundance and habitat surveys

Principle Investigators:
John Butler, PhD;, G. Randy Cutter, PhD; David Demer, PhD; David Murfin; *Kevin Stierhoff, PhD*
NOAA SWFSC
8604 La Jolla Shores Drive
La Jolla, CA 92037

Yuri Rzhanov, PhD
University of New Hampshire
Center for Coastal and Ocean Mapping
24 Colovos Road
Durham, NH 03824

Goals

The Advanced Survey Technologies (AST) and Benthic Ecology groups at the SWFSC are presently using remotely-operated vehicle (ROV) and acoustic survey data (Collaborative Optically-assisted Survey Technologies or COAST) to provide estimates of groundfish population sizes in the Southern California Bight (SCB). The present method uses species identifications and lengths measured from ROV images and laser calipers to develop probability density functions (PDFs) which are subsequently used to apportion acoustic backscatter into numbers of fish of different species, Key to this conversion is a length-weighted, mean target strength (*TS*) for each species. Succinctly, improved estimations of fish length PDFs will directly improve the acoustic estimates of fish densities and biomass.

The goals of this study were to improve the methods outlined above through 1) the addition of a stereo digital photography system to the ROV, and 2) the development of stereo-image analysis software for fish measurements. Stereo digital photography provides three-dimensional (3-D) images of fish, which removes the need for laser calipers and the requirement that the lasers' points are on each fish to ensure accurate measurement. With few exceptions, fish that are in the common field-of-view of the stereo cameras will be candidates for length measurements.

Priorities

The two major priorities of this project were to 1) develop a stereo-camera system that could be integrated into the existing ROV platform, and 2) develop image analysis software that provides accurate length estimates for fish in stereo image pairs. The camera system was developed by the PIs at the SWFSC, and the software development was headed by Dr. Rzhanov at UNH with design input from the PIs at the SWFSC.

Approach and work completed

To achieve the first goal, a Videre Designs Model STH-MDCS3-9CM stereo camera was interfaced with a PC104 computer (Celeron 850 MHz processor, 496 MB RAM) and packaged into a self-contained, water-tight housing (16.5 cm diameter x 30.5 cm length) rated to 100 m depth (200 m capable) (Figure 1). This camera system has a low-noise, high-sensitivity CMOS imager capable of color or monochrome uncompressed video at megapixel resolution (7.5 fps) or VGA (30 fps) (http://www.videredesign.com/vision/sth_mdcs3.htm). Calibration images of a fixed grid were collected by a diver in a test tank (Figure 2). These images were later used to generate calibration parameters using the Camera Calibration Toolbox in Matlab.

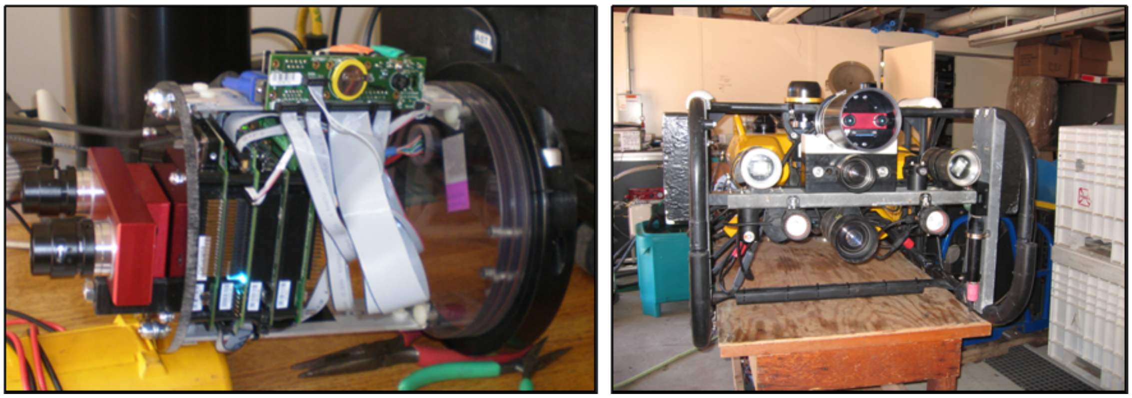


Figure 1. Several views of the stereo camera package.

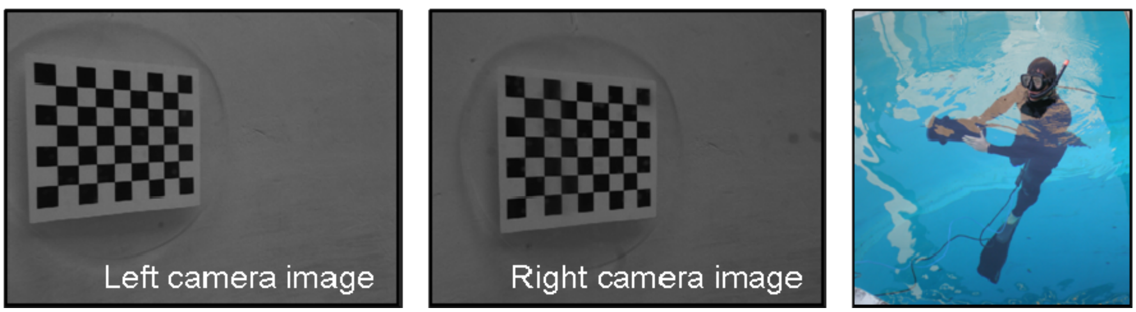


Figure 2. Diver-collected stereo image pair from left and right cameras.

To achieve the second goal, Dr. Rzhanov developed StereoMeasure (Figure C) to accurately measure lengths of objects observed in stereo image pairs. The software allows for the selection of any number of points along the object to be measured in the left image (Figure 3, left image). The software automatically places the corresponding conjugate points in the right image (Figure 3, right image), but gives the analyst the option of manually adjusting the placement of that point to improve accuracy when image properties degrade the automatic placement of the conjugate point. Lastly, StereoMeasure logs fish measurements into a delimited text file for further analysis.

A preliminary laboratory study was conducted in December 2008 (see Results below). The stereo camera system will be mounted on the ROV for upcoming COAST cruises for field testing. The measurements of fish from stereo image pairs using StereoMeasure will then be compared with those obtained from laser calipers and traditional image analysis techniques.

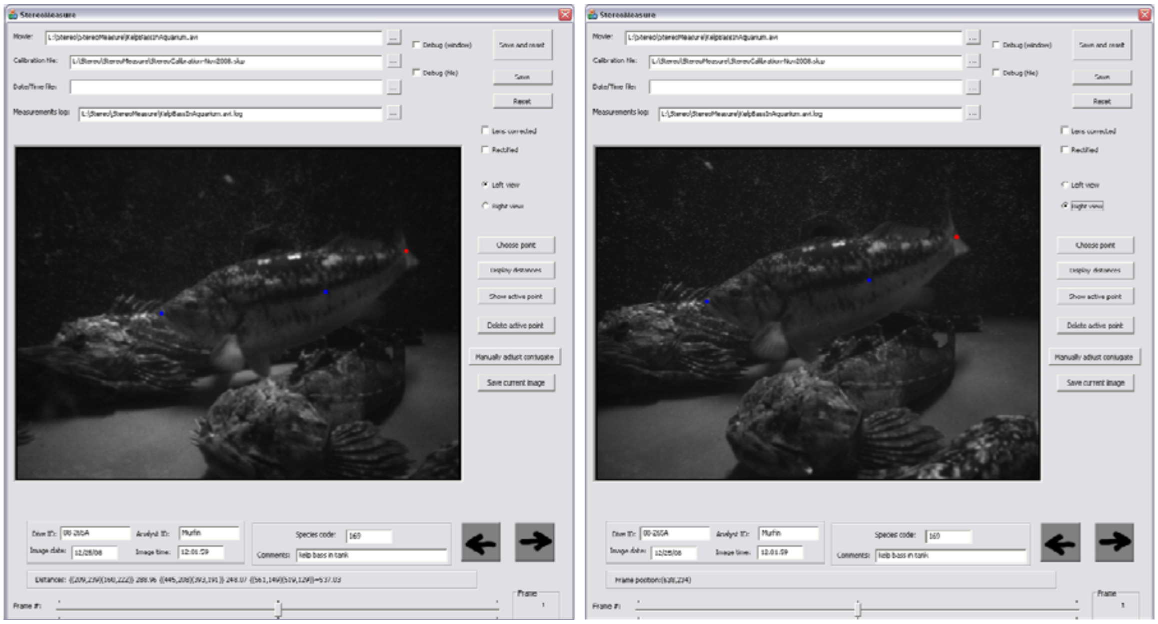


Figure 3. Screen grabs of StereoMeasure user interface showing three conjugate points on left and right camera images.

Results

Measurements on a calibrated grid

Distances were measured between two points from multiple frames of a movie containing images of the calibration grid collected during the AUV calibration (Table 1). Screen grabs of three of those measurements are shown in Figure 4 below. The average difference and average percent distance between the actual and measured distance (using StereoMeasure) were 3.2mm and 1.6%, respectively.

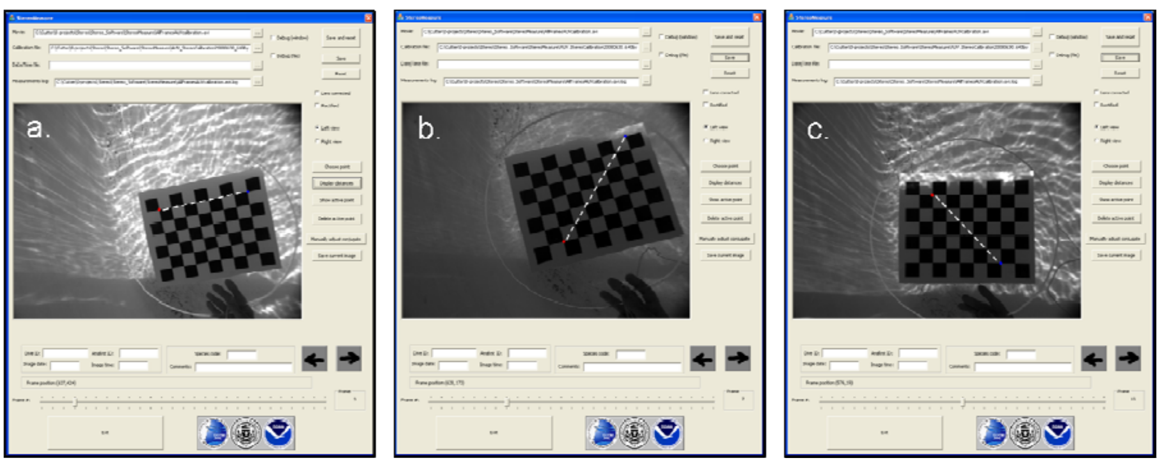


Figure 4. Screen grabs of measurements of calibrated grid. Dashed lines connect measurement points.

Table 1. Accuracies measurements from StereoMeasure using the AUV calibration grid.

N	Frame #	Measurements	Cells	Actual Distance*	Measured Distance	Difference (mm)	Difference (%)	Comment
1	3	1	7	210	214.63	4.63	2.2	
2	3	2	5	150	150.71	0.71	0.5	
3	4	1	7	210	218.69	8.69	4.1	
4	4	2	5	150	153.81	3.81	2.5	
5	7	1	6	180	182.58	2.58	1.4	
6	7	2		254	255.32	1.32	0.5	Diagonal
7	8	1	4	120	122	2	1.7	
8	8	2	7	210	211.24	1.24	0.6	
9	9	1	9	270	279.1	9.1	3.4	Distant and blurry
10	13	1		213	213.97	0.97	0.5	Diagonal
11	13	2	7	210	209.84	-0.16	0.1	Vertical

**Note that actual distance may be different from the ideal true corner-to-corner distance, because during point selection, the image is viewed at 100% zoom level, not magnified. Hence, the points chosen manually probably do not actually match exactly with the corner locations. Also, differences can be related to the calibration process (i.e. calibration image quality and calibration errors).*

Measurements of a live specimen

An initial study was conducted measuring the fork length of a kelp bass using the StereoMeasure V2.2 software. A total of 20 measurements were made. Distances were determined using two-, three-, four-, and five-point methods, five times each (Figure 5). The average length and percent error measured using StereoMeasure was 538mm and 5.7%, respectively. Length estimates from measurements using varying numbers of chosen points varied between 503.3±3.8mm (2 points) and 579.5±22mm (5 points) (Table 2, Figure 5). The true length is 530 mm as determined by two independent physical measurements of the fish's total length.

Measured distances on the same image varied substantially depending on the number of points chosen (Figure 5). The three- and four-point methods produced the most accurate results of 534.2mm and 534.6mm, respectively (Table 2). The two-point method with a mean of 503.3mm consistently underestimated fish length, while the five-point method with a mean of 579.5mm consistently overestimated fish length. This discrepancy could be the result of the curvature of the fish's body not being realized in the two-point method as it would be in the five-point method.

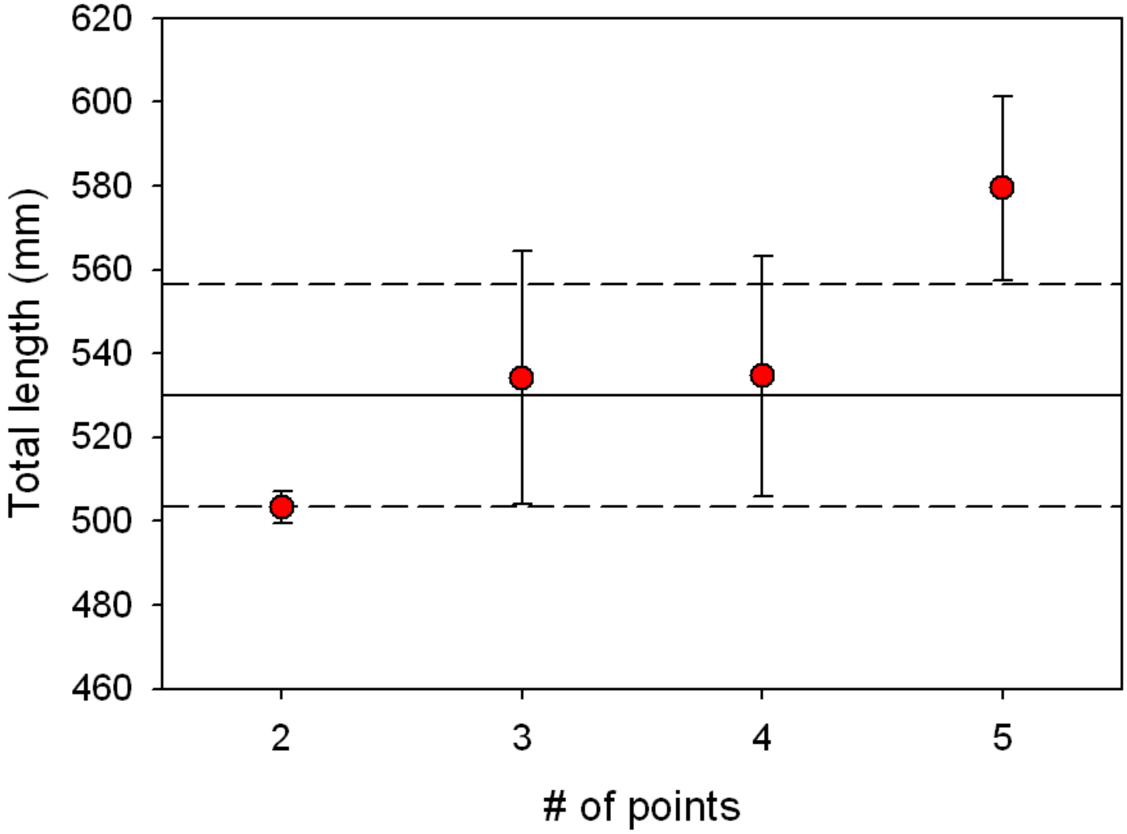


Figure 5. Results of StereoMeasure measurements of a kelp bass in the laboratory. The actual total length of the animal was 530mm. The broken lines indicate 5% intervals around the actual total length.

Table 2. Results of two- to five-point measurements of a kelp bass in the laboratory. The actual total length of the animal was 530mm.

# of points	Distance Measured	% error
2	497.6	6.11
2	502.4	5.21
2	504.3	4.85
2	504.4	4.83
2	508.0	4.15
mean	**503.3**	**5.03**
SD	**3.8**	
3	500.3	5.60
3	510.0	3.78
3	534.7	0.89
3	551.9	4.14
3	574.1	8.32
mean	**534.2**	**4.55**
SD	**30.2**	
4	497.1	6.20
4	526.2	0.72
4	529.2	0.15
4	544.8	2.80
4	575.8	8.64
mean	**534.6**	**3.70**
SD	**28.7**	
5	544.7	2.77
5	570.9	7.72
5	590.0	11.32
5	593.8	12.04
5	597.9	12.81
mean	**579.5**	**9.33**
SD	**22.0**	

Impacts / Applications

The use of a stereo imaging system with automated measuring software will increase the percentage of fish measurements to a level that is more than adequate for use in stock assessments. In addition, since distances to targets can be calibrated, line transect methods can be utilized to obtain independent estimates of densities from ROV transects. This technique will improve abundance estimates of both fish and benthic invertebrates.

Transitions

Considerations to improve the accuracy of the measurements and functionality of the ROV stereo camera system are discussed here.

Upgrading the PC-104-processor module will allow for higher resolution images and increased frame rate for acquiring stereo image pairs. This will not only produce more frames that the user can choose from for making measurements, but will also allow the user to choose more precise measurement points.

Refining the calibration method for the camera system to include radiometric calibration will be preformed in effort to improve the ability of StereoMeasure to automatically and accurately locate conjugate points. Perhaps the next stage of significant improvements to the measurement software will be the added ability of the program to automatically detect boundary lines of a fish within an image. The software then could produce length measurements of fish while requiring little effort or time from the user.

A system of individually housed cameras is being considered to expand the systems measurement baseline (i.e. the distance between camera lenses). This has the potential to improve the 3-D-image resolution and make the system easier to mount on an ROV. This approach does, however, present issues in accurately aligning cameras.

Ship time is currently being secured to collect survey images of *in situ* fish with the ROV-stereo-camera system. This survey is expected to occur before mid-February 2009.

Related Projects

Two projects supported by ASTWG are benefitting directly from the software developed for this project. These are: FasTowCam (Cutter et al., 2006. *Optical Validation of Acoustical Targets Using a High-Speed Underwater Camera System*) and the NOAA Fisheries AUV that has a similar stereo camera system to the one developed here. StereoMeasure has been applied to calibration images from the AUV, and will be used to measure fish in images from the FasTowCam that are to be collected in April, 2009.

Publications

This work has not resulted in any publications to date.

Expenditures

Expenses pertaining to the development of the ROV stereo camera system total $15,694 to date. Further costs will be incurred to complete the work outlined in the transitions section above. Additional costs will include two days of ship time aboard the F/V Outer Limits for field testing

Item	Vendor	Cost
PC-104 Stack	RTD Technologies	$3,609
Windows XP	CompUSA	$120
Stereo Camera	Videre Designs	$1,385
Housing	AGO Environmental	$1,410
Mounting hardware	Marshalls	$20
Whips	Impulse/Seacon	$150
StereoMeasure	Dr. Rzhanov-UNH	$9,000
Ship time	Outer Limits Sportfishing	$8,000
Total		$23,694

Advanced Sampling Technology Working Group
Progress Report to
The Office of Science and Technology

Acoustic identification and enumeration of epipelagic fish and jellyfish

Principle Investigators:

G. Randy Cutter, Ph.D.
David Demer, Ph.D.
SWFSC
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508

Scott Benson
SWFSC 7544 Sandholdt Rd.
Moss Landing, CA 95039

Sean Hayes, Ph.D.
R. Bruce MacFarlane, Ph.D
SWFSC 110 Shaffer Road
Santa Cruz, CA, 95060

James Harvey, Ph.D.
Moss Landing Marine Lab
8272 Moss Landing Rd.
Moss Landing, CA 95039

Goals

The primary goals of this project were to collect laboratory measurements of acoustic target strength (*TS*) of coastal pelagic fish and jellyfish and collect and interpret *in situ* acoustic data using multiple-frequency, multi-beam, and side-scan sonar systems. Another goal was to conduct acoustical surveys using the proposed system to measure the abundances and distributions of jellyfish and fish to assess ecological relationships.

Priorities

The priority of this project was to assemble a multiple-frequency, side-looking-sonar array, and deploy it on a survey of jellyfish off California.

Approach

The project involves characterizing scattering spectra of jellyfish and coastal pelagic fish species (e.g. anchovy, sardine, mackerel, and salmon) using target strength measurements of *ex-situ* animals. These results and *in situ* estimates of *TS* and differences in volume backscatter strength (S_v) measured at multiple-frequencies are used to interpret the down- and side-looking measurements made from multiplexed Simrad EK60 echosounders configured with both split-beam and sidescan transducers. A 200 kHz SM20/2000 multibeam sonar is operated concurrently to identify the target depths and acoustic incidence angles.

Work Completed

Review

A review of published literature and recent unpublished results was conducted to describe the relationship for jellyfish *TS* vs. frequency. This can be used to characterize a frequency response for separating echoes from jellyfish vs. other scatterers in the multi-frequency acoustic data. While there are no published *TS* results for the target jellyfish species (*Chrysaora fuscescens*), *TS* results for a congener were reported.

Development of a multi-frequency sidescan and multibeam system

Procurement, fabrication, integration, testing, and deployment of a two-frequency side-looking side-scan and multi-beam system was completed. The system comprises a 200-kHz Kongsberg Mesotech SM2000 with an external transmitter array controlled by a SM20 producing a 180° (nominally 155° undegraded) swath with 128 beams (each 1° by 2°); a 120-kHz Simrad KSV-088606 sidescan (2° by 50° beam); and a 200-kHz Odom SS200-0.7x50 sidescan (0.7° by 50° beam) (**Figure 1**). Both of the sidescan transducer were operated using ES60 transceivers. An additional dual-frequency transducer was procured, but there was not time to integrate it prior to field deployment. The new transducer will be integrated and deployed during 2009.

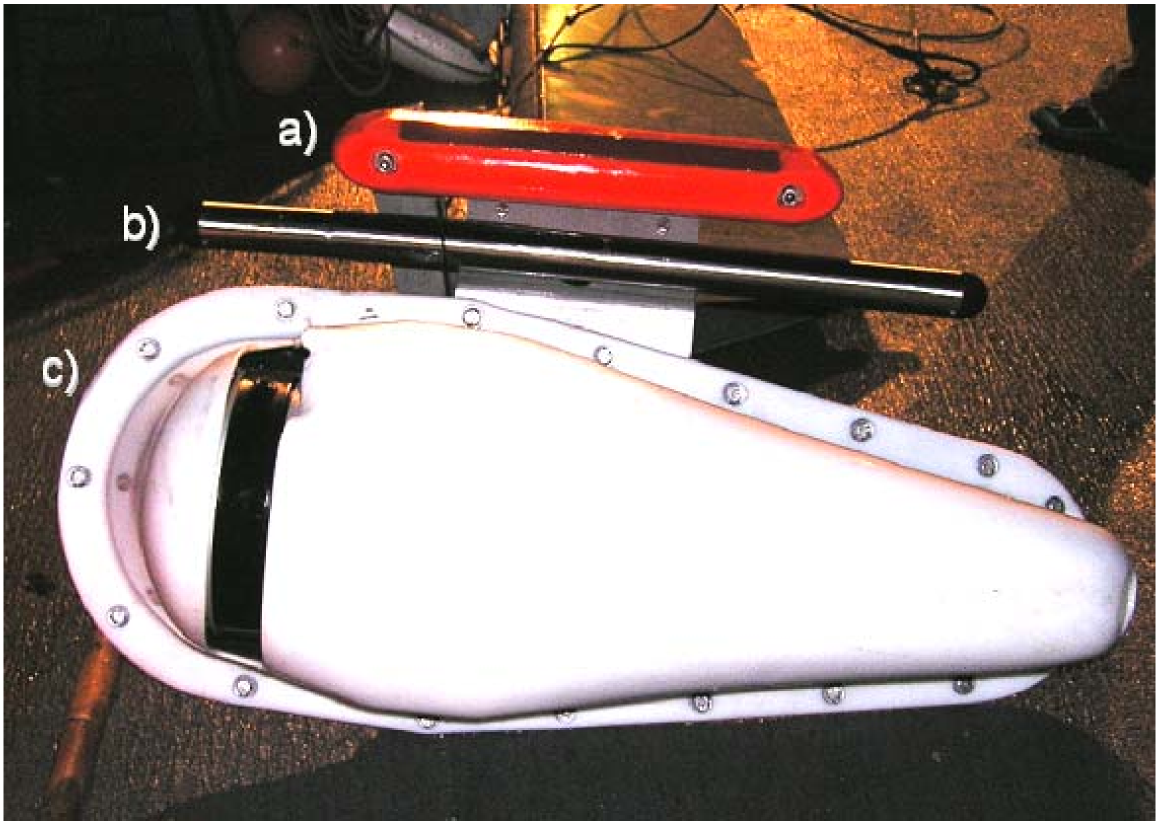


Figure 1. The three-transducer, dual-frequency, side-looking multibeam and sidescan array on deck after deployment. a) Simrad 120-kHz sidescan, b) Odom 200-kHz sidescan, and c) Kongsberg-Mesotech 200-kHz SM2000 multibeam transducers.

Deployment and survey of CPS fish and jellyfish

A large-scale field survey of CPS and jellyfish was conducted for this project as part of the Leatherback Use of Temperate Habitat (LUTH) Survey 24 August – 22 September 2008 aboard the NOAA FSV *David Starr Jordan* (*DSJ*). The multiple-frequency acoustic survey utilized the *DSJ*'s four-frequency, split-beam EK60 echosounder array, and the dual-frequency multi-beam and sidescan array developed for this project. The EK60 array is hull-mounted at a depth of 3.75 m below the sea surface. The multibeam and sidescan transducers were mounted on a pole on the port side of the ship at angles of 30° and 45° off vertical to allow insonification of a region from the sea surface to approximately 70° (**Figure 2**). The transducers were mounted approximately 4.7, 4.8, and 5.1 m below mean sea level. The same geometric region was insonified, simultaneously by the sidescans, and then 0.5 s later by the multibeam, i.e. the areas insonified were separated by approximately 2.57 m along-track at a survey speed of 10 knots. Hence, the same targets were not necessarily observed by the multibeam and sidescans. The delay was necessary because one of the sidescans operated at the same frequency as the multibeam.

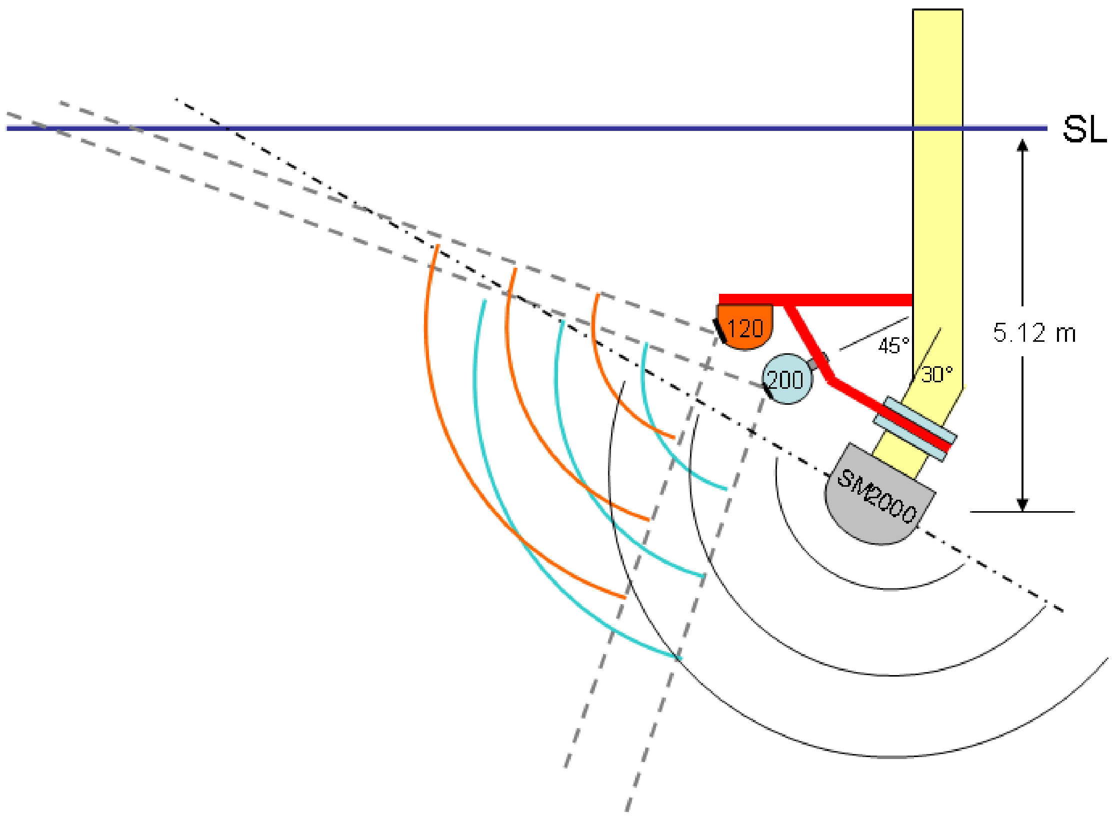


Figure 2. Diagram of the side-looking multibeam and sidescan system.

The hull-mounted EK60s were operated for the entire duration of the survey. However, the multibeam and sidescans were operated only during Leg 2 of LUTH when personnel were available to oversee the operation. The hull-mounted EK60s, multibeam, and sidescans were triggered sequentially at 0.5 second intervals.

The EK60s transmitted pulse lengths of 1024 μs and reverberation data was collected to a range of 250 m. SM20 and sidescan data were collected to a range of 150 m. Occasionally during testing, the range settings of the sidescans and SM20 were adjusted, but these were recorded in ancillary files not considered for the analysis. Bottom detection ranges for the ES60s were set to a minimum of 150 m and maximum of 151 m.

The EK60s were calibrated using the standard sphere method in San Diego Bay prior to the survey. The sidescans and SM20 were not calibrated prior to the survey. However, a calibration sphere was insonified and raw data were collected for the SM20 and 200-kHz sidescan during a period when the ship was on anchor overnight. Power and angle data (.raw format) were recorded from the EK60s and ES60s, and unbeamformed raw data were recorded from the SM20.

Although the 120 kHz sidescan operated normally during tests on the pre-cruise calibration day (**Figure 3**), it malfunctioned during the survey. It is believed that the transducer failed. Regardless, the unit was operated in case something could be salvaged from the data during post-processing. The 200-kHz sidescan operated normally and performed well during the survey.

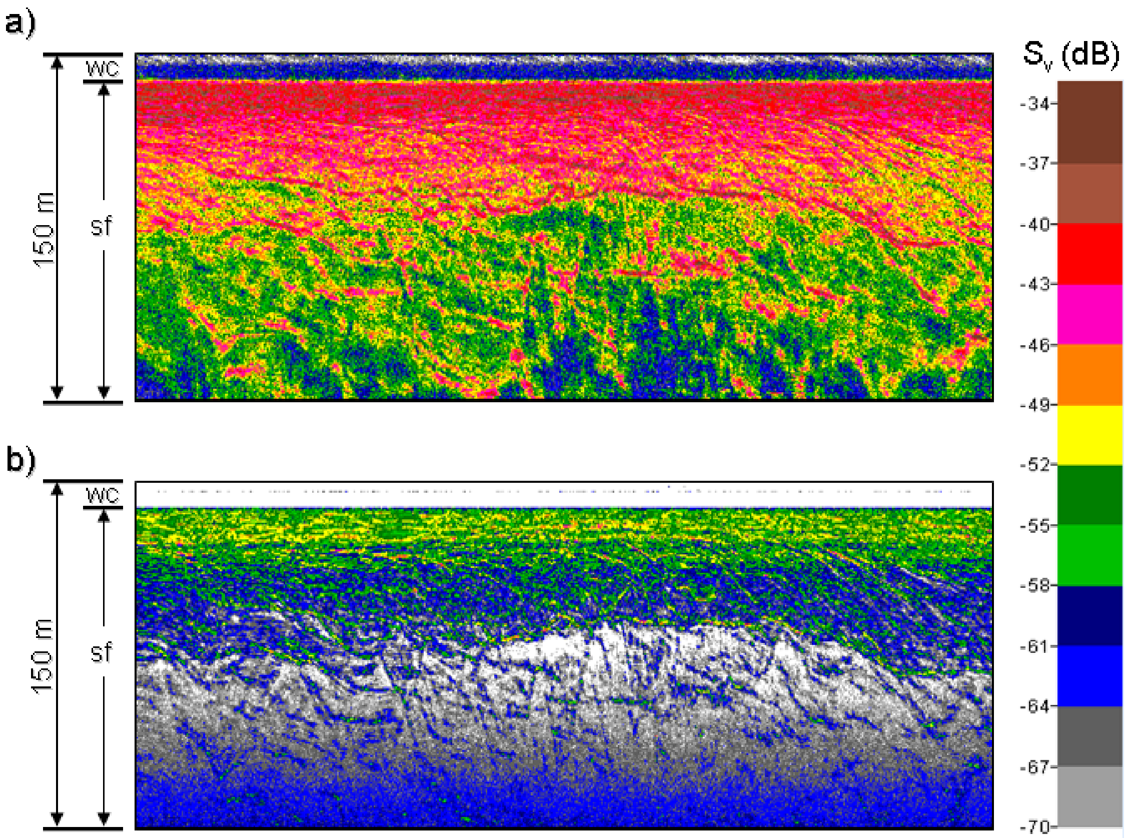


Figure 3. Echograms from the a) 120-kHz and b) 200-kHz sidescan sonars collected during the calibration of the EK60s, prior to the LUTH survey. Volume backscattering (S_v) data were collected from both to a range of 150 m, and the data show water-column (wc) and seafloor (sf) echoes.

The LUTH survey covered a region from just north of San Francisco to just south of Monterey Bay, CA, and offshore to about 275 km (**Figure 4**), following adaptive sampling of oceanographic anomalies and transect sampling of CalCOFI Stations.

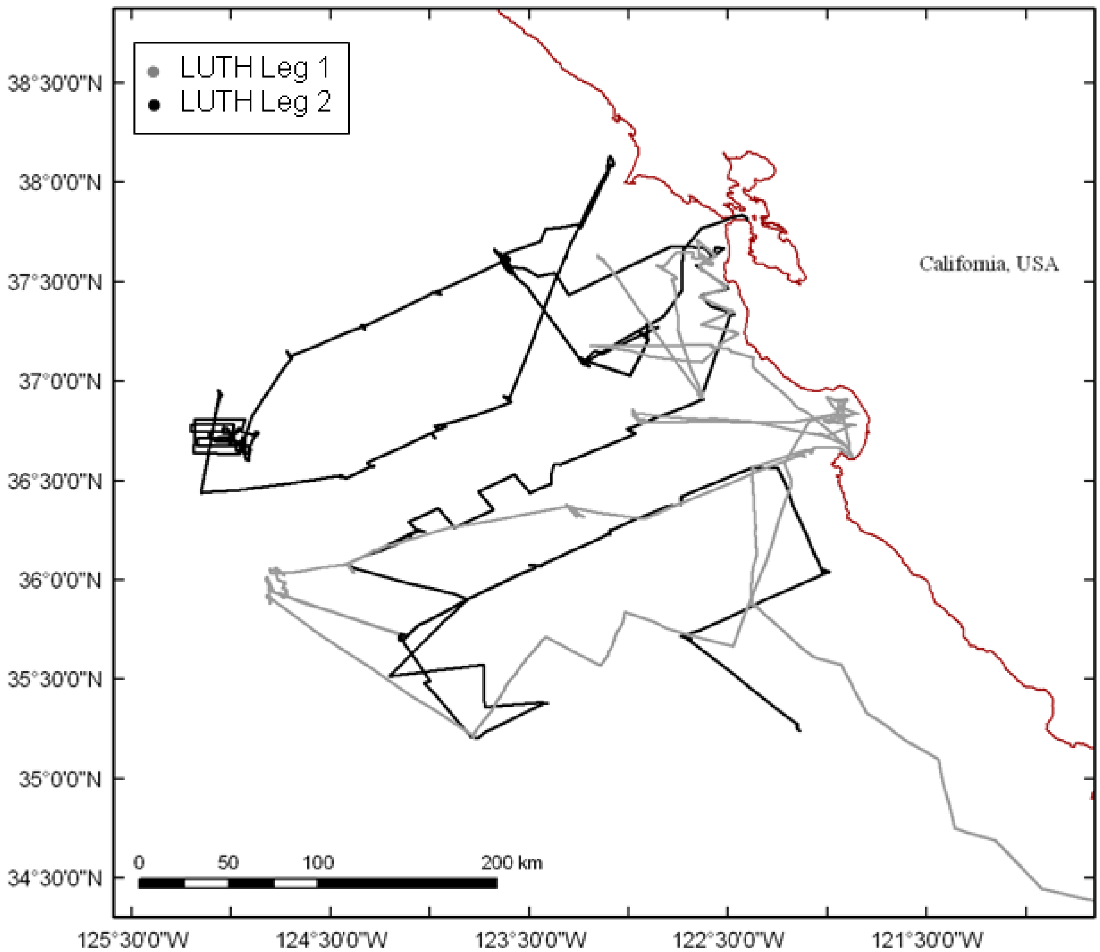


Figure 4. LUTH survey tracklines. Multi-frequency hull-mounted EK60s were operated during Legs 1 and 2; multibeam and sidescan systems were operated only during Leg 2.

Results

Published jellyfish *TS*

Published results show that mean *TS* typically decreases with increasing frequency (from 18 to 200 kHz) for jellyfish (Mutlu 1996; Brierley, et al. 2001; Brierley et al. 2004; **Table 1**). These studies have used frequencies including 18, 38, 120 and 200 kHz. However, due to the large measurement variation, it is unclear which frequency combinations will provide the best discriminatory power for jellyfish.

Table 1. Published *TS* measurements for jellyfish.

Organism	Mean Diam. (cm)	Frequency (kHz)	*TS* (dB)	Source
Aurelia aurita	*9.5*	*120*	*-60.24*	*Mutlu, 1996*
Aurelia aurita	*9.5*	*200*	*-64.27*	*Mutlu, 1996*
Aurelia aurita	*11.5*	*200*	*-62.48*	*Mutlu, 1996*
Aurelia aurita	*15.5*	*120*	*-57.10*	*Mutlu, 1996*
Aurelia aurita	*15.5*	*200*	*-56.47*	*Mutlu, 1996*
Chrysaora hysoscella	*26.8*	*18*	*-51.5*	*Brierley, et al. 2001*
Chrysaora hysoscella	*26.8*	*38*	*-46.6*	*Brierley, et al. 2001*
Chrysaora hysoscella	*26.8*	*120*	*-50.1*	*Brierley, et al. 2001*
Chrysaora hysoscella	*41*	*18*	*-60.0*	*Brierley, et al. 2004*
Chrysaora hysoscella	*41*	*38*	*-65.5*	*Brierley, et al. 2004*
Chrysaora hysoscella	*41*	*120*	*-68.0*	*Brierley, et al. 2004*
Chrysaora hysoscella	*41*	*200*	*-70.5*	*Brierley, et al. 2004*
Aequorea aequorea	*7.4*	*18*	*-68.1*	*Brierley, et al. 2001*
Aequorea aequorea	*7.4*	*38*	*-66.3*	*Brierley, et al. 2001*
Aequorea aequorea	*7.4*	*120*	*-68.5*	*Brierley, et al. 2001*
Aequorea aequorea	*6.5*	*18*	*-66.0*	*Brierley, et al. 2004*
Aequorea aequorea	*6.5*	*38*	*-66.5*	*Brierley, et al. 2004*
Aequorea aequorea	*6.5*	*120*	*-71.5*	*Brierley, et al. 2004*
Aequorea aequorea	*6.5*	*200*	*-73.0*	*Brierley, et al. 2004*
Aurelia autrans	*8.0*	*38*	*-54.0*	*Nakken, in Mutlu 1996*
Aurelia autrans	*8.0*	*38*	*-51.7*	*Nakken, in Mutlu 1996*
Aurelia autrans	*16.0*	*120*	*-54.2*	*Nakken, in Mutlu 1996*
Aurelia autrans	*16.0*	*120*	*-50.1*	*Nakken, in Mutlu 1996*

A graphical summary of these published data is provided in **Figure 5**.

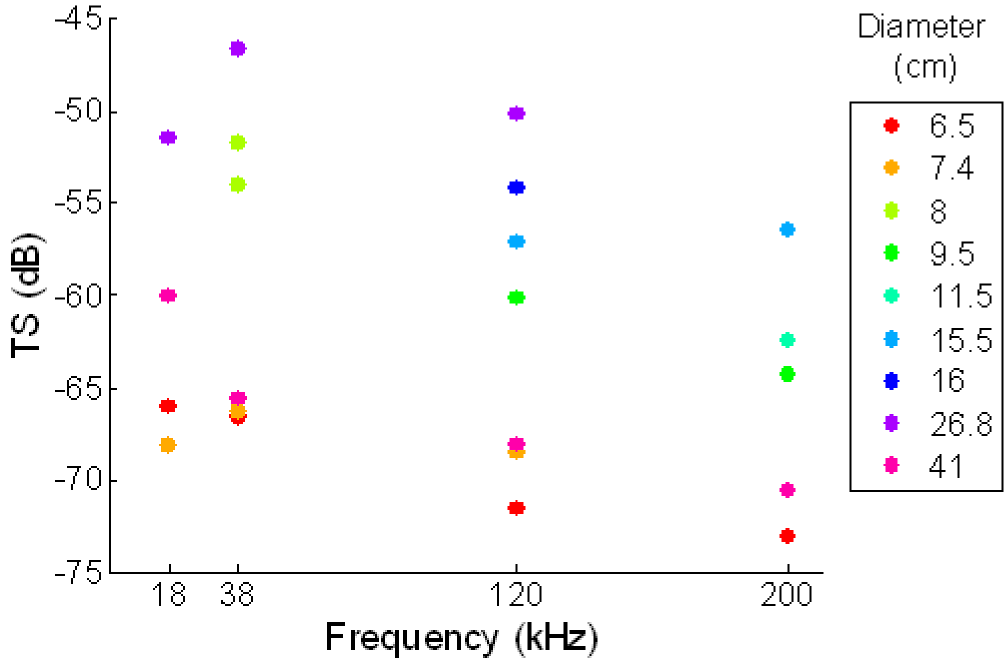


Figure 5. Published *TS* values from four frequencies for four species of jellyfish of various sizes; the legend indicates size (cm).

<u>*TS*: of *ex situ* Jellyfish</u>

Collections of jellyfish for new *ex situ* measures of jellyfish *TS* were to be done, but because of the late date when funds were made available, this effort had to be postponed until 2009.

<u>TS of *in situ* Jellyfish</u>

Estimation of *TS* for *C. fuscescens* is underway, using data from the four-frequency EK60s during the LUTH survey.

<u>Jellyfish insonified by the multibeam and sidescan system</u>

The SM20 sonar head was tilted 30° to the port side of the ship and produced a swath spanning from the sea surface on the port side to approximately 60° to the starboard side. The advantage of the side-looking multibeam over conventional, vertical hull-mounted sounders is its capability to insonify the entire water column, from the sea surface to the seafloor (in water depths to ~ 250 m), and can image a portion of the water column normally missed by typical echosounders.

On 11 September 2008, SM20 data were logged in an area (38° 07.427' N, 123° 05.605' W) where jellyfish were visible at the surface. The SM20 insonified and detected many jellyfish (**Figure 6**).

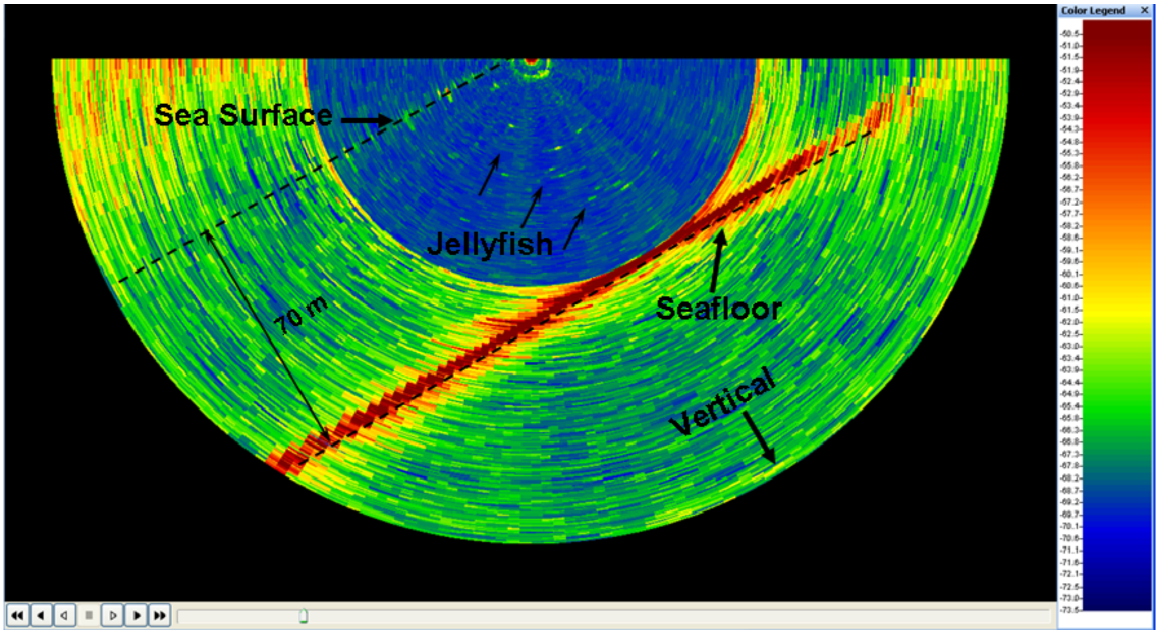


Figure 6. Data from the SM20 multibeam in an area with large *Chrysaora fuscescens* jellyfish.

The principal acoustic targets in the SM20 water-column data presented in **Figure 6** are believed to be *C. fuscescens*, with bell diameters of approximately 25 cm, and some reaching 45 cm, based on visual observations and trawl catches from the area (**Figure 7**).

Figure 7. Jellyfish (*C. fuscescens*) observed (a) and collected (b, c) during LUTH survey in Trawl 46 from 15 Sep. 2008.

<u>Sidescan and multibeam data</u>

Echograms from the multibeam, sidescan, and split-beam echosounders collected during Trawl 46 on 15 Sep. 2008 reveal many individuals and aggregations of targets that are believed to be from the jellyfish *C. fuscescens* (Figure 8).

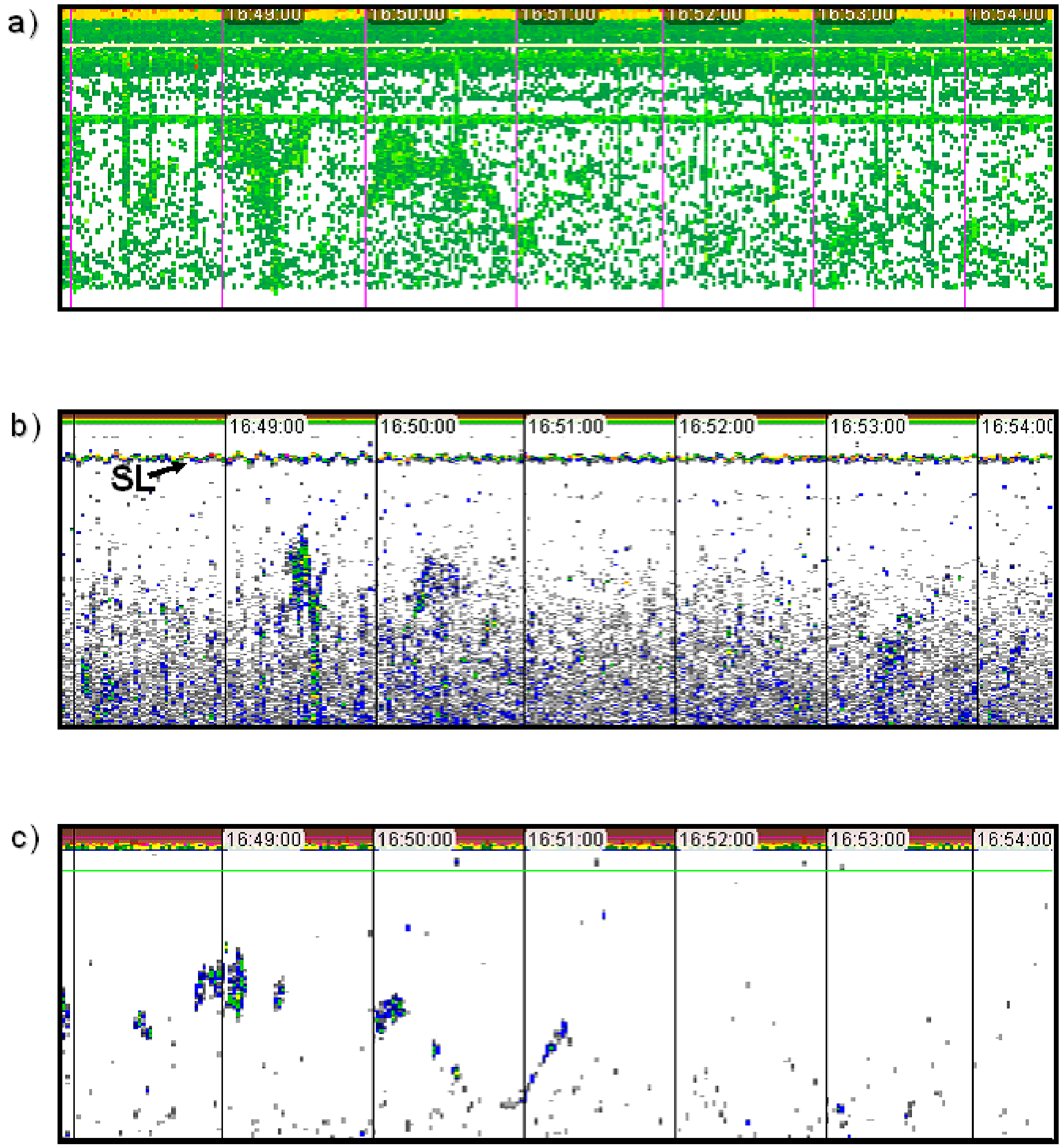


Figure 8. Echograms collected during LUTH Trawl 46 on 15 September 2008: a) single targets by range in the SM20 data for beams spanning a swath 5° below the sea surface on the port side to 25° beyond vertical to starboard; b) 200-kHz sidescan (ES60) echogram; and c) 38 kHz EK60 split-beam echogram. In b) SL is the primary echo from the sea surface.

Although each sonar insonified a different part of the water column (**Figure 9**), there is correspondence among the target aggregations detected by each.

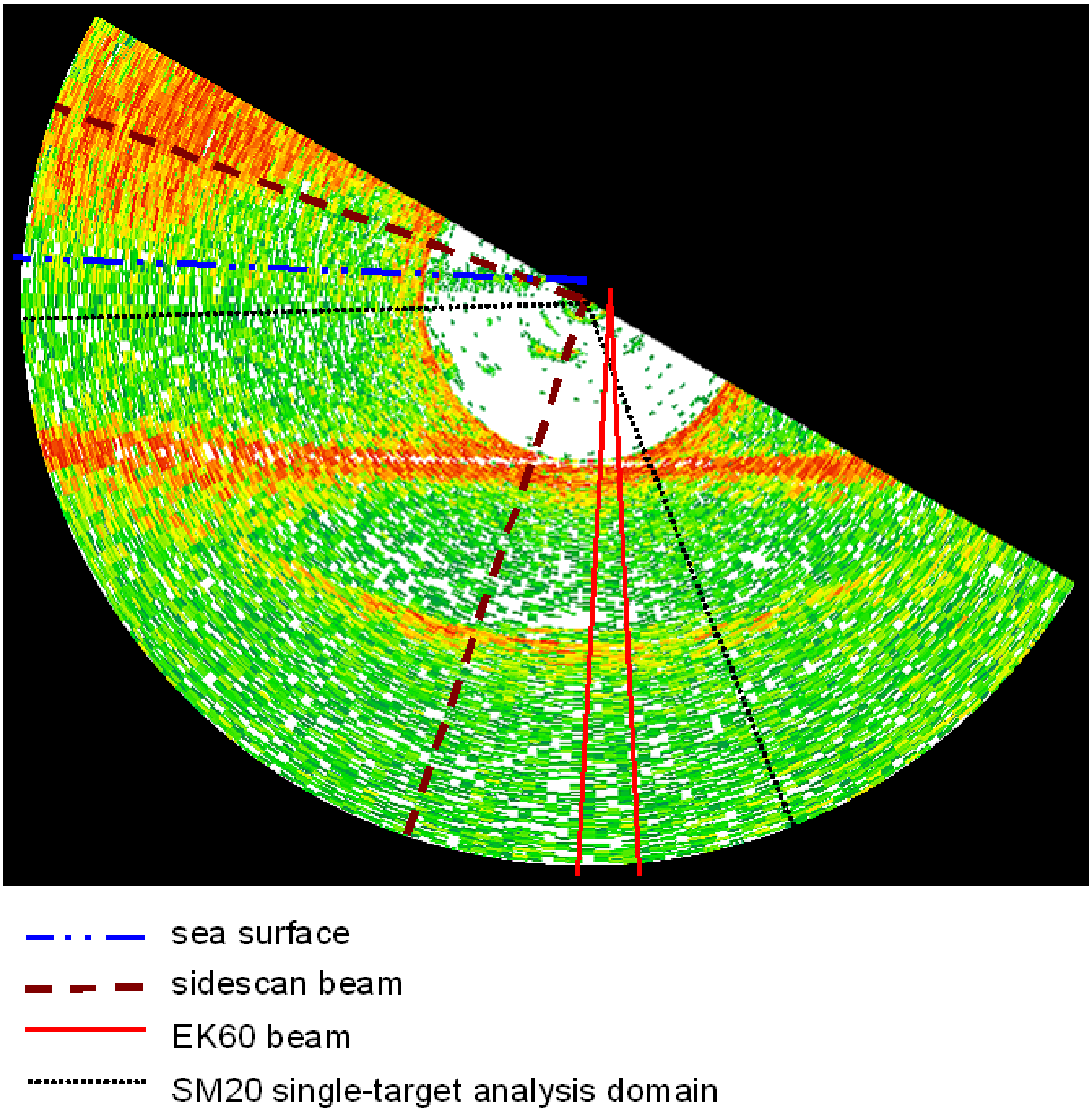


Figure 9. Approximate geometry of overlapping beams from the multibeam, sidescan, and EK60s.

Multibeam echosounder data collected during Trawl 46 show a large number of targets within 4-30 meters range whose estimated length from the SM20 data corresponded well with the size distribution of the large *C. fuscescens* that were caught in the trawl (**Figure** 10). The mean diameter of the jellyfish caught by Trawl 46 was 42 cm (std. dev. = 4.8 cm).

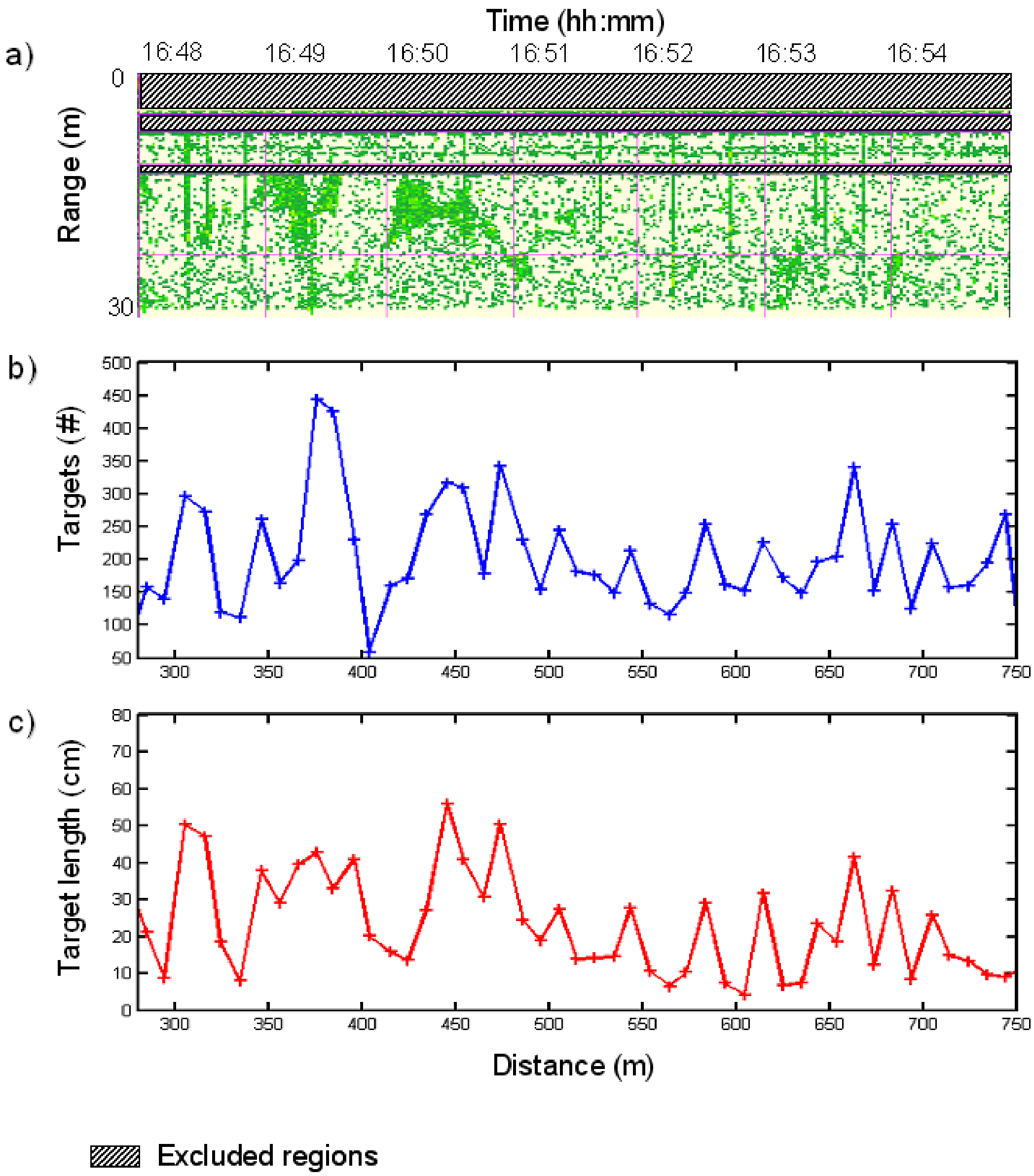


Figure 10. Single targets detected from the SM20 multibeam data during LUTH Trawl 46 on 15 Sep. 2008. a) Single target echogram from the SM20, b) number of targets per 10-m distance interval, c) average target length (cm) estimates (from Echoview 4.50).

Multi-frequency echosounder data analysis

An algorithm was developed for apportioning mean S_v to groups of organisms whose primary constituents were: jellyfish; fish with swim-bladders; and plankton or bladderless fish. The differences of S_v from four frequencies (38, 70, 120 and 200 kHz) and the mean values are used to classify the $S_v(f)$ into groups (Figure 11). The algorithm for jellyfish was developed based on published literature and training data gathered from echograms acquired during trawls for jellyfish collected during Leg I of the LUTH survey. Post-processing is underway to verify and tune the algorithm. Subsequently, the apportioned volume scattering coefficients (s_a) will be used to estimate the abundances and biomasses for each group, and to map their spatial distributions.

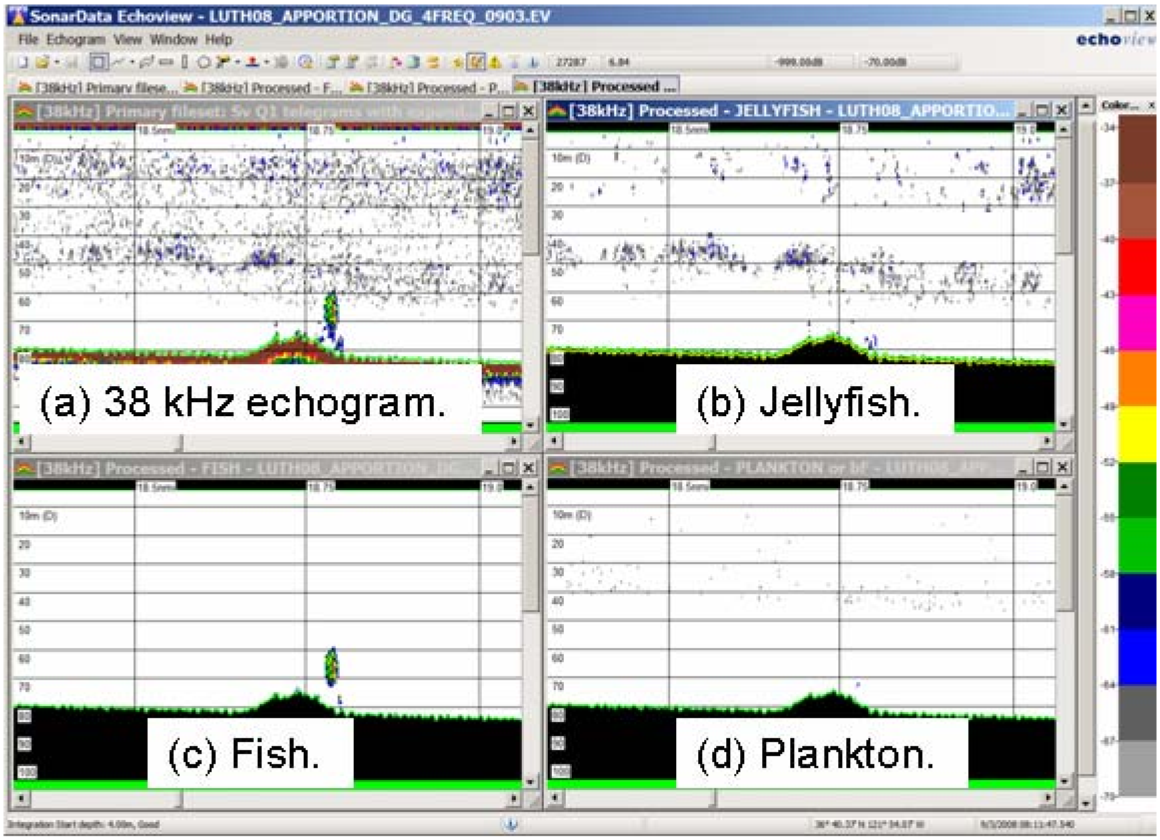


Figure 11. Echograms of mean volume backscattering strength S_v (dB) from (a) the original 38-kHz record, S_{v38} apportioned to (b) jellyfish, (c) fish, and (d) plankton.

<u>Application of the EK60 algorithm</u>

Data from the multibeam and 200-kHz sidescan collected during the LUTH survey may be used for estimation, however, apportioning to species or groups is unlikely since they both operated at the same frequency. After the replacement sidescan transducer and the new, dual-frequency transducer are integrated into the system, more data will be collected using the side-looking system in 2009. The apportioning algorithms developed from the EK60 data from LUTH 2008 will be applied to these new data and will facilitate estimation of biomass of jellyfish and CPS in the near-surface region - the blind zone of the traditional, down-looking, hull-mounted transducers.

<u>Problems encountered</u>

Sidescan malfunctioned

The 120-kHz Simrad sidescan transducer failed and did not collect good data during the deployment. The transducer has been replaced by Simrad. The signal in Active mode was identical in appearance to that in Passive mode. Sometimes, when switched from Passive to Active mode, a couple of pings look normal before the echogram reverts to one that is identical with that from the Passive mode. Changing the pulse length from 256 to 1024 μs did cause a difference in the signal, but the data was still mainly noise, and any good signal was hidden or contaminated. We confirmed that the transducer was faulty by temporarily disconnecting the ES120-7 transducer from the EK60-120 kHz split-beam GPT and connecting the 120 kHz sidescan transducer.

Pole dislodged

On 9 September, 2008, during the LUTH survey, the mounting apparatus for the side-looking sonar array pole failed. The pole had come out of the receptacle U-bracket and was outboard of the lower bracket. During that time, the ship's roll caused the upper pivot bracket to bend the ship's rail where it attached. The pivot-joint base was bent as well, but not as severely. Further inspection revealed that the lower bracket receptacle was also bent - the outer lip of the bracket was opened. Underway repairs and reinforcements by the engineering and deck department personnel of the *DSJ* allowed redeployment of the pole and operations resumed a few days later.

Impacts / Applications

The new multi-frequency methods for ensonifying, identifying and quantifying jellyfish and epipelagic fish will greatly improve the accuracies and precisions of surveys for coastal pelagic species. With the apparent global increase in jellyfish populations, these methods should also facilitate ecosystem-based surveys of animals located near the sea-surface.

Transitions

The multi-beam and sidescan survey equipment and associated multi-frequency algorithms for target identification are being used on SWFSC's bi-annual surveys for anchovy, sardine and mackerel. With further development, they may soon be integrated into the data analyses which feed the stock assessments for these commercially harvested species.

Related Projects

The FasTowCam, also funded by ASTWG and being developed by researchers in the Advanced Survey Technologies group at SWFSC, should provide visual validation of multi-frequency species identifications.

Publications

An extensive survey report for LUTH has been drafted. This will ultimately be published as a NOAA Technical Memorandum. Other related manuscripts are being drafted for possible publication in the peer-reviewed literature.

Expenditures

Expenditures for the jellyfish project.

Contracts	50422.00
Transcucers/equipment/software	32965.89
Travel for LUTH survey	2294.09
Institute charges	4627.00
Supplies & fabrication	886.02
OT/ND/OH	1345.00

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Advanced Sampling Technology Working Group
Grant Progress Report to
The Office of Science and Technology

Development and evaluation of new technology for the remote identification and enumeration of larval fish

INVESTIGATORS:

Jonathan A. Hare
Northeast Fisheries Science Center
Narragansett Laboratory
Narragansett, RI 02882
Phone: (401)-782-3295
Email: jon.hare@noaa.gov

Robert K. Cowen
Rosenstiel School of Marine and Atmospheric Sciences
4600 Rickenbacker Causeway
Miami, FL 33149
Phone: 305.421.4023
Email: rcowen@rsmas.miami.edu

GOALS:

The goals of our ASTWG project are to 1) to support the development of imaging technology software for the automated recognition, identification and enumeration of larval fish and 2) evaluate the *In Situ* Ichthyoplankton Imaging System (*IS*IIS) technology in the context of ongoing efforts to improve stock assessments. These goals specifically address Theme 3 of the ASTWG FY08 RFP – Remote species identification and enumeration.

PRIORITIES:

FY08

- Work on *IS*IIS software will be conducted and efforts will focus on improving image recognition, classification and enumeration routines.
- Plan a trial deployment of *IS*IIS on Georges Bank targeting larval Atlantic herring during October 2008

FY09

- Work on *IS*IIS software will be conducted and efforts will focus on improving image recognition, classification and enumeration routines using data collected during trial deployment
- Deploy *IS*IIS during NEFSC Ecosystem Monitoring Survey during October 2008

WORK COMPLETED AND RESULTS:

It is important to realize that funds were received in March 2008 and >90% were transferred to University of Miami, Rosensteil School of Marine and Atmospheric

Sciences (RSMAS) for Cowen's part of the project. RSMAS received their funds in June 2008.

Priority 1 - Work on ISIIS software will be conducted and efforts will focus on improving image recognition, classification and enumeration routines. - We continue to make considerable headway with the image analysis software. Our efforts on the software development can be broken into three components: 1) development of image analysis algorithms, 2) development of image library, and 3) validation and fine tuning of algorithms based on data collected during the October cruise. Substantial progress has been made on component 1 and 2. Additional progress on component 1 and 2 and progress on component 3 will be achieved in FY09.

1. Development of image analysis algorithms - Using a trial image-set collected in the Florida Current, we have been working on a fully automated system for the recognition of five (5) taxa categories (*Trichodesnium*, larvaceans, fish larvae, copepods, and chaetognaths) from raw *IS*IIS images, based on state-of-the-art Machine Vision and Learning tools. We can now recognize *simultaneously* multiple specimens of different types directly from the input images, without any user interaction. To the best of our knowledge, all other recognition methodologies assume that the target specimens are somehow cropped from the input images, and then they tackle the recognition problem as *single specimen recognition.* Our current work is different and consists of three major stages. **(a)** Automatic segmentation of the specimens of interest from the *IS*IIS images (Tsechpenakis et al. 2007a, b, 2008a). **(b)** Extraction and modeling of the visual features of each segmented region (Tsechpenakis et al. 2007a). **(c)** Specimen recognition using visual features and topology: this is our major innovation, based on our Active Learning-driven Collaborative Conditional Random Field (CoCRF) (Tsechpenakis et al 2008b, Tsechpenakis and Metaxis 2007). For each *IS*IIS image, after extracting the candidate regions of interest along with their features, we solve a global optimization (recognition) problem: we estimate the optimal label combination for the segmented regions, based on an objective posterior. The key-points of our recognition framework are: **(i)** it requires very few (5-10) training samples for each specimen class, and therefore it avoids the tedious work of collecting "good" training samples; **(ii)** it uses the idea of active learning to dynamically improve the recognition accuracy (in an online manner, we include *informative* newly recognized regions in the training sets); **(iii)** our collaborative formulation of the CoCRF can recognize partially detected specimens or oversegmented specimens (when different parts of a single specimen are detected as different regions of interest), and therefore it is robust to off-focus effects, noise, and low resolution; **(iv)** it is computationally efficient during recognition (online/testing phase).

2. Development of category library. To train our data analysis system, one should first determine the taxonomic categories of specimens to be recognized. Each category is described by "representative" examples, in terms of the appearance; i.e., for each category we needed to manually crop instances of the specimen from the original *IS*IIS data, and store them along with their estimated visual features (Tsechpenakis et al. 2007a). As we mention above, our methodology is such that initially we need only a limited number of such images to train our system. During recognition, we are able to automatically enrich our library by including new informative images for each category, excluding redundant samples that do not contribute new knowledge about the specimen's appearance; this is done with the active learning scheme described above, which can be run on a regular basis independently from the recognition task. For our initial training work we utilized 5 categories (per above). Once we have data from Georges Bank, we will manually select a new training set of locally relevant organisms and evaluate the software on these new data.

3. Validation and fine tuning of algorithms based on data collected during the October cruise – Work on this priority will be undertaken in FY09.

Priority 2 - Plan a trial deployment of ISIIS on Georges Bank targeting larval Atlantic herring during October 2008 – Planning for this deployment is completed and implementation is starting now. The NEFSC Ecosystem Monitoring survey has dedicated three days to *IS*IIS work which will provide plenty of data for developing a training dataset for Georges Bank and validating and fine tuning the identification algorithms. Initial planning started in March when Hare traveled to Florida to consult with Cowen. This consultation also included a discussion of the funds transfer from the NEFSC to RSMAS. Hare traveled to Florida again in June to make more concrete plans on the logistics for the cruise. Measurements of *IS*IIS and the fiberoptic winch were made to plan deployments off the NOAA Ship Delaware. Winch specifications were also provided so hydraulic hook-ups could be planned. Based on these two meetings, Hare sent a detailed outline of operations to the NOAA Ship Delaware and met with officers and crew from the ship to discuss operations. Cowen then traveled to Woods Hole in August and toured the NOAA Ship Delaware with Hare. They discussed logistics and operations with the ship's officers and crew and a plan was finalized.

*IS*IIS will be shipped to Woods Hole in the middle of October along with the fiberoptic winch that has been used with *IS*IIS. Once in Woods Hole, the winch will be loaded onto the ship and a hydraulic intermediary will be built to connect the winch to the ship hydraulics. The plan calls for the ship to travel to Georges Back and deploy *IS*IIS in combination with traditional plankton sampling gear.

The actual deployment of *IS*IIS will take place in FY09.

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Tsechpenakis, G., and D. Metaxas. 2007. CRF-driven Implicit Deformable Model. IEEE Conference on Computer Vision and Pattern Recognition (CVPR'07), Minneapolis, MN.

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Tsechpenakis, G., L. Bianchi, M. Driscoll, and D. Metaxas. 2007b. Tracking *C. elegans* Populations in Fluid Environments for the Study of Different Locomotory Behaviors. In Proc. 2nd Int'l Workshop on Microscopic Image Analysis with Applications in Biology, Piscataway, NJ.

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55(5), pp. 1539-1549.
Tsechpenakis, G., B. Lujan, O. Martinez, G. Gregori, and P.J. Rosenfeld. 2008b. Geometric Deformable Model Driven by CoCRFs: Application to Optical Coherence Tomography. 11th Int'l Conf. on Medical Image Computing and Computer Assisted Intervention (MICCAI'08), NYC, NY.

IMPACTS/APPLICATION:

The impacts and applications of *IS*IIS are potentially huge, but the software and hardware need to be evaluated in a fisheries context and this is one of the priorities of this project. If *IS*IIS software works in the manner planned, then *IS*IIS data could become an important fishery-independent contribution to the stock assessment process. Using funds from the Fisheries And The Environment (FATE) program, a post-doc, David Richardson, has been working with Hare to develop a larval index for use in the Atlantic herring stock assessment. The index has been completed, a paper is in preparation, and ongoing discussions are underway with stock assessment scientists about the inclusion of the index in the upcoming stock assessment in spring 2009. Through the FATE funding, the pathways for larval data to be included as a fishery-independent measure of stock size have been established. The development of *IS*IIS software and hardware can then be transitioned into this application. There are still several steps between *IS*IIS and the stock assessment, but our ASTWG project is making the initial steps with *IS*IIS: develop software and evaluate the technology in a fisheries context.

TRANSITIONS:

Work completed as part of this ASTWG proposal will contribute to the overall development of *IS*IIS for NMFS-wide application. Discussions have already been held with the Victor Restrepo (SEFSC Sustainable Fisheries Division Chief) on the evaluation and application of *IS*IIS in the southeast. The SEFSC is very interested in the development of *IS*IIS. Depending on the continued funding of this ASTWG project, collaboration with the SEFSC has been discussed to use of *IS*IIS to provide quantitative, fishery-independent stock assessment, and habitat/spatial distribution data on larval bluefin tuna in the Gulf of Mexico.
Transitions to Centers other than the SEFSC have not been discussed, but if this project is successful, there is wide-applicability. Presentations are planned at AFS during the summer of 2009 and transition to other Centers can be discussed on a scientist-toscientist level. Hopefully, our results will also generate interest at the HQ-level and promote discussion of a NMFS-wide implementation plan of ISIIS for use in developing fishery-independent indices for use in stock assessments.

RELATED PROJECTS:

Bob Cowen submitted a proposal to LMRCSC to support student involvement in the evaluation of *IS*IIS in the NEFSC and the SEFSC; Hare and Victor Restrepo are cooperators on this project. For NMFS to implement and use new technologies, it is critical that students be trained in the development, evaluation and application of these technologies in the context of fisheries. The LMRCSC proposal requests funds for 2 graduate students and 2 undergraduate students to become involved in the evaluation of *IS*IIS in both the NEFSC (in collaboration with this study) and in the SEFSC (as a transitional activity from this study to a broader NMFS-wide application).

PUBLICATIONS:
None to date

PRESENTATIONS:
None to date

EXPEDITURES:
Funds (96.2K) were received by NEFSC in March 2008. The process to transfer funds to RSMAS was initiated soon afterwards and funds (88.2K) were transferred through the Cooperative Institute for Marine and Atmospheric Studies by the beginning of June. The SEFSC was integral to the transfer of funds. The 8K that remained in the NEFSC was used to fund two trips to Florida to work out the logistics of the field deployment of *IS*IIS (3K), the purchase of a MatLab license so image analysis routines could be run at the NEFSC (2.3K), and the purchase of supplies for the November cruise (2.7K). RSMAS will spend money over 1 year from the time that they received it (June 2008) and very little has been spent to date. Some funds have been used to support a technician working on the software development described here (5.7K) and support will continue. Some improvements to *IS*IIS optics have been made (2.1K) and supplies have been purchased to support the October cruise (1.7K). Funds will also be used to support the shipment of *IS*IIS and travel of researchers to Woods Hole from Miami for the October cruise. A student will start on the project in January 2009 after data from Georges Bank and will work on software development (priority 1).

Advanced Sampling Technology Working Group
Progress report to
The Office of Science and Technology

Remote Detection and Identification of Marine Animals to Improve Fish and Habitat Assessment, and Reduce By-Catch using the ASTWG Dual Frequency Identification Sonar (DIDSON)

INVESTIGATORS

Kresimir Williams and Christopher Wilson (NMFS/AFSC/RACE, 7600 Sand Point Way NE, Seattle, WA 98115 chris.wilson@noaa.gov), **David Demer** (NMFS/SWFSC, 8604 La Jolla CA 92037 david.demer@noaa.gov), **Mike Jech** (NMFS/NEFSC/FEMAD/ESB, 166 Water St., Woods Hole, MA 02543 michael.jech@noaa.gov), **Christine Lipsky** (NMFS/NEFSC, 17 Godfrey Dr. Suite 1, Orono, ME 04473 christine.lipsky@noaa.gov)

GOALS

Considerable research is directed at *in situ* experiments designed to understand the sources of variability of fish population estimates and reduction in by-catch. Underwater video is often utilized by scientists to investigate sources of variability in these estimates through direct verification of acoustic fish backscatter, observations of fish behavior, and avoidance reaction and escapement from sampling gear. However, the range of conventional underwater optics is typically limited to only a few meters resulting in its inability to adequately address behavioral reactions to sampling gear. For example, fish often avoid the lighting from underwater cameras, and even low-light CCD cameras require some degree of lighting during the night or at deeper depths. Recently, the Dual Frequency Identification Sonar (hereafter DIDSON; Ocean Marine Industries, Inc.) was developed to reduce this problem. The DIDSON provides high-resolution acoustic images for remote identification of individual fish and other marine animals well beyond the range of conventional optics without the need for lighting. The DIDSON is a portable, self-contained sensor that can be deployed on a wide variety of platforms or gear such as an AUV, towed bodies, and fixed or mobile fishing gear (e.g., fish traps, trawls). A Didson was purchased with ASTWG funds and delivered to AFSC in September 2006.

Projects from three different Fisheries Science Centers were continued during FY 2008 and are listed below with their respective project goals.

Project 1) Characterize selectivity of a large midwater research trawl to walleye pollock (K.Williams and C. Wilson, AFSC) The goal of this project is to describe the behavioral mechanisms underlying size-dependent escapement of fish from a midwater survey trawl. Didson data collected from the trawl can provide individual fish trajectories to determine whether escapement is primarily a passive process where fish are not actively "herded" by the trawl panels, or where the behavior is an active process where fish actively respond to the trawl meshes during the capture/escapement process. Information on these behavioral processes will potentially be used to modify the survey trawl design and/or alter fishing tactics to reduce selectivity.

Project 2) Quantification of shortnose sturgeon in an overwintering site in the Penobscot River, Maine, using DIDSON (C. Lipsky, NEFSC and G. Zydlewski, UMaine). The goals of this project were to pinpoint the overwintering site of shortnose sturgeon in the Penobscot River, Maine, to estimate the number of individuals using the site, and to characterize the substrate in the overwintering site.

Project 3) Acoustic Observations of Atlantic herring using the DIDSON Sonar (J.M. Jech and J. Godlewski, NEFSC) The goals of this pilot project were to observe and monitor the behavior of Atlantic herring in the water column (i.e., in the pelagic region) and near the sea floor (i.e., demersal region).

Progress reports for these three projects are presented below.

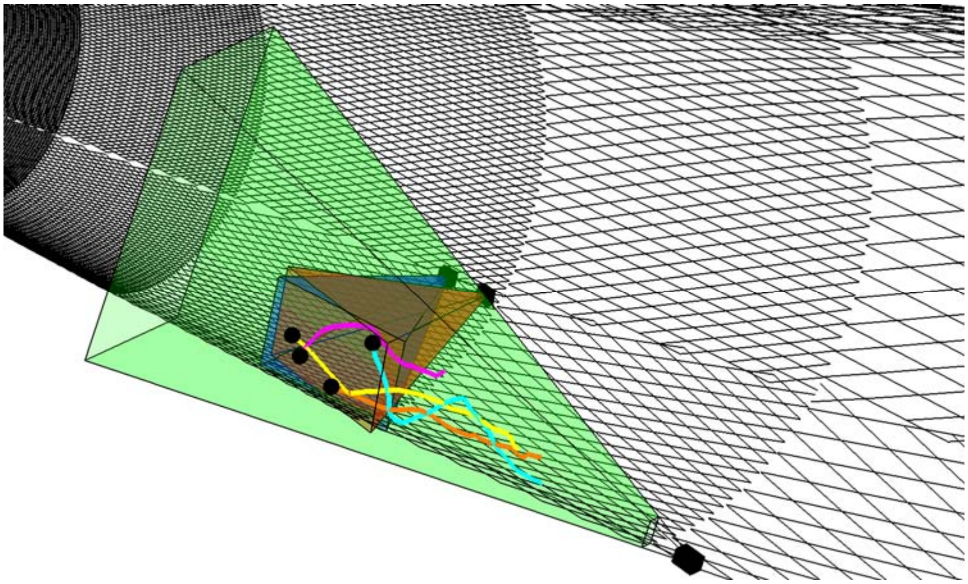
***PROJECT 1* – Characterize Selectivity of a Large Midwater Trawl**

INVESTIGATORS
Kresimir Williams and Christopher Wilson, NOAA Fisheries, Alaska Fisheries Science Center, Seattle WA

PRIORITIES
Primary objectives in 2008 were to: 1) develop target tracking software to process Didson data to quantify fish movements within the trawl to assess whether these behaviors could be considered mostly active or passive, and 2) include a stereo camera system to the net to determine size and species identification of a subsample of the Didson targets. This information will be valuable for developing strategies for modifying the trawl gear and/or changing fishing methods to potentially reduce selectivity of the trawl.

APPROACH
The DIDSON along with its autonomous deployment accesories as well as the stereo camera were deployed on the midwater survey trawl primarily in the aft portion of the trawl near the codend.

WORK COMPLETED AND RESULTS
The DIDSON was used to observe fish escapement behavior in survey trawl gear during acoustic abundance surveys for walleye pollock conducted in winter and summers of 2007-2008. A stereo-camera system was simultaneously deployed to identify DIDSON targets and provide fish length measurements during the summer survey. Both instruments were placed inside the trawl at the location of maximum fish escapement (Figure 1). DIDSON data were processed using automated tracking application (Handegard and Williams, 2008) to provide information on fish movements relative to the lower trawl panel (Figure 2). Fish lengths and identification were estimated from stereo-images using a customized computer application for deriving measurements developed using Matlab software and the camera calibration toolbox (Figure 3; Jean-Yves Bouguet, California Institute of Technology). The DIDSON enabled high-rate unbiased sampling of fish positions without the need for continuous lighting, which can bias fish behavior. Periodic sampling using the stereo-camera provided target specific data not resolvable using the DIDSON data. The simultaneous use of both the Didson and stereo camera systems provide a more complete picture of the interaction between the fish and the trawl as part of the investigation to assess the selectivity of walleye pollock to large midwater trawls.



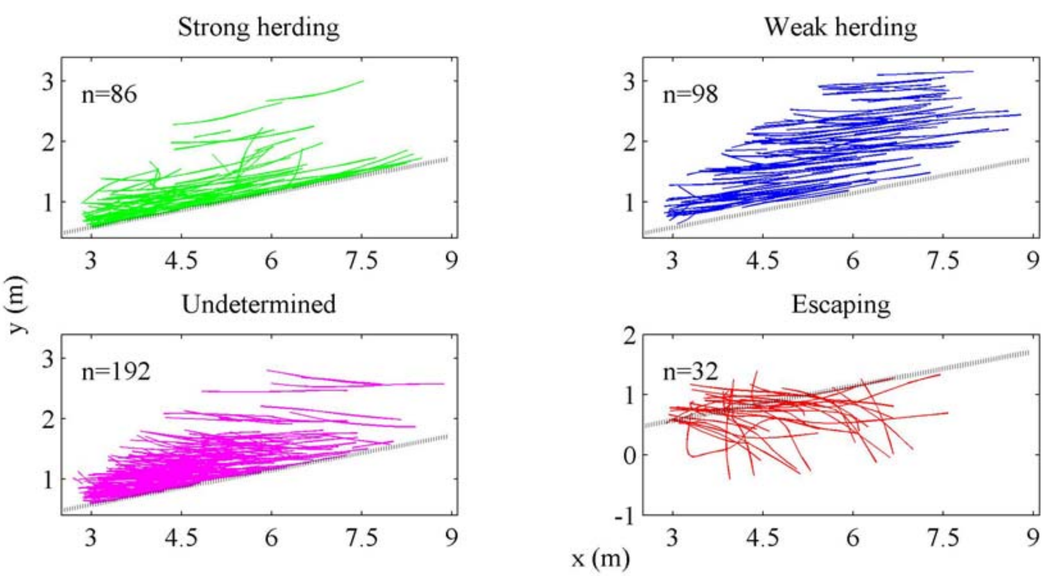


Figure 2. Four observed types of fish responses relative to the trawl panel from tracks based on DIDSON data. The tracks were aggregated over 5 deployments taken during the summer 2007 eastern Bering Sea acoustic survey of walleye pollock.

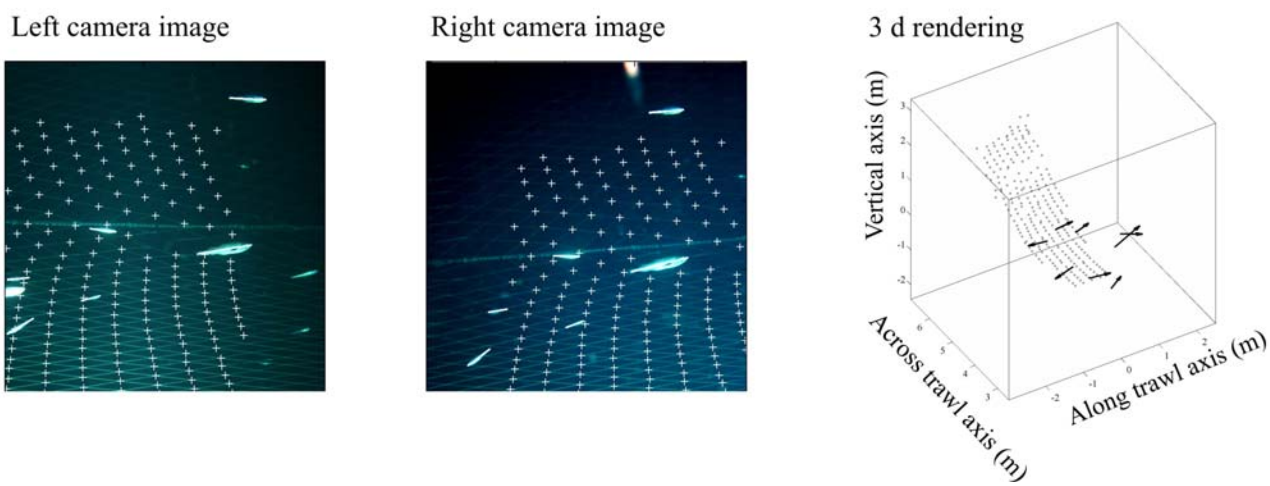


Figure 3. Stereo-camera image analysis of pollock with the AFSC midwater survey trawl. Equivalent points in both images are manually indicated, and stereo-based calculations are then used to estimate three dimensional positions. Fish length, position, and orientation are estimated by selecting the snout and tail of the fish in both images.

IMPACT/APPLICATIONS

Data on fish reactions to the survey trawl gear will will help evaluate gear effectiveness. The information will increase our understanding on how these sampling tools perform under different environmental conditions and will ultimately provide methods to quantify and potentially reduce this source of uncertanty and potential bias in walleye pollock abundance assessment surveys.

TRANSITIONS

Deployment of the DIDSON on the large midwater trawl used during acoustic-trawl surveys of walleye pollock may continue at some level following the complete analysis of the current data so that net selectivitiy correction coefficients can potentially be derived for these nets under a wide variety of environmental situations.

RELATED PROJECTS

Software being developed for the Didson will be useful to researchers on other projects that involve this device.

PUBLICATIONS

Handegard, NO and Williams, K. 2008. Automated tracking of fish in trawls using the DIDSON (Dual frequency IDentification SONar). ICES J. Mar. Sci. 65:636-644.

PRESENTATIONS

None at this time

HONORS/AWARDS

None at this time

PROJECT 2 ***- Quantification of Shortnose Sturgeon in an Overwintering Site in the Penobscot River, Maine, using DIDSON***

INVESTIGATORS

Christine Lipsky, Northeast Fisheries Science Center, Orono, ME, and Gayle Zydlewski, School of Marine Sciences, University of Maine, Orono, ME.

GOALS

The goals of this project were to pinpoint the overwintering site of shortnose sturgeon in the Penobscot River, Maine, to estimate the number of individuals using the site, and to characterize the substrate in the overwintering site.

APPROACH

Acoustically tagged sturgeon were actively tracked to determine the approximate location of the overwintering site. We then developed a sampling grid which encompassed the overwintering site, and established survey points within the grid that were 25 meters apart. Random points were chosen to be sampled each day, and sampling occurred on three consecutive days. At each sampling point, the DIDSON and a ROS pan and tilt unit were attached to a tripod and deployed off the side of a University of Maine research vessel. The DIDSON image was optimized for a 10 meter viewing range, and the DIDSON was slowly rotated 360 degrees using the pan and tilt. All images were recorded electronically.

All images were reviewed in the laboratory, and we characterized substrate and determined the sturgeon density at each sampling point. The densities were entered into a GIS database created using ESRI's ArcMAP program. A kriging interpolation was then run to estimate sturgeon density and distribution throughout the overwintering site.

WORK COMPLETED

Sampling occurred over the course of three days, with 14-23 points sampled each day. All images have been reviewed twice, and one day's results have been analyzed using the Spatial Analyst tool in ArcGIS.

RESULTS

Preliminary estimates after analyzing one day of sampling data indicate that there could be as many as 800 individuals aggregating in one 100m by 225m area. We were able to more accurately define the area being used by shortnose sturgeon in the winter, and were able to characterize the substrate of the overwintering area.

IMPACT/APPLICATIONS

Shortnose sturgeon were listed under the U.S. Endangered Species Act in 1967, and although the Penobscot River was listed as one of the 18 distinct rivers harboring shortnose sturgeon, a contemporary population was officially documented in this river in 2006. We have recently begun to acquire information about their population, habitat, and habits in the Penobscot River, and the DIDSON (in conjunction with acoustic telemetry) has allowed us to estimate the number of overwintering individuals. This information is critical to determine the number of individuals that will potentially be affected by several in-river dredging projects occurring in an area adjacent to the overwintering site. In addition, this population estimate will inform managers as to the current status of the population in the Penobscot River, which has been relatively unknown up to this point, and to inform decisions on critical habitat.

RELATED PROJECTS

None at this time.

PUBLICATIONS

None at this time.

PRESENTATIONS

"Using acoustic technology to estimate the population of overwintering shortnose sturgeon in the Penobscot River, Maine," by Christine Lipsky, Theresa McGovern, Kevin LaChapelle, Phillip Dionne, and Gayle Zydlewski was presented by Lipsky at the Ninth NEFSC Science Symposium in Newport, RI in January 2009.

HONORS/AWARDS

None at this time.

***PROJECT 3* - Acoustic Observations of Atlantic herring using the DIDSON Sonar**

INVESTIGATORS

Mike Jech and Joe Godlewski, Northeast Fisheries Science Center, Woods Hole, MA

GOALS

The goals of this pilot project were to observe and monitor the behavior of Atlantic herring in the water column (i.e., in the pelagic region) and near the sea floor (i.e., demersal region).

PRIORITIES

Knowing the behavior of herring is important for scaling the relative index of herring to absolute abundance because of its effects on target strength. Underwater video measurements have had limited use in monitoring behavior due to its limited range. In this project, we investigated the capabilities of DIDSON sonar for monitoring and quantifying fish behavior and detecting fish near the sea floor.

APPROACH

The DIDSON sonar was deployed off the FRV DELAWARE II during Sept. 2008. Atlantic herring historically aggregate in pre-spawning and spawning groups on the northern edge of Georges Bank in the Gulf of Maine. The NEFSC annually surveys herring at this time for abundance estimates. Atlantic herring aggregations were detected using near-surface-mounted echo sounders (18-, 38-, and 120-kHz Simrad echo sounders). The DIDSON was then deployed on these aggregations from the vessel using the DIDSON mounted "looking" forward (horizontal) in the nose section of our Advanced Fisheries Tow Vehicle. During these deployments, different data acquisition parameters and instrument settings were set to determine optimal settings.

WORK COMPLETED

A field study was conducted in the Georges Bank region of the Gulf of Maine in September 2008. Analyses of the data are currently underway (e.g., Figure 4).

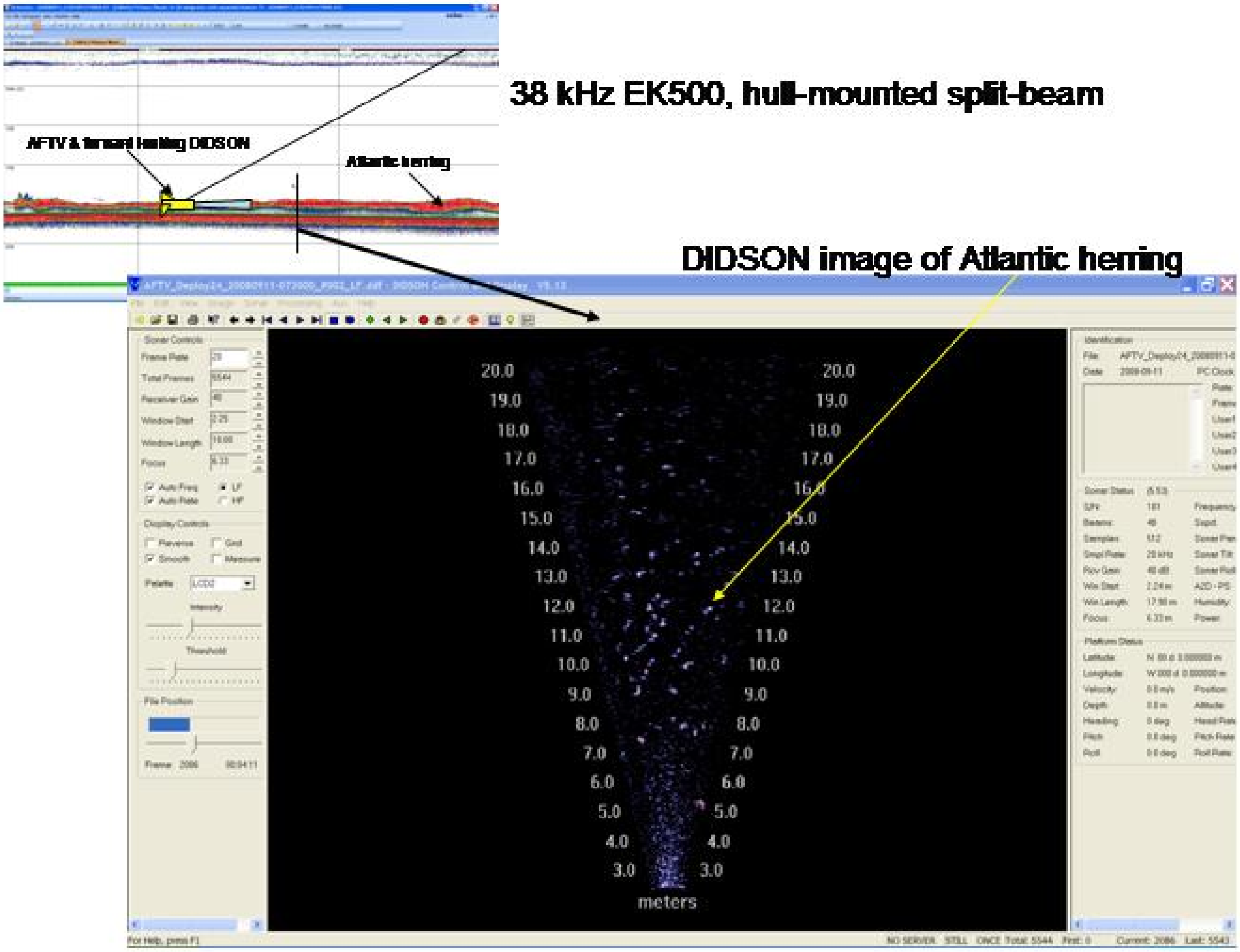


Figure 4. Echogram of volume backscatter from a hull-mounted 38-kHz EK500 echo sounder (upper panel) and echogram of a single transmission ("ping") from the ASTWG's Dual-frequency IDentification SONar (DIDSON) (lower panel). The DIDSON was "looking" forward (horizontal) operating at 1.1 MHz, with 48 0.4^o by 12.0^o beams and 7 cm range resolution. The upper panel demonstrates a dense layer of Atlantic herring (*Clupea harengus*), where individual echoes are indistinguishable. The lower panel shows individual echoes from herring within the dense aggregations. From a single transmission of the DIDSON, we can measure the density (numbers per unit volume), interfish spacing, fish orientation, and fish length. From sequential transmissions, we can monitor the change in these variables over time and infer behavior.

RESULTS

We are currently evaluating a commercial software package Myriax Echoview for processing DIDSON data.

IMPACT/APPLICATIONS

With the DIDSON, we are able to directly count individuals within an aggregations and estimate densities, orientation, and length directly. These measurements can be compared to density and abundance estimates using echo integration to evaluate estimates of target strength. In addition, detecting and enumerating fish in the acoustic "dead zone" - i.e., near the sea floor - is an important component to accurate estimates of Atlantic herring stocks in the Gulf of Maine and Georges Bank regions. Future work will focus on quantifying these echoes and behavior.

RELATED PROJECTS

None at this time.

PUBLICATIONS

None at this time.

PRESENTATIONS

None at this time.

HONORS/AWARDS

None at this time.

Advanced Sampling Technology Working Group
Grant Progress Report to
The Office of Science and Technology

Development of GSM remote receiving stations for the enhancement of ecological assessments of protected species.

INVESTIGATORS:
Charles Littnan
NOAA fisheries
Pacific Islands Fisheries Science Center
1601 Kapiolani Boulevard
Tel: 808-944-2171
E-mail: Charles.Littnan@noaa.gov

GOALS

The goal of ASTWG supported efforts at the Pacific Islands Fisheries Science Center (in partnership with the Alaska and Southwest Fisheries Science Centers) is to develop a portable, autonomous GSM archival node to study populations of seals and sea lions in remote areas outside of commercial network GSM coverage.

PRIORITIES

The priorities for FY07 were threefold:

1) Complete the field testing of the GPS/GSM transmitters on free roaming animals to ensure the devices were fully functioning and delivered the high resolution data expected prior to developing a PAGAN prototype,

2) Continue research and receive feedback to ensure that GSM was the most cost effective method of data transmission for this type of system or whether modification of the tag and creation of alternate PAGAN system would be better,

3) Develop clear statement of work for developing a PAGAN prototype, and

In FY08 our priority was to successfully award the contract and begin developing the PAGAN concept.

WORK COMPLETED AND RESULTS

The first GPS/GSM dive recorder to be used in the U.S. was deployed on an adult female Hawaiian monk seal in October 2007. The tag has functioned flawlessly and is continuing to transmit high resolution dive and location data. The data to data more than demonstrates and justifies the utility of applying these tags in and developing these stations for remote locations.

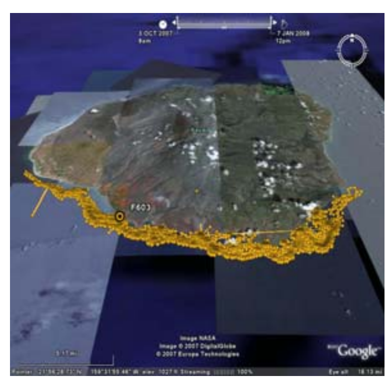


Figure 2: All GPS location fixes from an adult female monk seal on the south coast of Kauai. The record is from October 3 - January 7 and represents over 5000 GPS quality locations and clearly demonstrates near shore habitat use by a monk seal.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 3: The top image is a 7 day record of GPS locations for an adult female monk seal. The bottom graph is the dive record for the seal during that time. The x-axis is time in days and the y-axis is depth in meters from (0 - 200).

We conducted market research with various universities and commercial enterprises to determine how to best utilize existing commercial technology and what method of transmission would best accomplish our goals. We are currently working on cost-benefit analyses for using either GSM technology or UHF.

Due to the lateness in receiving funds the awarding of the contract was delayed until FY08. We were successful in soliciting contractors to complete the PAGAN project. The contract was awarded to the University of St. Andrews Sea Mammal Research Unit which has been working in this field for some years.

We are still in the project development stage with construction of the prototype projected to begin in May 2009 and completion of the system in early 2010.

IMPACT/APPLICATIONS

PIFSC/AFSC/SWFSC efforts in support of the national ASTWG initiative will improve NMFS's ability to monitor protected marine resources with much greater accuracy, increased data returns and in a more cost-effective manner.

EXPENDITURES [$100K]

The Pacific Islands Fisheries Science Center was allocated $100K in FY07 to support the development of the PAGAN system. The contract was awarded for $94K with $6K remaining to use for additional expenses.