NOAA-Fisheries Advanced Sampling Technology Working Group (ASTWG) FY 09 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. Priorities for the ASTWG in FY09 included development of an AUV as an alternative sampling platform, a review of information on the capabilities of the ME70 hydro-acoustic system, and a workshop on monitoring radiated noise from acoustic survey vessels.

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 and other reports generated as part of the ASTWG activities.

Regional Support of FY09 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 improve stock assessments by developing and deploying advanced sampling technologies that can provide increased accuracy, precision, or efficiency in the stock assessment process.

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

FY09 activities addressed improving reef fish assessments. Fishery-independent surveys for reef fish have typically been 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, count, and measure fish in video or still image sequences. This effort was continued in FY09.

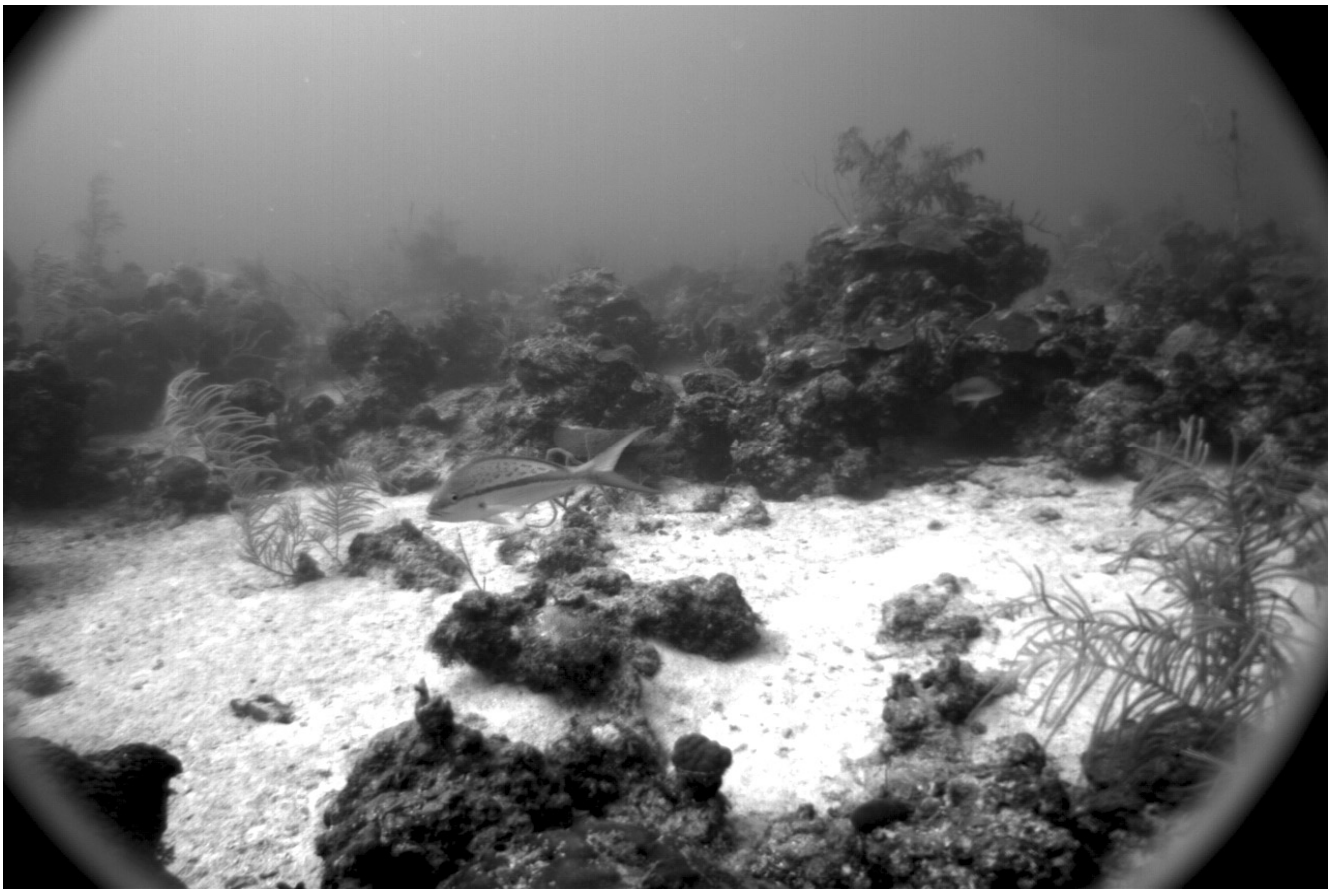
Figure 1. Combined stereo/video camera systems.

WORK COMPLETED AND RESULTS

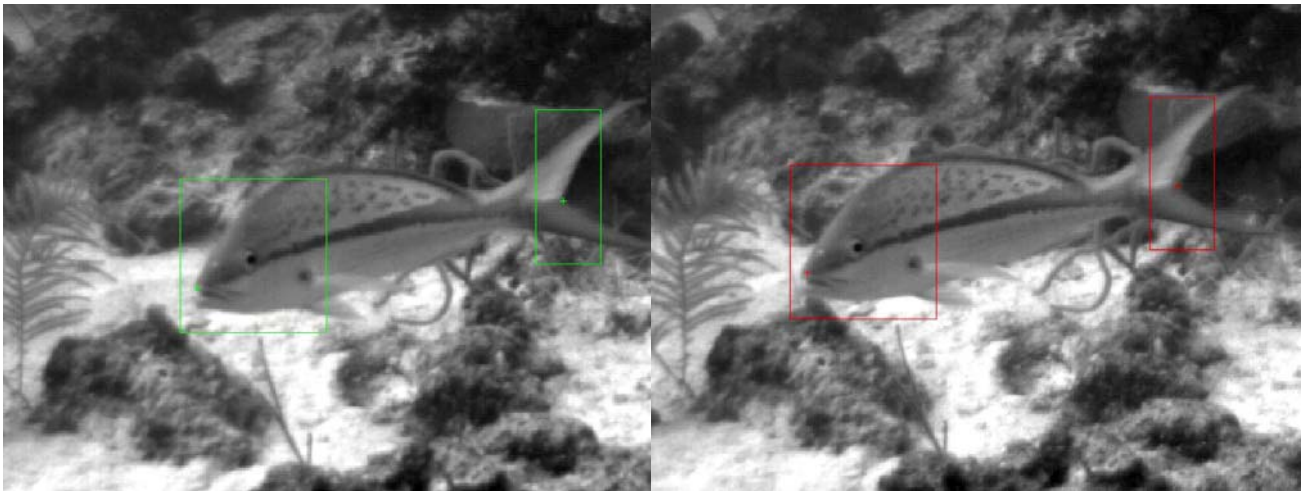
Development of stereo video camera systems was continued during FY09. The system is composed of color video and stereo monochrome still cameras controlled by a PC104+ computer and installed in an underwater housing. In FY09, four completed camera systems were fielded for the duration of the SEFSC reef fish survey conducted by the Pascagoula Laboratory. Three other systems were assembled, one as a backup for the Pascagoula systems, and two for use by the Panama City Laboratory. Vision Metrology System (VMS) software is being used to measure fish lengths in images from the stereo cameras allowing length-frequency distributions for observed species where previous video surveys provided, at best, a rough estimate of size range.

Algorithms to automatically detect fish in video and image sequences were developed in FY08. Efforts to develop automated image processing continued in FY09 and focused on tracking individual fish through sequences of images and edge detection methods to establish fish shape. Accurate fish shapes will be important for future efforts to automatically measure and classify fish. Tracking is a necessary step in producing an accurate count of individuals over a given time. Software was developed to track detected fish from frame to frame, account for fish entering and exiting the field of view, and cases where detected fish merge (or separate) into fewer (or more) detected objects. The algorithms are currently being tested and on a variety of image sequences. Several issues remain to be resolved with the approach that has been developed. One is that new fish may be detected in the frame without having crossed one of the edges, either by swimming in toward the camera from a distance at which their size is below the detection threshold or by appearing out of the murk in turbid situations. Another is that under some illumination conditions fish can cast a strong enough shadow on the bottom that the shadow is incorrectly detected as a fish.

Current stereo length measurement software requires the operator to identify matching locations in the left and right images. SEFSC has developed an algorithm that will reduce the number of steps involved in making stereo fish length measurements by automatically locating the best match of a feature selected in one image in the conjugate image of a stereo pair. An example is shown below. The first image is the left camera image of a stereo pair showing a yellowtail snapper against reef background on Tortugas Bank.



Enlargements of the area around the fish from left and right stereo images are shown below. The shift in location of the fish relative to the background, due to parallax, is apparent in these close-up views. The algorithm uses each feature selected in the left stereo image, shown in the enlargement below outlined in green, as a template, and searches the right stereo image for the best pattern match using a two-dimensional cross correlation. The matching locations calculated by the algorithm are shown on the enlargement on the right, outlined in red. When the selected template contains predominantly fish rather than background, the algorithm precisely locates the same fish feature in the conjugate image.



SEFSC received funds through the ASTWG grant program to conduct a workshop for the purpose of multibeam sonar user development. This workshop will take place in 2010. ASTWG funds were also used to participate with SWFSC on development of the NMFS AUV. This effort was directed at debugging and testing AUV control software and conducting a demonstration survey as described in the report on AUV development.

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.

TRANSITIONS

None at this time.

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 and analysis automation will support the effort to survey within boundary areas (near-surface, near-bottom, irregular topography) using AUVs, ROVs, and other camera systems.

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 $9.3K of funds allocated to SWFSC for collaborative work on the ASTWG AUV.

Regional Support of FY08 ASTWG:
Pacific Islands Fisheries Science Center

(Representatives: Frank Parrish frank.parrish@noaa.gov and Scott.Ferguson@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

Globally, seamounts play an important role in shaping the distribution of pelagic species, such as tunas and sharks. Cross seamount in the Hawaiian archipelago --- a seamount with a 5 nmi diameter 400 m deep plateau, rising from a 5000 m seafloor and lying in the path of the North Equatorial Current (NEC) and internal tides generated at the Main Hawaiian Islands chain --- is known to aggregate economically important fish such as juvenile and subadult bigeye tuna, a population which is heavily targeted by the local fishery. Reported moderate exploitation rates have recently raised concerns that the local fishery removes too many juveniles that could otherwise recruit to adult grounds and help maintain Pacific stocks. Since adult bigeye tuna are an important target species of both local and international fisheries, reducing recruitment into adult populations of bigeye could have wide ranging negative effects. These concerns call for closely monitoring the biomass of bigeye tuna aggregated at Cross seamount. Since conventional fisheries dependent stock assessment methods are known to be inaccurate and biased, the current research undertakes the development of a fisheries independent

method of bigeye tuna biomass estimation using active acoustics. Further, since populations of bigeye tuna depend on the biological and physical environment, the distribution, composition, and movement patterns of bigeye tuna forage, micronekton, as well as the effects of the unique environment at Cross seamount on both bigeye and micronekton, are investigated.

As all proposed field work for the project was completed in FY08, work during this fiscal year focused on completing all *in situ* (bioacoustics, currents, CTD casts) and satellite (sea level anomaly and sea surface color) data analyzes. Since data analyzes during FY08 revealed that micronekton biomass is higher over the plateau and flanks of the seamount than in nearby waters, and that bigeye tuna aggregate at the seamount at least partially to feed, data analyzes during FY09 focused primarily on quantitatively describing the effect of the environment on the composition and distribution of micronekton at Cross Seamount as well as at different regions within the study area. At present, a manuscript is being prepared for publication in a referred journal on the composition and distribution of micronekton, the characterization of the seamount environment and its effects on micronekton.

Data analyzes during FY09 revealed that the increased micronekton biomass is likely due to the availability of increased forage that is not the result of a trophic cascade originating in higher primary production due to upwelling caused by island effects. Current data shows that the interaction of currents with the abrupt topography results in anticyclonic flow near the surface, although sometimes the rotary flow is cyclonic. When current speeds exceed 40 cm s^{-1}, no rotary flow is observed in the upper 200 m. Currents with depth exhibit a more and more anticyclonic flow around the flanks (Figure 3). Small doming of density contours were observed most times, especially during the evening hours, within 200 m of the plateau floor (Fig. 1), too deep to result in upwelling of nutrients into the eutrophic zone. This corresponds with the apparent lack of an effect of the seamount on chloropigment concentrations. Interactions between the abrupt topography and impinging currents and internal tides are likely trap planktonic organisms that are not able to swim against currents that can reach 50 cm s^{-1} magnitudes, thus providing forage for the increased micronekton biomass.

The Seamount's effects on micronekton are confined to the plateau and the immediate flanks, not extending to more than 1-2 km from the shallow, 700-1600 m flanks (Figure 2). On a 24 hrs cycle, the largest difference between micronekton biomass in the shallow scattering layer (SSL) over the plateau and away from it is between 00:00 to 18:00. After 18:00, as micronekton start migrating into the SSL, the SSL biomass increases over the flanks and surpasses that over the plateau by 20:00. Between 20:00 and 24:00, micronekton migrate over the plateau and restore the overall daytime and nighttime pattern.

Anticyclonic eddies that are generated at the Main Hawaiian Islands and travel west-southwest seem to have an important effect on micronekton biomass at Cross Seamount.
During the 2008 cruise, Cross Seamount was under the influence of a relatively strong anticyclonic eddy. During the 2005 and 2007 cruises, upper 200 m current directions were to the northwest, while in 2008, when the high-shear region of the anticyclonic eddy was occupying the seamount environment, currents were to the northeast, as expected from the geostrophic balance. Current speeds also exceeded those in 2005 and 2007. Micronekton biomass and density were the highest during the 2008 cruise, as well as chloropigment concentrations. However, the higher chloropigment concentrations seem to be the result of large-scale interannual differences as evidenced by the SeaWiFS sea-surface Chl-*a* data.

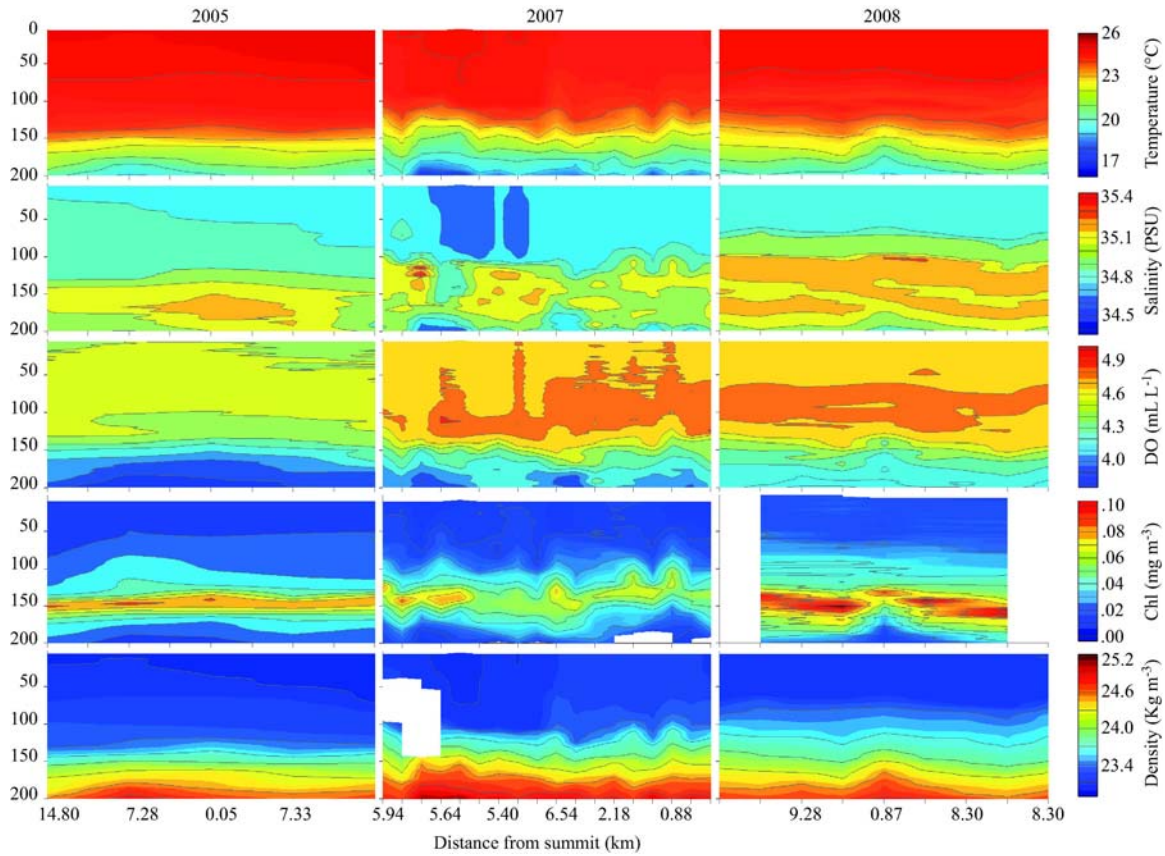


Figure 1. Upper 200~m temperature, salinity, DO, chloropigment, and density (from top to bottom) during the 2005 (left), 2007 (middle), and 2008 (right) surveys.

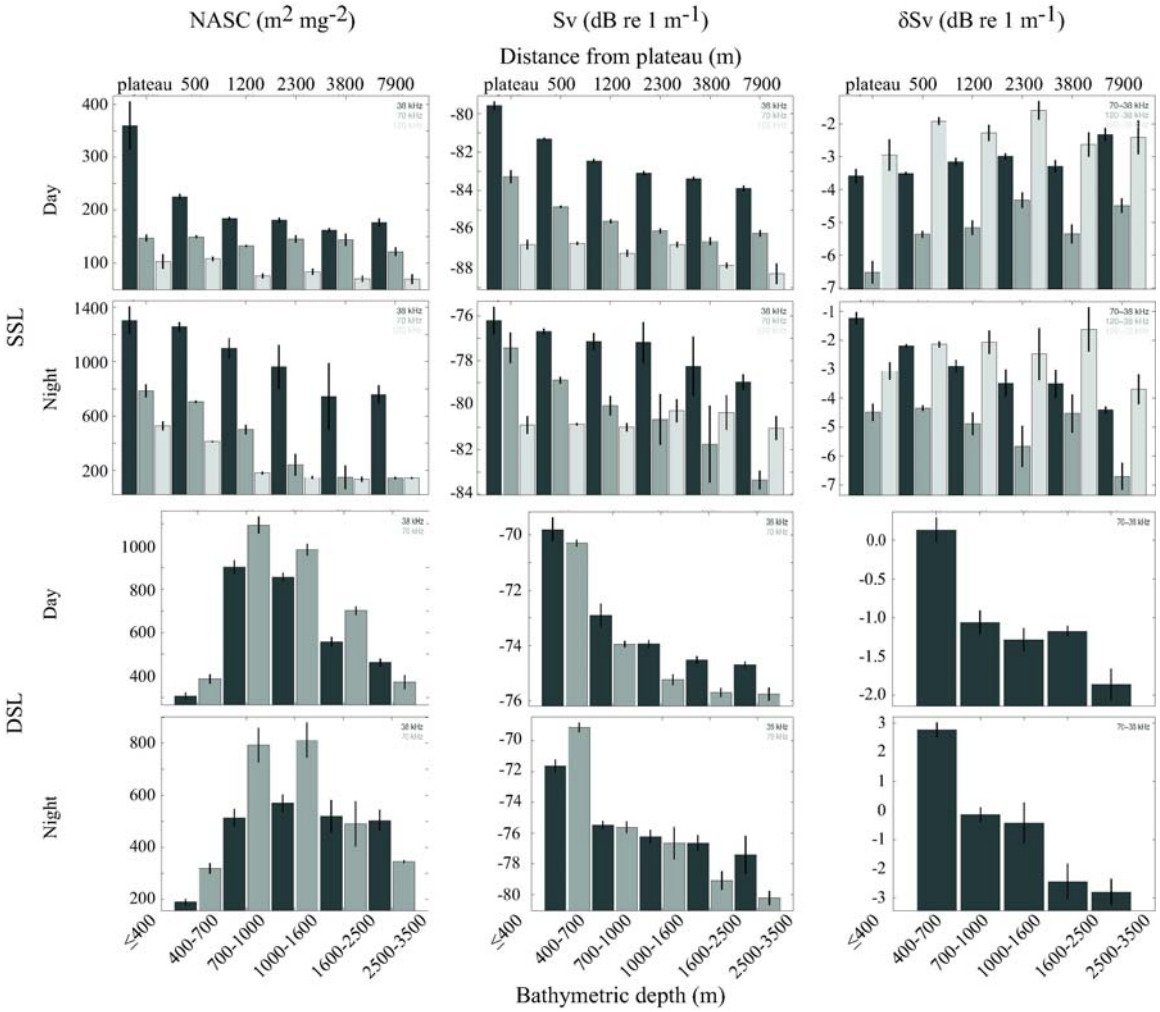


Figure 2. Relative biomass (NASC, right), density (S_v, middle), and composition δS_v, right) of the SSL (upper two panels) and DSL (lower two panels) during daytime (first and third rows) and nighttime (second and fourth rows) with increasing distances from the plateau. Black, dark gray, and light gray are the 38, 70, and 120 kHz frequencies for NASC and S_v while 70-38, 120-38, and 120-70~kHz for δS_v, respectively. Note that each plot has different scales on the y axes.

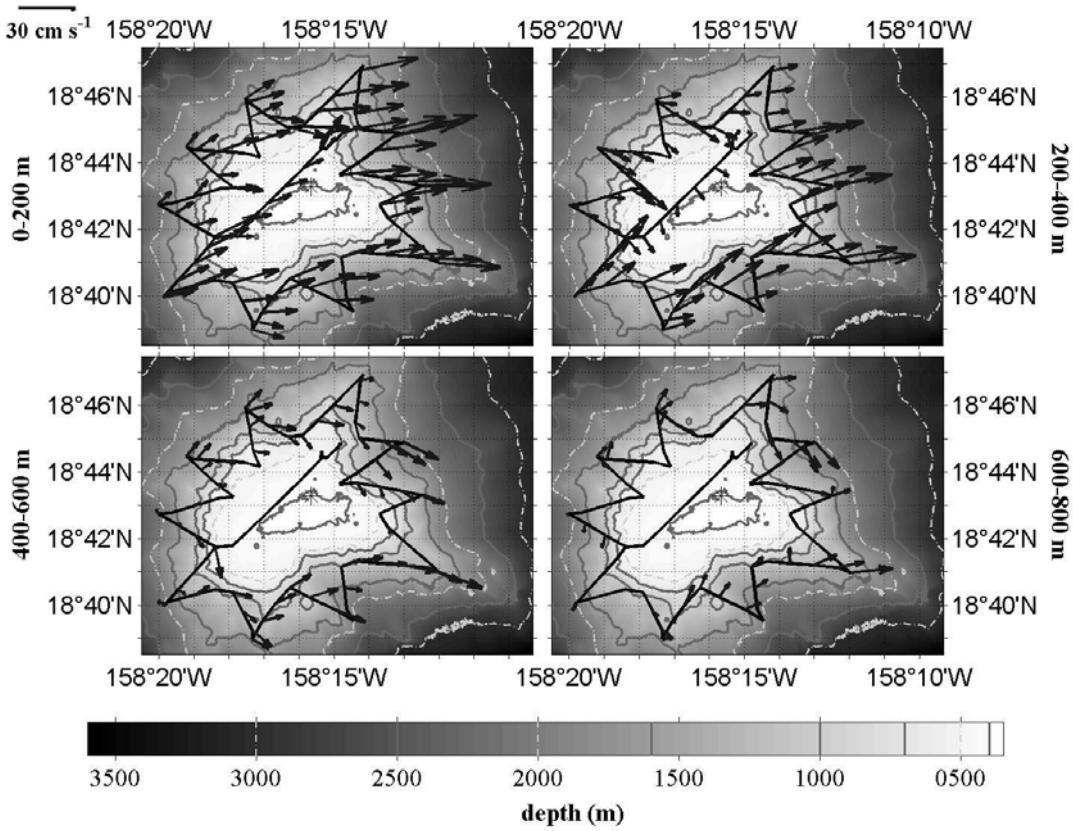


Figure 3. Current vectors for the mean (clockwise from top left) 0-200, 200-400, 400-600, and 600-800~m depth ranges. Note the anticyclonic rotation of currents at depth. Data were collected during a survey sampling the flanks of the seamount in 2008. Bathymetric contour lines are as in Figure 2.

Project 2) 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. Further, there has been an extended amount of BOTCAM work conducted in recent years to study the commercially important bottomfish in this area.

Using the FY07 data, the number of bottom fish during all surveys in the Three Fingers area was estimated based on expected target strength values, based on theory. An approximate 50 cm FL fish with gasbladder, the expected mean size of bottom fish targeted by the fishery, would give TS values of -40 dB. Based on this theoretical value, echograms were thresholded and fish tracks with TS above -45 dB were counted. The -45 dB threshold gave mean TS values of the tracks counted (4774 for the 2007 surveys) near the expected value: -39.3 dB (Figure 4). As the distance covered was approx 350 nmi during 2007, the number of fish detected was 13.6 per each nmi.

After completing an initial survey in FY07, a second survey was conducted during FY09 on board the NOAA ship *Oscar Elton Sette*, equipped with a hull-mounted, split-beam Simrad EK60 system, operating at the 38, 70, and 120 kHz frequencies. In addition to the acoustics data, simultaneous baited and unbaited BOTCAM recordings were conducted to learn to better identify acoustic targets based on target strength (TS) values, aggregation shapes, sizes, and depth.

The BOTCAM was deployed in regions with bottom topography observed to be best suitable to pink snappers, previously observed to form nearly homogeneous aggregations. In addition, the BOTCAM was deployed at predetermined locations (Figure 5, left) and also when the acoustics showed a fish aggregation near the bottom (Figure 5, right), with acoustic descriptors consistent with what is expected for those of the affected bottomfish species. Interestingly, even the baited BOTCAM did not attract bottom fish only about 100 m away, as observed by the acoustic recordings. However, when the BOTCAM was deployed over an aggregation, the aggregation got denser around the BOTCAM but slowly dissipated within one hour.

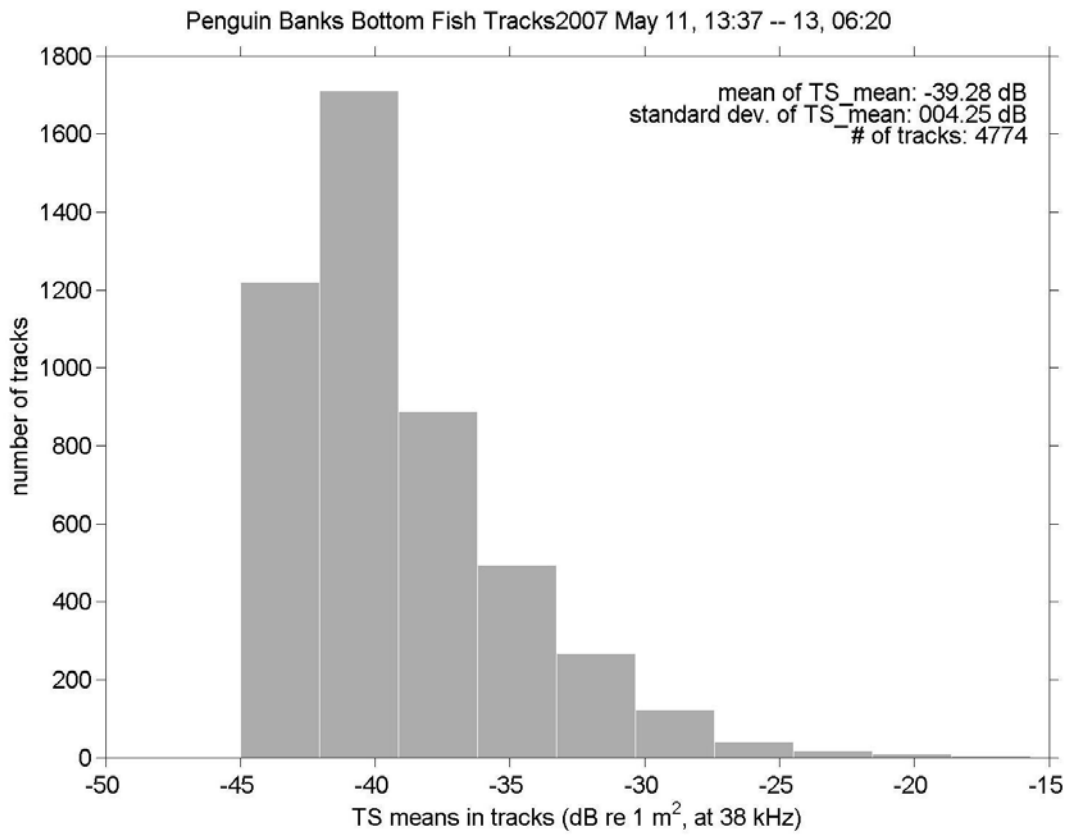


Figure 4. Example of TS values from tracks counted during the 2007 survey operations, approx a 350 nmi-long track.

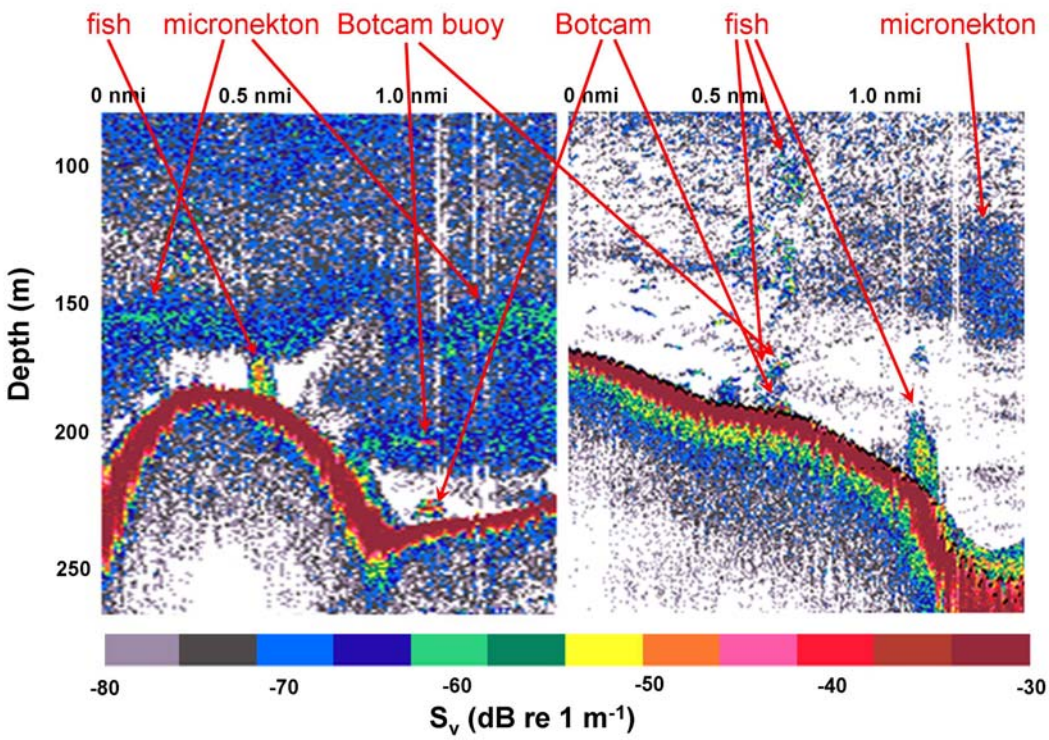


Figure 5. Echograms showing the BOTCAM without fish (left) and with fish aggregations (right).

Project 3) Characterization of micronekton and the environment in the Transition Zone Chlorophyll Front and nearby environment

The region of the Transition Zone Chlorophyll Front (TZCF), which separates the oligotrophic subtropical gyre waters form the more productive subarctic waters to the north, and the nearby environment have generated interest in recent years. Bigeye tuna and swordfish, target species of the local longline fishery, occupy these regions and are the fishing grounds for the fishery. In addition to concerns the fishery has on bigeye and swordfish populations, the fishery has occasional bycatch of loggerhead turtles by hooks set for swordfish. Information on the environment and feed for bigeye and swordfish, mostly micronekton, are needed to improve out understanding of the ecological regions that bigeye, swordfish, and loggerhead turtles occupy to assess the fishery's influence on bigeye and swordfish populations and to reduce loggerhead bycatch.

As part of this research, a 2-week long cruise was conducted on the NOAA ship *Oscar Elton Sette* along the 158°W meridional in March, 2009. To better understand this habitat, Conductivity-Temperature-Depth (CTD), oxygen and fluorometric measurements were taken from the ocean surface down to 1,000 meters along the transect line from 23°-36°N. Additionally, water samples were collected at these stations using Niskin bottles for later laboratory analysis of chlorophyll a and chloropigments. Bioacoustic backscatter, collected at the 38, 70, and 120~kHz frequencies by a Simrad EK60 sprit-beam, 7º beam-width, hull-mounted transducers, and currents with a hull-mounted Acoustic Doppler Current Profiler, operating at the 75 kHz frequency, were continuously monitored as well to tie together any observed changes in the depths of the sound scattering layers with the changes

in the regional oceanography. To groundtruth the bioacoustics data, micronekton samples were collected both from the shallow (SSL) and deep (DSL) scattering layers along the transect line.

Preliminary results show that the physical front was further south than the biological one. Temperature, salinity and oxygen showed the physical front to be at about 31ºN (Figure 6, three middle panels), while the front in chloropigment concentrations was at 35ºN (Figure 6, bottom panel). Previous results from a cruise in 2008 are consistent with these findings and show that the chlorophyll front is further north than in previous years.

The changes in the characteristics of micronekton follow those of the physical changes, as opposed to those of the biological ones. In subtropical gyre waters, south of 31 ºN, the SSL extends to about 200-220 m in depth, with the DSL occupying the 400-750 depth-ranges. In transition zone waters, north of 31 ºN, the SSL is thinner, occupying the upper 150 m, with the DSL being thicker and denser than in the subtropical gyre, extending from about 400-900 m in depth (Figure 6). I addition, the DSL in the frontal zone is more of a persistent layer, appearing to have similar biomass and densities during daytimes and nighttimes then in the subtropical gyre. Both SSL and DSL seem to be comprised of smaller organisms in the subtropical gyre then further north, as the 70-38 and 120-38 kHz δS_v are lower north of 31 than south of that latitude, although the 120-70 kHz δS_v does not show a change. Further analyzes will be used to estimate biomass and composition of the SSL and DLS in the subtropical gyre and in the North Pacific Frontal Zone.

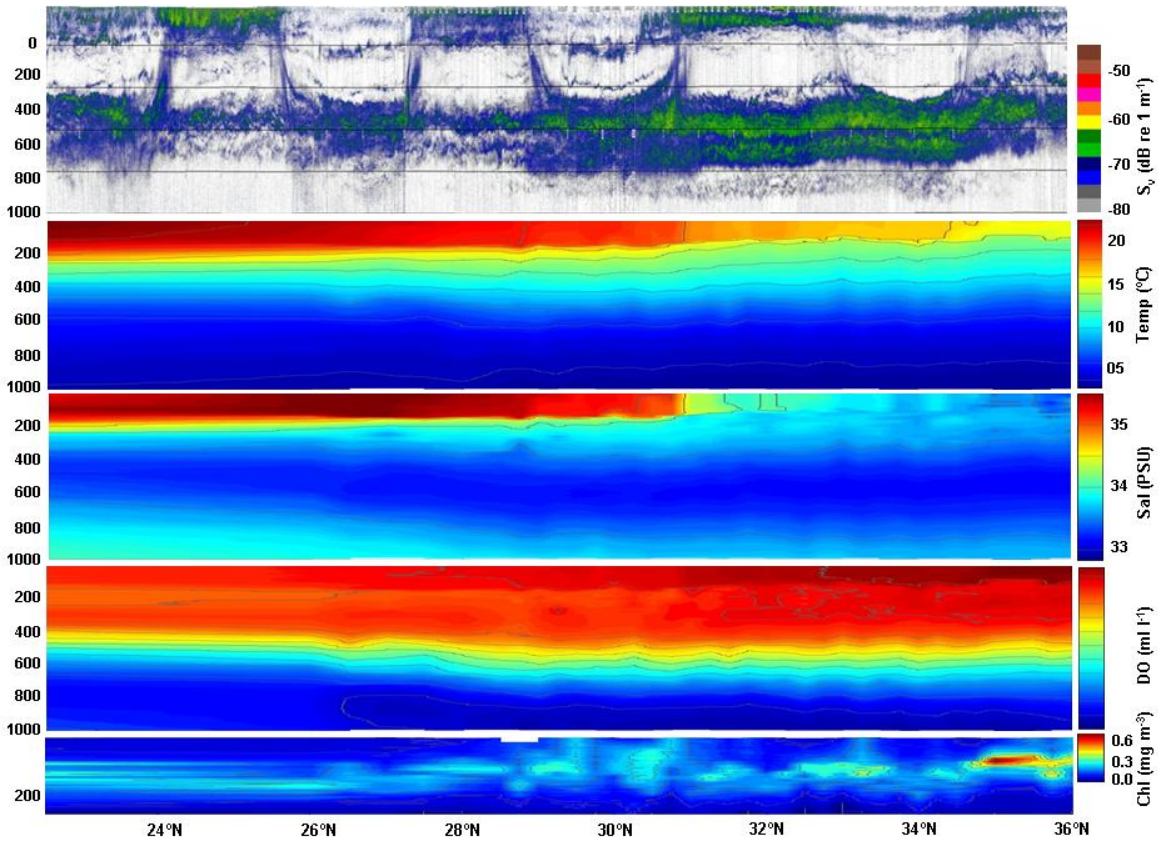


Figure 6. From top to bottom: Echogram of backscatter from micronekton (38 kHz), temperature, salinity, oxygen, and chloropigment concentrations. Note that the depth scale is 0 to 1000 m for the upper flour panels, while the bottom panel has a depth-range of 0-200 m.

PRESENTATIONS:

Domokos, R. Environmental effects on forage and longline fishery performance for albacore tuna in the American Samoa EEZ. Pelagic Fisheries Research Program PI meeting, Honolulu, Hawaii, Nov.

Domokos, R. Characterization of the Environment at Cross Seamount and its Effects on the distribution and Biomass of Micronekton. Pelagic Fisheries Research Program PI meeting, Honolulu, Hawaii, Nov.

Domokos, R. Bigeye tuna and its forage base at Cross seamount. 60th International Tuna Conference, Lake Arrowhead, California, May

PUBLICATIONS:

Domokos, R. Environmental effects on forage and longline fishery performance for albacore (Thunnus alalunga) in the American Samoa Exclusive Economic Zone. Fisheries Oceanog

Regional Support of FY09 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 FY09 were to continue developing the technical infrastructure required to improve fish stock assessments, participate in ASTWG national initiatives, continue the ASTWG-supported research FY09 projects, and develop technologies for improving our fisheries monitoring capabilities. The ASTWG FY09 projects included: 1) "Multibeam (Simrad ME70/MS70) users workshop for fisheries applications", 2) "Remote detection and identification of marine animals to improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON)", 3) "Development and evaluation of new technology for the remote identification and enumeration of larval fish", and 4) "Development of an acoustic microtome imaging system".

Three FY09 priorities for the NEFSC Advanced Sampling Technologies group were: 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; designing an electronic range calculator for Marine Mammal group to use during surveys; and developing improved ship-board measurement capabilities (e.g., "Ichthystick II").

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, Marine Mammal Surveys, and Gear Performance Studies.

WORK COMPLETED

The Electronics Engineer hired with the ASTWG Center funds has provided engineering support for various advanced sampling technology projects such as 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.

The NEFSC is field testing 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.

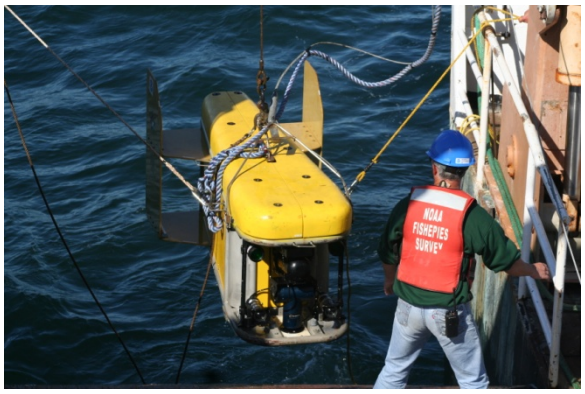


Figure 1. The AFTV being retrieved on the NOAA ship FRV DELAWARE II during the annual Atlantic herring acoustic survey in the Gulf of Maine during September 2009. Note the DIDSON unit and underwater cameras in the forward section.

The NEFSC is also continuing its efforts to field a new electronic fish measuring board based on the Alaska Fisheries Science Center design. The electronics engineer built and tested a pre-production model of this new measuring board (Fig. 2).

We have 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.

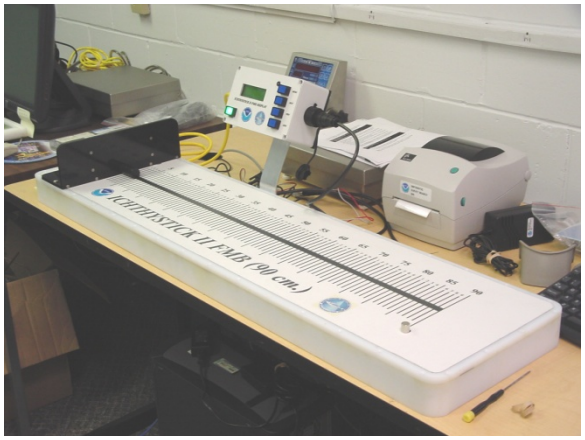


Figure 2. New electronic fish measuring board – Icthystick II – developed at the NEFSC and AFSC. The Icthystick II successfully measured thousands of fish during its inaugural tests on the NEFSC acoustic and bottom trawl surveys during fall 2009.

We also participated in the ASTWG Workshop on monitoring vessel noise on the new FSV class vessels. This workshop included representatives from NMAO, NOAA Fisheries, and the Navy

(Carderock). The objective of the workshop was to come up with a plan to monitor and mitigate noise levels on the FSV vessels. The report of the workshop is provided under a separate document.

RESULTS

The DIDSON sonar was deployed on the northern flank of Georges Bank during the NEFSC's annual acoustic survey of Atlantic herring in September – October 2009. 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 and individuals within dense aggregations.

A pre-production model of the new electronic fish measuring board (Figure 2: Icthystick II) based on a design from Rick Towler at the Alaska Fisheries Science Center was built and tested on three legs of the Hydroacoustic cruise during September and October 2009. The new fish board performed well. Final engineering drawings are currently being produced with the intent of going into production at the end of 2009.

A prototype device was developed to allow Marine Mammal researchers to obtain sighting distance and angle electronically. This device allows the observer to obtain the perpendicular distance between the target and ship electronically, with no need to perform a lengthy calculation by hand. The device was field tested on FSV Bigelow in August 2009 with excellent results. Five more units have been requested by the NEFSC Marine Mammal group.

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 four projects in FY09 that the NEFSC participated in:

- Multibeam (Simrad ME70/MS70) users workshop for fisheries applications by D. Demer (SWFSC), Chris Wilson (AFSC) and M. Jech (NEFSC),
- 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, M. Jech (NEFSC), J. Godlewski (NEFSC), and C. Lipsky (NEFSC),
- Development and evaluation of new technology for the remote identification and enumeration of larval fish by J. Hare (NEFSC) and R. Cowen (U-Miami), and

- Development of an acoustic microtome imaging system by D. Chu and S. Tomich (NWFSC) and M. Jech (NEFSC).

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. ICES J. Mar. Sci. 66: 1270-1277.

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. ICES J. Mar. Sci. 66: 1303-1309.

PRESENTATIONS

Jech, M., J. Horne, D. Chu, C. Clay, T. Francis, N. Gorska, V. Holliday, B. Jones, A. Lavery, B. Reeder, K. Sawada, and T. Stanton. 2009. Comparison of acoustic models for standard shapes. ICES WG-FAST, Ancona, Italy, May 2009.

Jech, J. M., and J. Godlewski. 2009. Observations of Atlantic herring using DIDSON sonar. ICES WG-FAST, Ancona, Italy, May 2009.

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 FY09 ASTWG:
Northwest Fisheries Science Center

(Representatives: Dezhang Chu, 206-861-7602, dezhang.chu@noaa.gov; Brad Hanson, 206-860-3220, brad.hanson@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 FY09 included participation in ASTWG national initiatives, attending the ASTWG semi-annual meeting, improving 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:

Automated Shipboard Acoustic Calibration System (ASACS)

During the FY 2009, we made a number of improvements on both hardware and software components of the ASACS:

- Hardware: We have added tension detection capability to the ASACS, it allows the central control unit to detect whether the wire tension of each downriggers is too high (wire is too tight) or too low (wire is loose) and react appropriately, i.e. sending warnings to the operator and/or stopping the motors (see the schematic diagram of motor control unit in Fig. 1). In addition, we increase the resolution from 2.5 cm to 1 cm by changing the sensor configuration. Figure 2 is the photo of the downrigger configured with an electronic control unit and tension sensing/wire counting unit.
- Software: We have revised our software to make it more flexible functionally and easier to operate (Figs. 3 and 4).

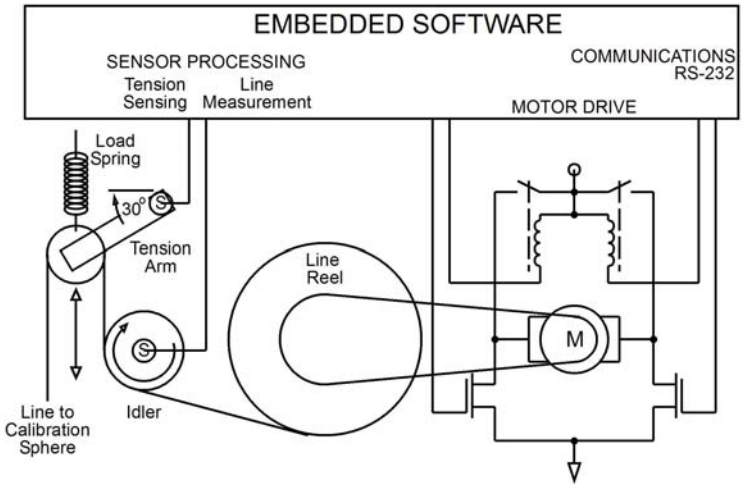


Figure 1. Diagram of motor control unit. Note that a tension sensing capability is added to the control unit.

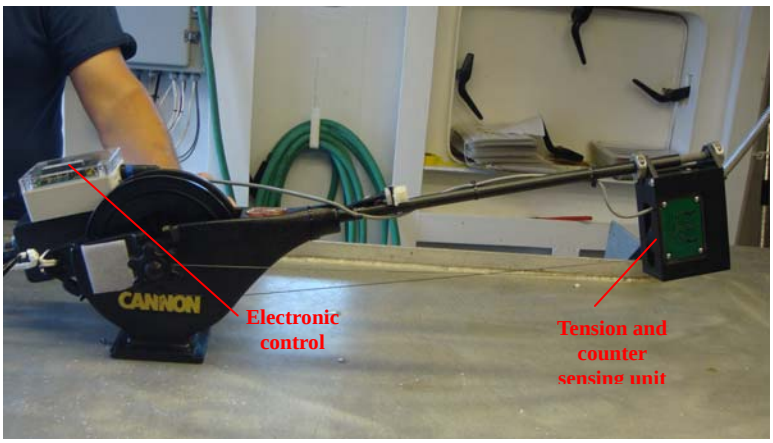
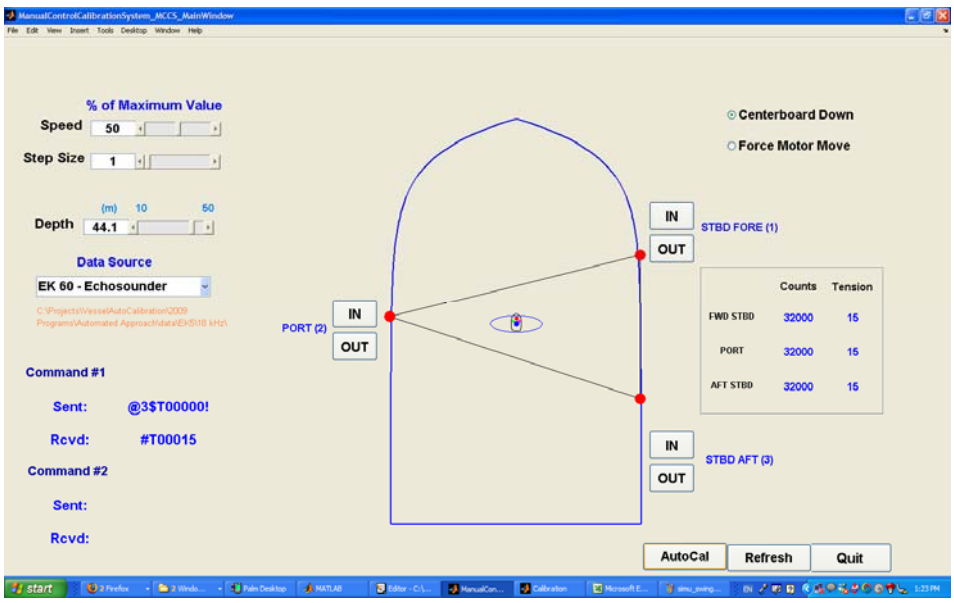
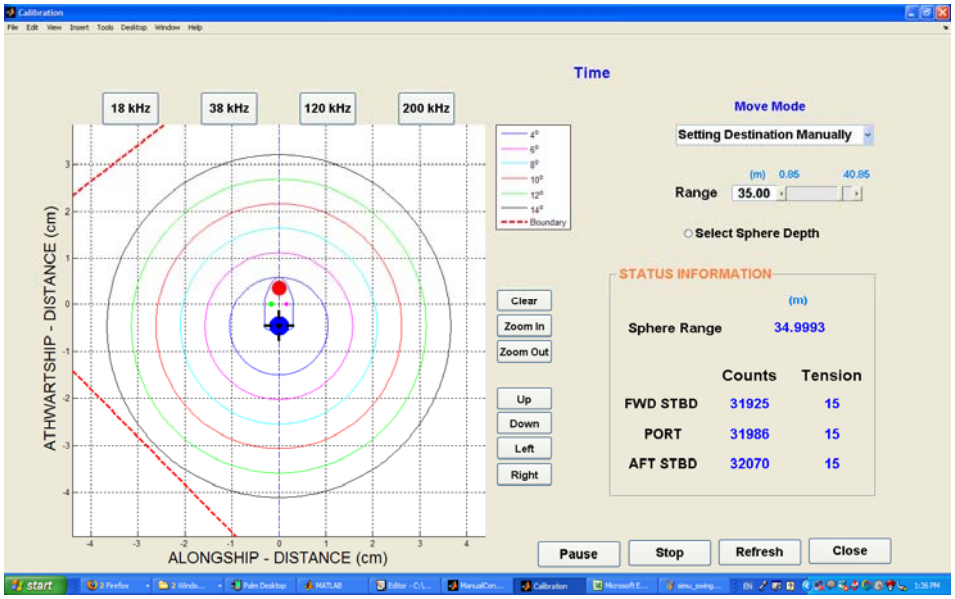


Figure 2.Photo of the motorized fishing downrigger. Microcontroller is included in the electronic unit while the line tension and counter sensing unit is on the end of the downrigger



(a)



(b)

Figure 3. GUI generated in MATLAB. (a) Manually controlled GUI; The three solid red circles represent the downrigger positions (two on starboard side and one on port side). Clicking on "IN" and "OUT" push buttons will control the "wire in" and "wire out" of the corresponding downriggers. (b) Automated Control GUI window. The four solid circles at the center of the concentric circles are transducers of different frequencies mounted on the centerboard. The circles represent the echosounder foot prints at a particular depth (35 m in this plot). The dashed lines on the left corners are the boundaries defined by the three downriggers shown in Fig. 3a (the boundary defined by the two downriggers mounted on the starboard side is not shown here but will show up by clicking on zoom-out button).

RESULTS

Automated Acoustic Shipboard Calibration System

The acoustic calibrations were conducted in Elliott Bay before and after the 2009 Integrated Hake Acoustic and Trawl Survey. The on axis calibration was very easy. The sphere swing operation to map the beam pattern was challenging but was accomplished successfully (Fig. 3).

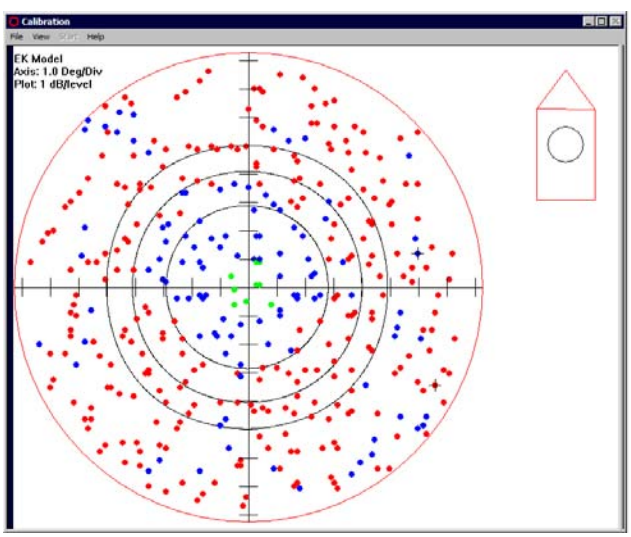


Figure 3. Field calibration swing results of the 18-kHz echosounder. The calibration sphere is a 64-mm diameter copper sphere. Blue dots represent the measured beampattern values that are below the current beampatern values while the red dots mean that the measured values are higher than the current beampattern values.

IMPACT / APPLICATIONS

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 a 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 Automated Acoustic Calibration System 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.

RELATED PROJECTS

The ASTWG funded three projects in FY09:

- D. Chu, S. Tomich, and J. M. Jech, "Development of an acoustic microtome imaging system (AMIS)" ($84.5K).

- V. Simon, D. Chu, S. Tomich, W. W. Wakefield, A. Keller, and I. Stewart, "Development of a Quantitative Optic Trawl Analysis System (QUOTAS)" ($59.5K).

- B. Hanson, "Redesign of medium-sized cetacean satellite-tag attachments to increase monitoring duration" ($15K).

Progress reports for these projects are appended as separate documents.

PUBLICATIONS

Tomich, S. D., L. C. Hufnagle, Jr., and D. Chu "Development of an Automated Acoustic Calibration System for fisheries acoustic survey" by Proc. MTS/IEEE Ocean's 2009 Conference, Oct 26-29, Biloxi, MS, paper index: 090601-042.

PRESENTATIONS

Tomich, S. D., L. C. Hufnagle, Jr., and D. Chu "Development of an Automated Acoustic Calibration System for fisheries acoustic survey" presented by Tomich at the MTS/IEEE Ocean's 2009 Conference, Oct 26-29.

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.

NOAA-Fisheries Advanced Sampling Technology Working Group (ASTWG) FY 09 Annual Report

Regional Support of FY09 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 FY09 priorities for AFSC projects, which involved some ASTWG-support were all continuation of existing projects including: 1) research with ASTWG DIDSON imaging sonar and a large midwater trawl to investigate net selectivity of walleye pollock to this trawl; 2) development of an autonomous lowered echo-sounding system to refine estimates of walleye pollock *in situ* TS; 3) development of an optical sampling trawl; and 4) work to evaluate performance characteristics of ME70 multibeam sonar. The Office of Science and Technology also provided funds to help construct a hydrophone mooring to investigate whether reliable radiated noise measurements can be accomplished in a convenient and cost- effective method to monitor the acoustic performance of noise-reduced FRVs.

APPROACH

Our approach in developing advanced sampling technologies for AFSC and NOAA 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 echo-sounding 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, recapture nets, 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. The primary emphasis during 2009 was development of methods and analysis of the 2007 and 2008 recapture-net data. Recapture nets are essentially fine mesh net bags attached to the outside of the trawl panels. The primary goal of this aspect of the research was to estimate trawl selection parameters and describe escapement patterns of walleye pollock for the standard survey midwater trawl. An attempt was made in 2009 to continue DIDSON observations in the trawl, but the unit was not

operational in the field. More detailed analyses of previously collected DIDSON data (see FY08 Annual Report) are planned in the near future.

Lowered echo-sounding system

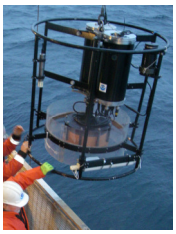


Figure 1. Lowered echosounding system includes gimbal-mounted 38 kHz splitbeam transducer.

The lowered echo-sounding system (Figure 1) 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. Since that time, AFSC researchers have refined various aspects of the system and developed the software for the remote monitoring and control of the instrument. Field tests of the lowered echosounding system indicated substantial back radiation of the transmit pulse (Figure 2). Various materials were positioned behind the transducer to absorb the sound. A neoprene rubber pad was ultimately found to reduce the back radiation to acceptable levels. Work on the software to monitor and control the system via the underwater modem focused on bug fixes and addition of features to help troubleshoot the back radiated noise issue. Thus the topside control software now allows the user to configure the transmit mode to active, passive, or test, and in active mode the transmit power level can also be altered. Additions to the software this winter will include a real time display which shows the probability of having greater than one target per reverberation volume to help the operator judge whether conditions are suitable for obtaining good single target detections.

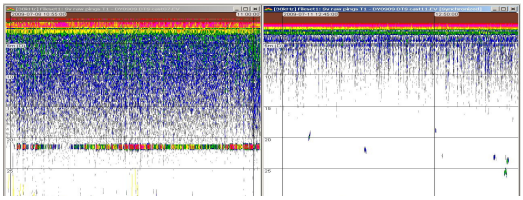


Figure 2. Left panel illustrates back-radiation problem that occurs in the absence of neoprene pad versus right panel which shows greatly reduced back-radiation with installed pad. Backscatter on left panel at 22 m represents calibration sphere. Instrument settings (and echogram display settings) were identical in both situations.

Although plans were made to use the lowered acoustic system to collect *in situ* target strength (TS) measurements of rockfish during an October cruise, poor weather prevented this work. Observations during field tests of the system did provide interesting findings that deserve additional work to fully understand (Figure 3). Attempts will be made beginning with the March 2010 pre-spawning pollock survey to use the system to collect TS measurements on pollock, and if time permits, on rockfish at the October cruise site.

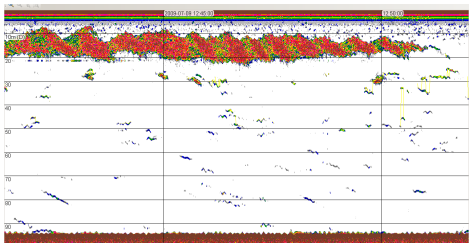


Figure 3. Possible response of age-1 pollock to lowered acoustic system. Pattern of pollock backscatter may result from fish moving upward toward lowered acoustic system (LAS) at particular tilt angle, sensing LAS and then descending away from LAS at different tilt angle, which results in the sinusoidal pattern as well as bands of relatively greater and lesser backscatter intensity. More work is needed to validate this hypothesized explanation.

Optical Sampling Trawl

Progress was made on the development of the high resolution, non-lethal Optical Sampling Trawl system (OST), including electronic component selection, purchase, and testing (Figure 4). The system development phase included the selection of adequate cameras, optics, and lighting to provide a high resolution (4 Mp), extended range (up to 5 m) stereo camera system. Several designs for camera underwater housing viewports were compared in the laboratory to determine optimal field of view, distortion, and sharpness. Additional work was done to determine the requirements for a miniature computer to compress and store images underwater, and to develop adequate power supplies for the lighting. Initial underwater tests are currently underway. The camera system will be deployed on a midwater trawl during March 2010 field trials.

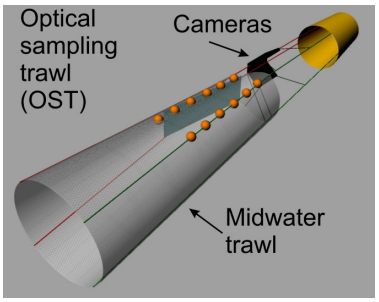


Figure 4. Conceptual view of Optical Sampling Trawl system attached to aft portion of large midwater trawl.

ME70 Multibeam Sonar

During FY09, AFSC, in collaboration with the University of New Hampshire and the Southwest Fisheries Science Center, continued to evaluate the capabilities of the Simrad ME70 multibeam sonar, and began to use the sonar for fishery-based work. Standard water column modes were used to collected bathymetric data (Figure 5) in the Bering Sea in June 2009. The data are being used to develop operational procedure(s) for the ME70 to simultaneously characterize the seafloor and investigate organisms in the water column. Algorithms used for generating both seafloor bathymetric soundings and seafloor backscatter mosaics have been developed, and will be quantitatively assessed in the coming year. Part of this assessment will be a direct comparison of bathymetry and seafloor backscatter, over identical track lines, of the ME70 with the Reson 8160 and 8111 multibeam sonars that have been used by the AFSC RACE Division Habitat Research Team.

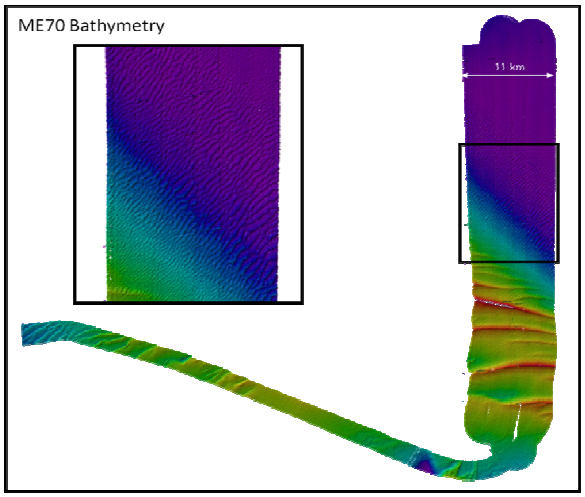


Figure 5. ME70 bathymetry collected 19 June 2009 showing a sandwave field along the east side of Unimak Pass, Alaska. Depths vary from 45 m (red) to 90 m (purple).

An early test of the ME70 simultaneous water column and seafloor sampling abilities has been an NPRB funded project (collaborative with UNH and SWFSC) aimed at rockfish assessment in untrawlable habitats. ME70 data collected during October 2009 will be used both for investigating rockfish aggregation morphology, and for characterizing the seafloor (i.e., aiding in the identification of trawlable versus untrawlable bottom). Preliminary results from this research show aggregations of rockfishes close to the seafloor in a region of moderate seafloor backscatter, and in close proximity to bubble plumes rising from the seafloor through the water column to the ocean surface (ca. 140 m bottom depth; Figure 6). The ability of the ME70 to

simultaneously collect data on substrate type, rockfish aggregation morphology, and bubble plume morphology, is expected to play an important role in understanding how these physical processes interact to structure rockfish distribution patterns.

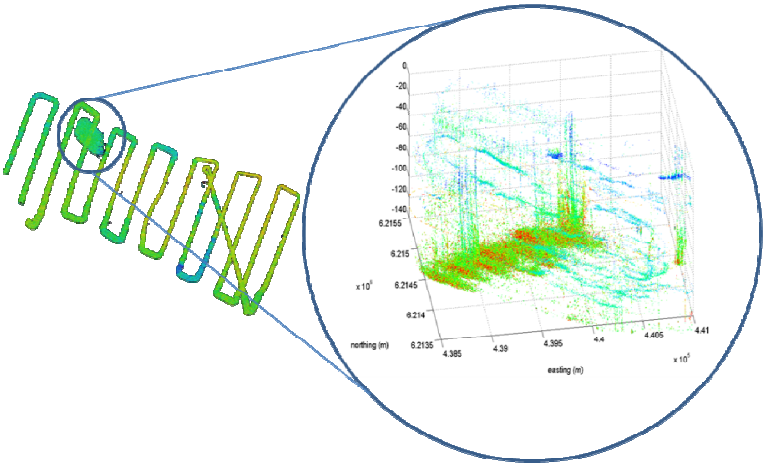


Figure 6. Seafloor backscatter (a proxy for bottom type) collected along 14 parallel transects near the shelf break southeast of Kodiak Island, Alaska is shown on the left. The small scale illustration shows, apparent bubble plumes (light blue) characterized by high vertical extent and narrow cross section. Rockfishes appear aggregated near and on the seafloor around the base of the plumes in this region of the study area, based on acoustic and ROV data.

Hydrophone-mooring to measure underwater radiated vessel noise

A semi-taught sub-surface mooring instrumented with hydrophones was deployed in Alaska on 25 Oct for one day in an attempt to make measurements of radiated noise of NOAA Ship *Oscar Dyson* (Figures 7, 8). The goal of this collaborative project between AFSC and SWFSC researchers is to investigate whether reliable radiated noise measurement can be accomplished in the field by NOAA personnel in a convenient and cost- effective method to monitor the acoustic performance of noise-reduced FRVs such as the *Oscar Dyson*. The measurements were made to be comparable to those conducted by the US Navy at the Southeast Alaska Acoustic Measurement Facility (SEAFAC), where the *Dyson* was noise-ranged the following day. Data analyses are currently underway.

Figure 7. Hydrophone data recorder during deployment.

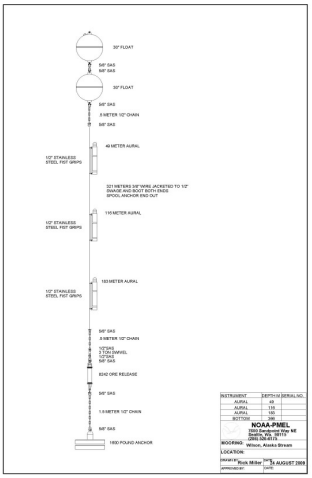


Figure 8. Hydrophone mooring schematic showing two 76 cm diameter subsurface floats, hydrophone loggers at 61, 91, 122 m depths, acoustic release, and 725 kg weight. The mooring was deployed in 366 m of water.

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 are developing 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. Although the transition period for this process is not immediate, the results of these studies will ultimately be used to refine and improve the stock assessment efforts where appropriate.

PUBLICATIONS (ASTWG funded)
Towler, R. and Williams, K. *submitted*. An inexpensive millimeter-accuracy fish length measuring board. Fish. Res.

PRESENTATIONS
Williams, K. Size-dependent escapement patterns of walleye pollock from the body of midwater trawls. ICES Joint FAST/FTFB session. May 2009. Ancona, Italy.

HONORS/AWARDS
None at this time.

EXPENDITURES [$250K]
The Alaska Fisheries Science Center (AFSC) continued to use the $135K that was permanently allocated to support the FTE position. Funds were also received to support two proposals: one involved work with the ME70 (as of Dec 2009, funds not available to University of New Hampshire ($50.5) or SWFSC ($8k)), and the other was for the Optical Sampling Trawl ($39.5K). Additionally, the Office of Science and Technology provided $25K towards construction of the hydrophone mooring to measure underwater radiated vessel noise.

Regional Support of FY09 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

To meet NOAA's mandate of ecosystem-based fisheries management, huge quantities of multi-disciplinary data must be efficiently collected over the areas and time periods that are important to the interactions of animals with each other and their environment. In particular, the areas near the sea-surface, seafloor and seashore (oceanic boundaries) must be sampled on large time- and fine spatial-scales. To accomplish this, surveys from large research vessels must be augmented with measurements from other sensor platforms such as satellites, buoys, small-craft, and autonomous underwater vehicles (AUVs). The Advanced Survey Technologies Group (AST) in the Fisheries Resources Division (FRD) at the Southwest Fisheries Science Center (SWFSC) enables ecosystem-based fisheries management through development and innovative uses of sensors and deployment platforms and analysis techniques.

PRIORITIES

During FY09, 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

Fisheries Surveys:

AST conducts acoustic-optical surveys of Pacific sardine and other coastal pelagic species and their prey, and rockfishes using state-of-the-art multifrequency, sidescan, and multibeam acoustic methods (i.e. Simrad EK60 and ME70 echosounders); a broad-bandwidth multiscattering hyperbaric tank and methods for measuring 'acoustic signatures' of various species; and a novel towed stereo-camera system (AST's FasTowCam) for validating the acoustic classifications. AST has led the development of the Collaborative Optically-assisted Acoustic-Survey Technique (COAST) to survey the dispersions and abundances of rockfishes in the Southern California Bight, by species. The technique uses historical fishing maps to initially define the survey sites,

echosounders to map rockfishes and their seabed habitat, and video and still images obtained with a remotely operated vehicle (ROV) to estimate the proportions and size-distributions of species in mixed assemblages.

Analytical Methods and Models Development:

AST invents methods and models for improving the science and management of marine, freshwater, anadromous, and aquacultured fishes. For example, AST has developed: a technique for using ADCPs to measure the three-dimensional (3D) velocities of marine organisms; a model for krill target strength (TS) which was adopted as the international standard; a procedure for quantifying total error (random and systematic components of measurement and sampling error) in acoustic surveys; and a versatile multiscattering technique. This technique can be used for: quantifying fish and zooplankton and their behaviors and growth rates in tanks; measuring their broad bandwidth sound scattering and absorption spectra ('acoustic signatures'); and, incidentally, acoustically measuring the numbers and sizes of humans in a room, and their amount of clothing. AST has also invented multiple powerful techniques based on Multifrequency Biplanar Interferometry (MBI; Fig 1) for greatly improved 3D imaging and classifications of fish and seabed.

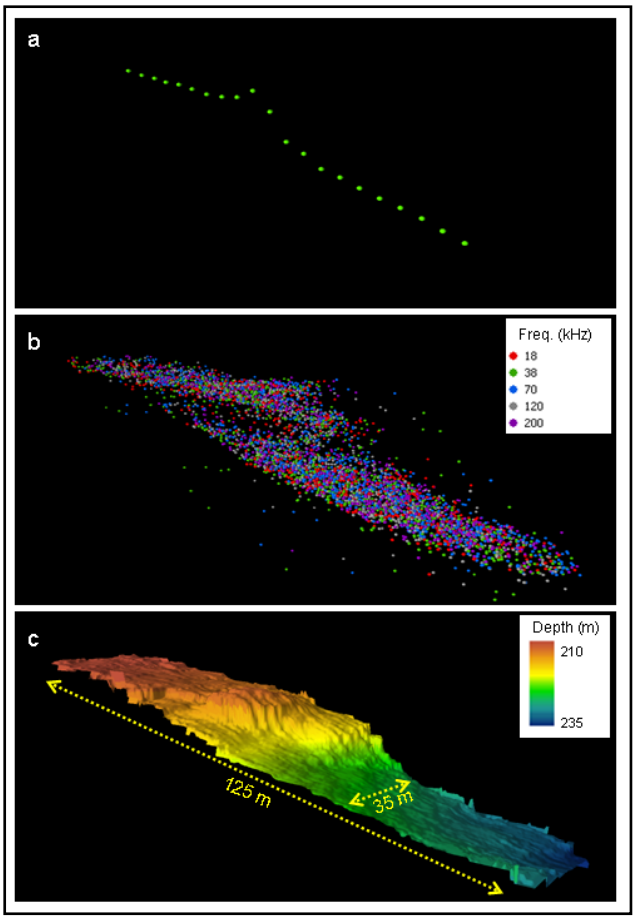


Fig. 1. Multifrequency Biplanar Interferometry increases the resolution of acoustic imaging by two orders of magnitude.

Sensor Development:

AST develops sensors (generally miniature, low-cost, low-power, and autonomous) to sample oceanic boundary zones on critical temporal-spatial scales. For example, AST has designed, constructed, and deployed: Remote Echosounder Modules (REMs) on ships and buoys of opportunity; micro-echosounders (EchoTags) for deployments on animals, bouys, and gliders; a deepwater cast echosounder (EchoProbe) for measuring TS accurately; and a towed stereo camera (FasTowCam; Fig. 2) for validating acoustic targets.

Fig. 2. The FasTowCam provides stereo images to identify the species and sizes of animals contributing acoustic backscatter.

Sensor Platform Development:

To survey fisheries resources in the context of their ecosystems, AST develops and increasingly utilizes instrumented small craft, buoys, and autonomous underwater vehicles (AUVs; Fig. 3). These instrumented platforms should improve the accuracies, precisions, and efficiencies of many routine studies, expand some to more critical time- and spatial-scales, and make other investigations feasible for the first time.

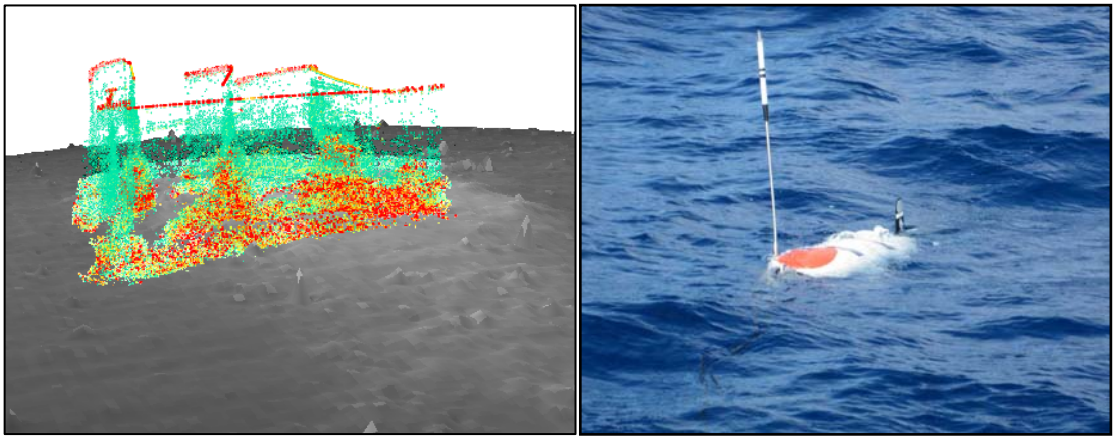


Fig. 3. The NOAA Fisheries AUV (right) and 3D imagery of echoes from rockfish collected by the AUV's 38-kHz EK60 echosounder (left).

WORK COMPLETED

During FY09, AST has:

- Developed novel methods for high-resolution imaging of the seafloor using split beam data. This method may revolutionize acoustic mapping and classification of the seafloor. Two papers published; another submitted; and six presentations given.
- Coordinated the acoustic-system calibration and data collection for two California Current Ecosystem Surveys of coastal pelagic species, particularly sardine, and their prey, from FV Frosti and NOAA ship Miller Freeman. The methods and results from the 2006 and 2008 surveys will be broadly vetted in 2010, for possible inclusion in the assessment.
- Led the development of the Collaborative Optically-assisted Acoustic-Survey Technique (COAST) to survey the dispersions and abundances of rockfishes in the Southern California Bight, by species. Towards use of the 2004/5 and 2007/09 survey results in stock assessments, the COAST will be reviewed by the Center for Independent Experts in 2010.
- Collaborated with colleagues from IFREMER and Kongsberg on the development and application of the new Simrad ME70 broad bandwidth multi-beam sonar for fisheries surveys.
- Led the design, construction and deployment of an EchoTag (micro echosounder), FasTowCam (towed stereo-camera), EchoProbe (cast deep-water echosounder), and broad bandwidth-multi-scattering salmon detector.

- Maintained and led development of the NOAA Fisheries AUV. Operationalized the AUV for fisheries surveys with functioning echosounder and stereo-camera payloads. Collaborated with researchers from SEFSC and NEFSC for AUV development, deployment, and surveys.
- Collaborated with colleagues from Scripps Institution of Oceanography on the development and use of instrumented buoy arrays (Fig. 4) for monitoring the biotic and abiotic components of the California Current Ecosystem.

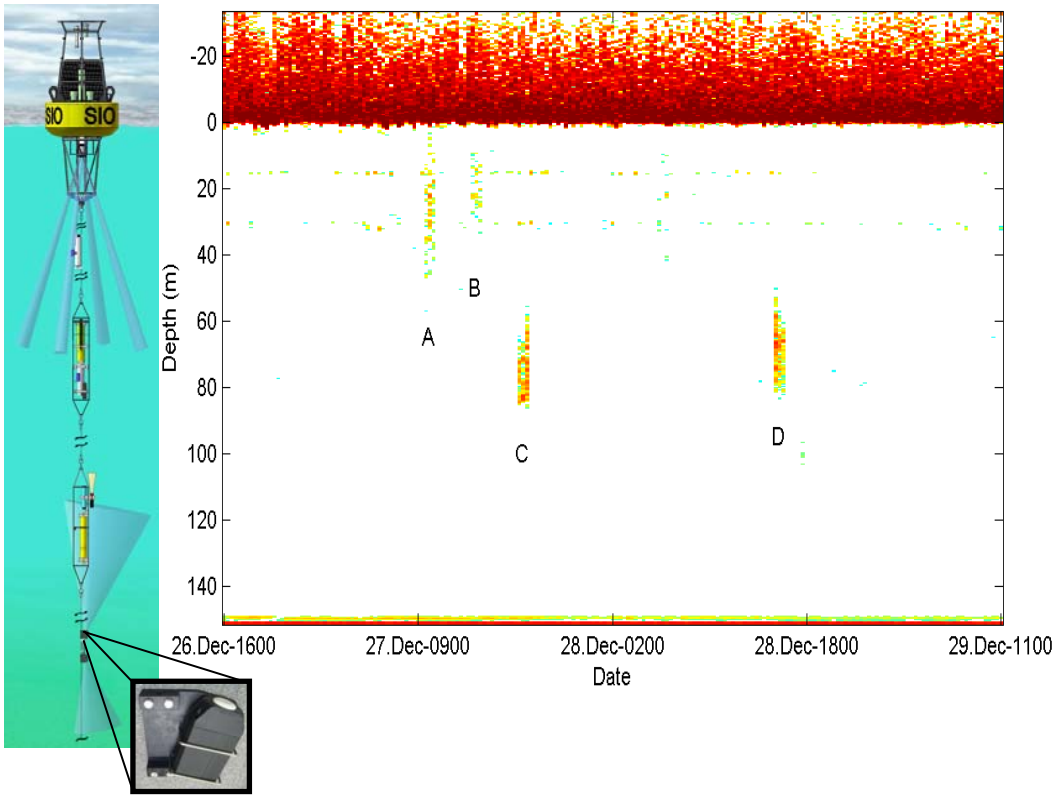


Fig. 4. AST's EchoTag mounted on the CCE1 mooring (left) and aggregations of krill (A and B) and fish (C and D) in the California Current Ecosystem (CCE), detected by the 190 kHz echosounder.

- Collaborated with researchers from AFSC, SWFSC, and UNH on an ME70 survey in the Bering Sea; and on an acoustical-optical survey of rockfish in the Gulf of Alaska.

RESULTS

Progress reports for projects funded by ASTWG in FY09 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:

- Elected Chairman (Demer; 2010-2012) of the NMFS Working Group on Advanced Survey Technologies (ASTWG);
- SWFSC Representatives (Demer and Cutter) to NMFS Working Group on Advanced Survey Technologies (ASTWG);
- NMFS Representative to the NOAA Working Group on Autonomous Underwater Vehicles;
- Member (Demer) of the ICES WG on Fisheries Acoustic Science and Technology (WGFAST);
- Chairman (Demer) of the ICES Study Group on the Calibration of Fisheries Acoustics instrumentation (SGCAL); and
- Invited Expert (Demer) to the CCAMLR's Study Group on Acoustic Survey and Analysis Methods (SGASAM).

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

RELATED PROJECTS

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

- D.A. Demer, J. Renfree, S.A. Hayes, and R.B. MacFarlane, "Multi-scattering detection, enumeration, and identification of anadromous species during migrations in streams and rivers," $88k.
- C.H. Thompson, C. Wilson, C.T. Gledhill, J.M. Jech, D.A. Demer, D. Chu, G.R. Cutter, and R. Domokos, "Multibeam sonar user development workshop," $35k.
- G.R. Cutter, and D.A. Demer, "Autonomous Underwater Vehicle Development," NOAA/NMFS/ASTWG, $100k

PUBLICATIONS

Papers published, in-press, and submitted for peer-reviewed publication in FY09:

1. C.S. Reiss, A.M. Cossio, V. Loeb, and D.A. Demer, "Variation in the biomass of Antarctic krill, (*Euphausia superba*), around the South Shetland Islands from 1996 to 2006," *ICES Journal of Marine Science,* 65:497-508. (2008).

2. D.A. Demer and J.S. Renfree, "Temperature dependent performance of echo sounder transducers," *ICES Journal of Marine Science,* 65: 1021–1035. (2008).

3. G.R. Cutter, J.S. Renfree, M.J. Cox, A.S. Brierley, and D.A. Demer. "Modelling three-dimensional directivity of sound scattering by Antarctic krill: progress towards biomass estimation using multibeam sonar." *ICES Journal of Marine Science*, 66: 1245–1251 (2009).

4. D.A. Demer, R.J. Kloser, D.N. MacLennan, and E. Ona. "An Introduction to the proceedings and a synthesis of the 2008 ICES Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies (SEAFACTS)". *ICES Journal of Marine Science*, 66: 961–965 (2009).

5. D.A. Demer, G.R. Cutter, J.S. Renfree, and J.L. Butler. "A statistical-spectral method for echo classification". *ICES Journal of Marine Science*, 66: 1081–1090 (2009).

6. M.J. Cox, D.A. Demer, J.D. Warren, G.R. Cutter, and A.S. Brierley, "Multibeam echosounder observations of Antarctic krill (*Euphausia superba*) swarms and interactions between krill and air breathing predators," *Marine Ecology Progress Series*, 378: 199–209 (2009).

7. J.S. Renfree, S.A. Hayes, and D.A. Demer. "Sound-scattering spectra of steelhead (*Oncorhynchus mykiss*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids" *ICES Journal of Marine Science*, 66: 1091–1099 (2009).

8. A. Širović and D.A. Demer, "Sounds of captive rockfishes," *Copeia*, 3: 502-509 (2009).

9. A. Širović, G.R. Cutter, J.L. Butler, and D.A. Demer. "Rockfish sounds and their potential use for population monitoring in the Southern California Bight". *ICES Journal of Marine Science*, 66: 981–990 (2009).

10. J.D. Warren, J.A. Santora, and D.A. Demer, "Response of avian and pinniped predators to changes in the submesoscale distribution of Antarctic krill before and after a near gale," *Marine Biology* (2009).

11. Report on the NMFS California Current Ecosystem Survey (CCES) between San Diego, California and Cape Flattery, Washington in April and July/ August 2008, *NOAA-TM-NMFS-SWFSC*-438 (2009).

12. G.R. Cutter and D.A. Demer, "Multifrequency biplanar interferometric imaging," *IEEE Geoscience and Remote Sensing Letters*. 7(1):000-000, doi: 10.1109/LGRS.2009.2029533 (online 2009; print 2010).

In-Press

13. M.J. Cox, J.D. Warren, D.A. Demer, G.R. Cutter, and A.S. Brierley, "Three dimensional observations of Antarctic krill (*Euphausia superba*) swarms using a multi-beam echosounder," *Deep Sea Res. II., Special Issue.* (2009).

14. J.H. Churnside, D.A. Demer, D. Griffith, R.L. Emmett, and R.D. Brodeur, "Fish lidar surveys on two scales in the Northeast Pacific Ocean," *CalCOFI Reports* 50: (2009).

Submitted

15. D.A. Demer, A.M. Cossio, J.S. Renfree and C.S. Reiss, "CCAMLR 2000 revisited," *CCAMLR Science*. (2009).

16. G. R. Cutter, L. Berger, and D.A. Demer. **"**Comparison of bathymetry mapped with the Simrad ME70 multibeam echosounder operated in bathymetric and fisheries modes". *ICES Journal of Marine Science* (2009).

17. J.D. Warren and D.A. Demer. "Abundance and distribution of Antarctic krill (*Euphausia superba*) nearshore of Cape Shirreff, Livingston Island, Antarctica during six Austral summers between 2000-2007," *Canadian Journal of Fisheries and Aquatic Sciences* (2009).

18. K.L. Stierhoff, D.R. Pinkard-Meier, J.L. Butler, and D.A. Demer, "Factors affecting biodiversity and community structure of deep-water rockfishes (*Sebastes* spp.) and thornyheads (*Sebastolobus* spp.) in Southern CA," *Marine Ecology Progress Series* (2009).

19. T.R. Graham, J.T. Harvey, S.R. Benson, J.S. Renfree, and D.A. Demer, "Acoustic identification and enumeration of scyphozoan jellies as prey for leatherback sea turtles (*Dermochelys coraiacea*) off central California," *ICES Journal of Marine Science* (2009).

EXPENDITURES

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

Advanced Sampling Technology Working Group
2009 Grant Progress Report to The Office of Science and Technology

TITLE
Development of an acoustic imaging microtome system (AIMS)

INVESTIGATORS
Dezhang Chu[1], Mike Jech[2], and Stan Tomich[1]

[1]Northwest Fisheries Science Center, 2725 Montlake Blvd E, Seattle, WA 98112
Tel: 206-861-7602, Email: dezhang.chu@noaa.gov,
Tel: 206-806-3351, Email:stan.tomich@noaa.gov

[2] Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543
Tel: 508-495-2353, Email: Michael.jech@noaa.gov

GOALS
The results from the proposed research are expected to provide solid evidence on how the volume and shape of swim bladders change with depth and will significantly strengthen our ability to model or theoretically predict the target strengths of swim bladder-bearing fish.

PRIORITIES
The priorities for FY2009/2010 are:
1. Design and test multi-element arrays
2. Assemble a complete prototype using 4 arrays
3. Integrate the arrays with a Y axis scanning system for use in scanning a live fish

WORK COMPLETED AND RESULTS
Since we didn't get the funding until late April, the project is still underway. The funds has been secured in a competitive bid contract which was awarded to GSA vendor Sound and Sea Technologies in Seattle for constructing the hardware based on the design provided by NWFSC (Tomich). The imaging array will consist of 7 rows of 16 acoustic elements as shown in Fig. 1. The array design will produce the circuit boards needed to build the scanning arrays.

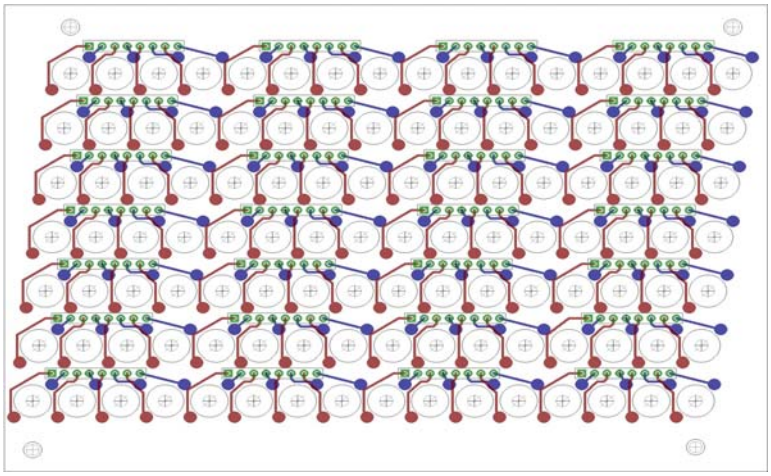


Figure 1. Layout of the PCB of the acoustic imaging array of the AIMS. The nominal acoustic frequency is 5 MHz.

There will be total of 4 arrays including a horizontal transmit/receive pair and a vertical transmit/receive pair. The apparatus that holding the array and allows the array to slide along the Y-axis have been partially built. A 3D conceptual plot of the AIMS is illustrated in Fig2. The design of the drive electronics is underway and will continue into early 2010.

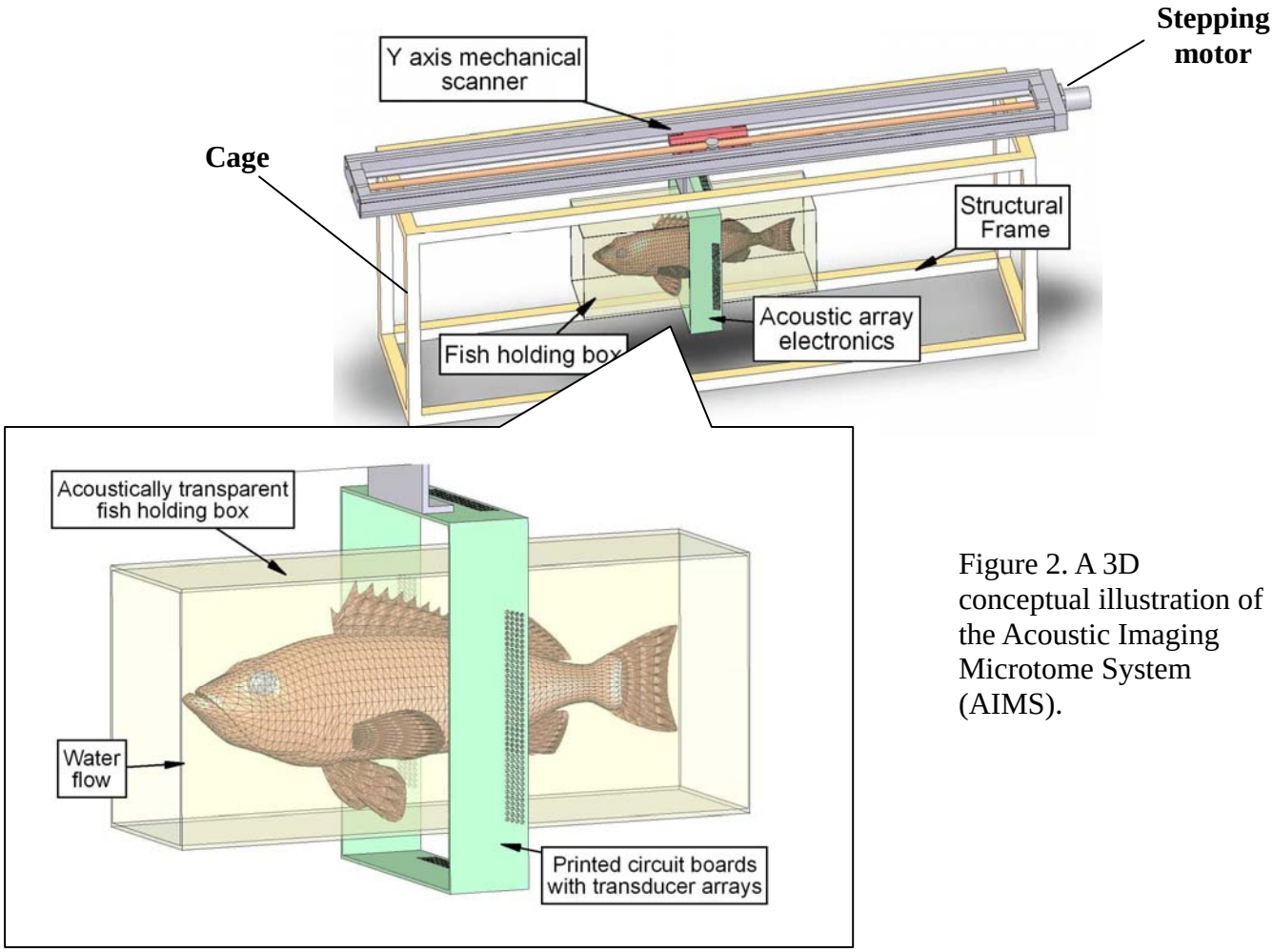


Figure 2. A 3D conceptual illustration of the Acoustic Imaging Microtome System (AIMS).

IMPACT/APPLICATIONS

This will strengthen our ability to predict the target strength of swim bladder-bearing fish and consequently improve the accuracy of stock assessments performed by acoustics surveys.

EXPENDITURES

NWFSC was allocated $84.5K for the prototype which is obligated under contract. The bulk of expenditures will occur in calendar year 2010.

Advanced Sampling Technology Working Group
2009 Grant Progress Report to The Office of Science and Technology

TITLE:
Development of a Quantitative Optic Trawl Analysis System (QUOTAS)

INVESTIGATORS:

Victor Simon, Dezhang Chu, Stan Tomich, Aimee Keller, and Ian Stewart

Northwest Fisheries Science Center
2725 Montlake Blvd E
Seattle, WA 98112
Tel: 206-860-3368
E-mail: victor.simon@noaa.gov

GOALS
The goal of ASTWG supported effort is to improve accuracy and reduce uncertainty of fish stock assessments by developing a non-lethal, efficient method of gathering data on important management species over wide areas via a deployed integrated optical camera system.

PRIORITIES
The priorities for FY09/10 are:
1) Test a single unit consisting of camera, laser diodes, and flash (CLF) components and build a benchtop prototype
2) Assemble a complete prototype using 6 cameras
3) Integrate the 6 camera system into the cod end of a trawl net and test in trawling operation.

WORK COMPLETED AND RESULTS
The funds were secured in a competitive bid contract which was awarded to GSA vendor Sound and Sea Technologies in Seattle. The camera and laser diode components are at the vendor for preliminary testing
and trials. The design for the flash circuitry will quickly follow for the benchtop prototype.

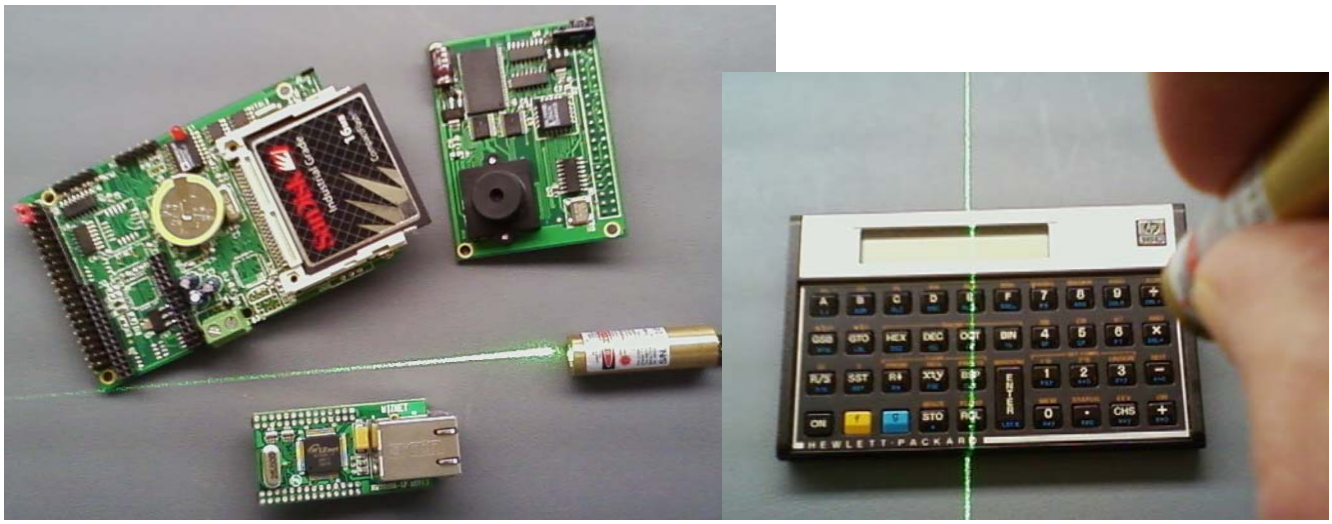


Figure 1. Components of the CLF unit of the QUOTAS prototype.

As shown in Fig. 1, the left above, the computer board (top left), the camera board (top right), Ethernet board (bottom center), and the laser diode. On the right, the laser diode draws a measuring line across a calculator. These CLF components are currently undergoing evaluation/testing. Preliminary design parameters are being developed for use in the prototype design. The final product will include 6 CLF units evenly distributed on a circular metal frame (Fig. 2).

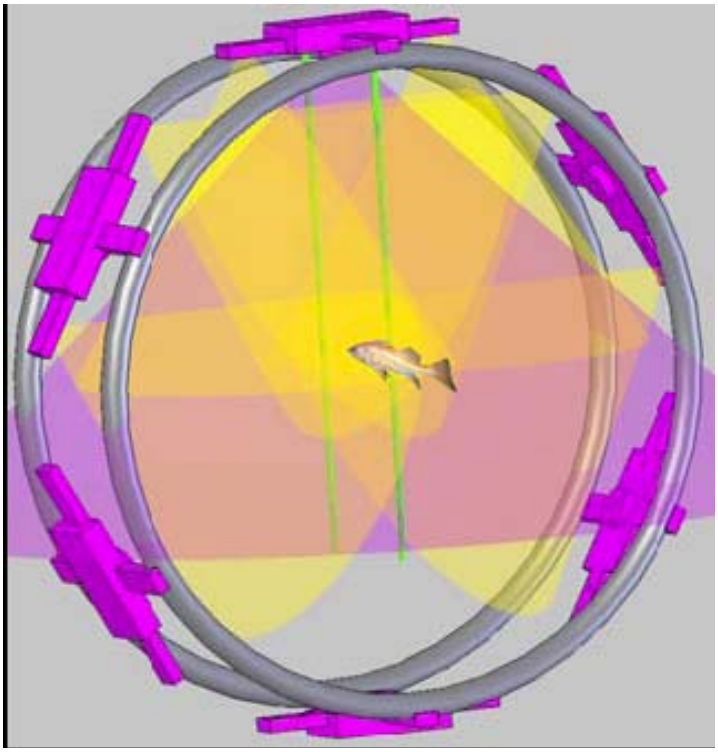


Figure 2. Diagram illustrating the configuration of the QUOTAS. A total of 6 CLF units will be activated in a group of 3 to illuminate sequentially the sample volume bounded by the ring frame. The laser pair on each CLF will be used to size the illuminated targets.

IMPACT/APPLICATIONS
This NWFSC effort supports the national ASTWG initiative will improve NMFS's ability to monitor protected marine resources without using lethal conventional trawling methods.

EXPENDITURES
NWFSC was allocated $59K for the prototype which is obligated under contract. The bulk of expenditures will occur in calendar year 2010.

Advanced Sampling Technology Working Group
2009 Grant Progress Report to The Office of Science and Technology

TITLE:

Redesign of medium-sized cetacean satellite-tag attachments to increase monitoring duration

INVESTIGATOR:

Brad Hanson

Northwest Fisheries Science Center
2725 Montlake Blvd E
Seattle, WA 98112
Tel: 206-860-3220
E-mail: brad.hanson@noa.gov

GOALS

The goal of cetacean tag attachment redesign project was to develop an attachment system that would provide longer durations of a attachment while minimizing the impact to dorsal fin tissue in order to allow collection of seasonal movement data needed for stock assessment of protected resources.

PRIORITIES

The priorities for FY09/10 are:
1) Finalize the design of the of dart prototype
2) Build prototype dart using Electron Beam Melting (EBM) technology
3) Revise prototype dart design and rebuild
4) Ballistic test dart system on foam target, synthetic tissue, and dorsal fin tissue to assess flight characteristics and dart structural integrity and retention strength. Modify design as needed to reinforce from breakage
5) Deploy new design on medium sized cetaceans

WORK COMPLETED AND RESULTS

Upon receipt of FY09 funds a contract modification was issued to Origins LLC to finalize the prototype dart design. The prototype design was finalized in August 2009 (Figure 1). A prototype of this dart was built using EBM process in September 2009 (Figure 2). Based on discussions with tag attachment design collaborators, revisions were made to the retention tine arrangement to provide a more uniform coverage of the anchoring system (Figure 3).

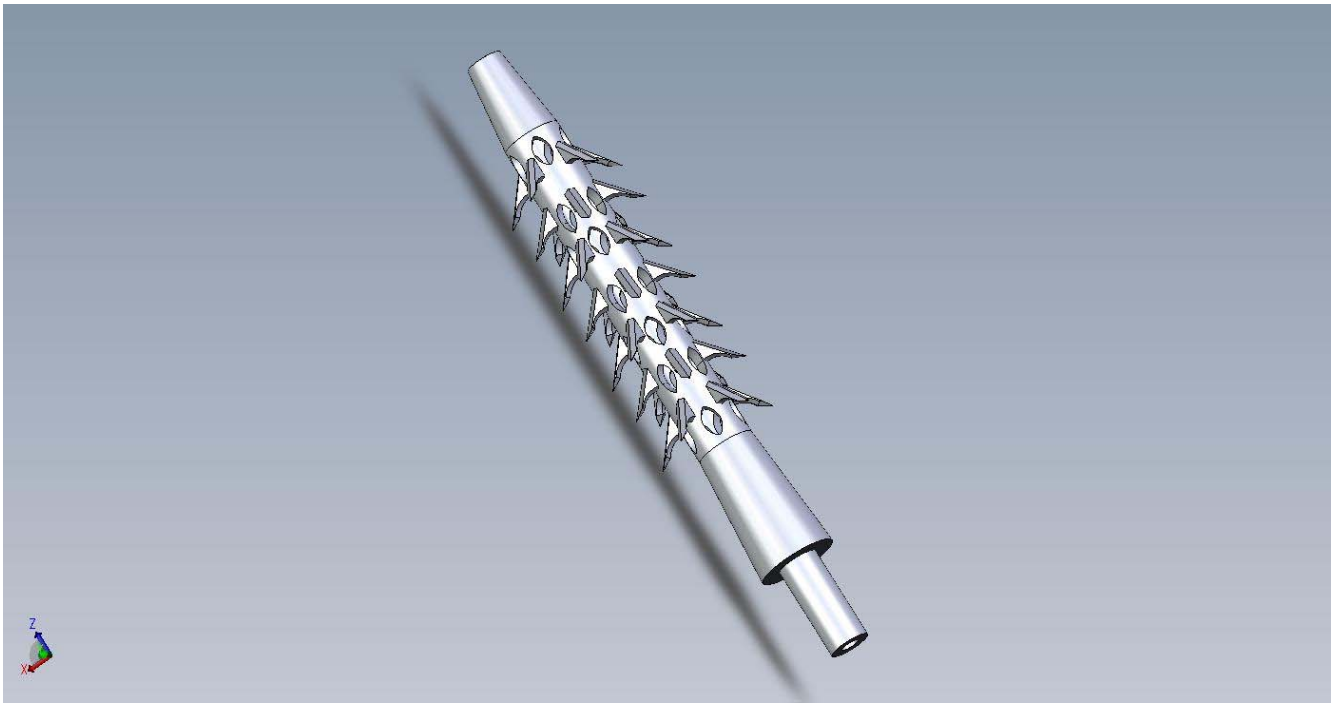


Figure 1. CAD drawing of final Dart Concept 8-1rev2 – August 2009

Figure 2. Attachment Concept 8-1rev2 built in medical grade titanium using EBM – September 2009

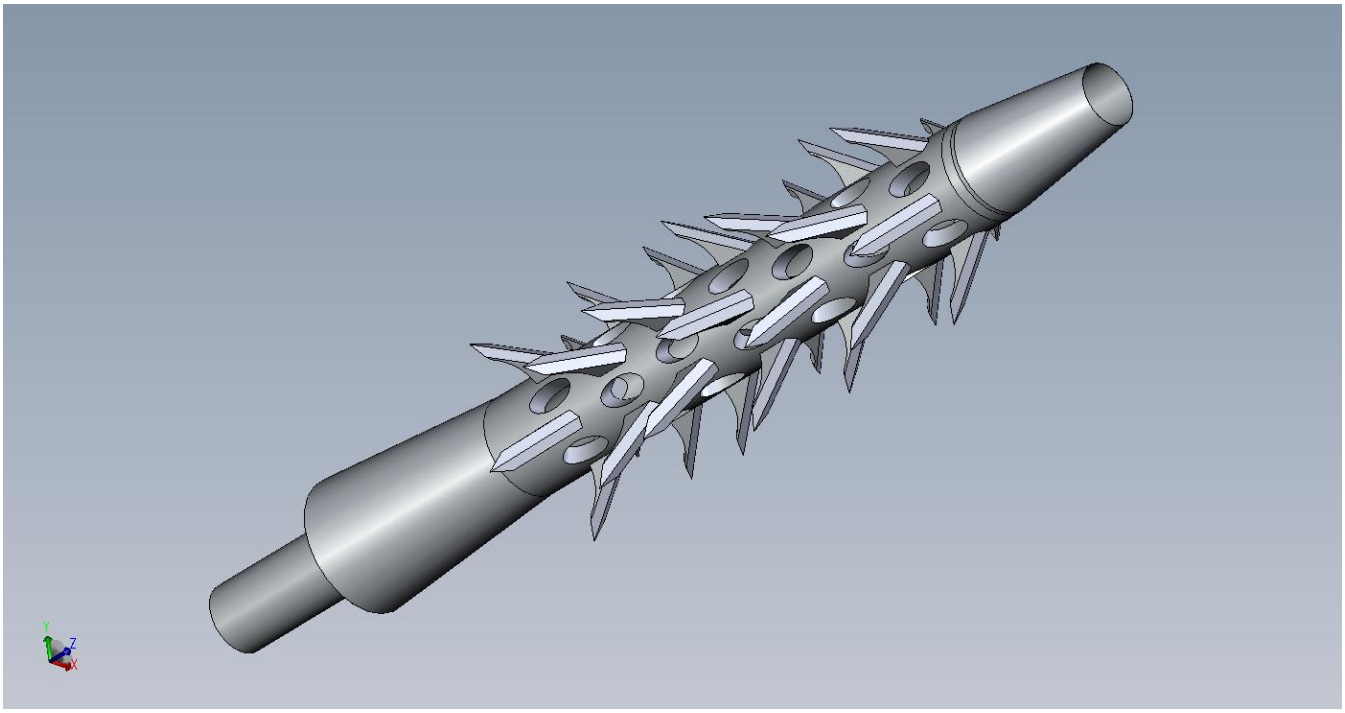


Figure 3. CAD drawing of revised Dart Concept 8-1rev3 to randomize anchor tine positions – October 2009

IMPACT/APPLICATIONS

This NWFSC effort supports the national ASTWG initiative to increase NMFS's ability to monitor protected marine resources in order to improve stock assessments for MMPA species or assess critical habitat to meet ESA requirements.

TRANSITIONS

None at this time.

RELATED PROJECTS

This project is closely related to a recent ONR NOPP BAA to improve tag attachments of cetacean tags and this effort was dovetailed into a propossl to ONR for related work.

PUBLICATIONS

None at this time.

PRESENTATIONS

None at this time.

EXPENDITURES

NWFSC was allocated $15K for dart attachment development which is obligated in a contract to Origins LLC for dart design and construction.

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

List of project progress reports:

-Development of the NOAA Fisheries Autonomous Underwater Vehicle

-Multi-scattering detection, enumeration, and identification of anadromous species during migrations in streams and rivers.

-Remote detection and identification of marine animals in improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON)

-Evaluation of bioelectrical impedance analysis (BIA) to measure fish energy density and reproductive potential for stock assessment.

-Development of an Optical Sampling Trawl (OST) for use in groundtruthing species and size composition of acoustic back scatter, and fine-scale, non lethal sampling.

-Working from top to bottom with the ME70 multibeam sounder: simultaneous water column and seafloor mapping.

Other reports

-Response to Steve Murawski's questions on the ME70 hydro-acoustic system

-Measurement of vessel radiated noise with moored hydrophones

-NOAA Vessel Acoustic Management Plan Recommendations Compiled during a workshop held 28-29 July 2009.

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

Project Title: **Development of the NOAA Fisheries Autonomous Underwater Vehicle**

INVESTIGATORS

Dr. G. 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

Joe Godlewski[3]
Joseph.Godlewski@noaa.gov

T. 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, 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
[3] NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA

PRIORITIES

The NOAA Fisheries AUV (Figure 1) is designed to conduct ecosystem-based fish stock assessments, autonomously.

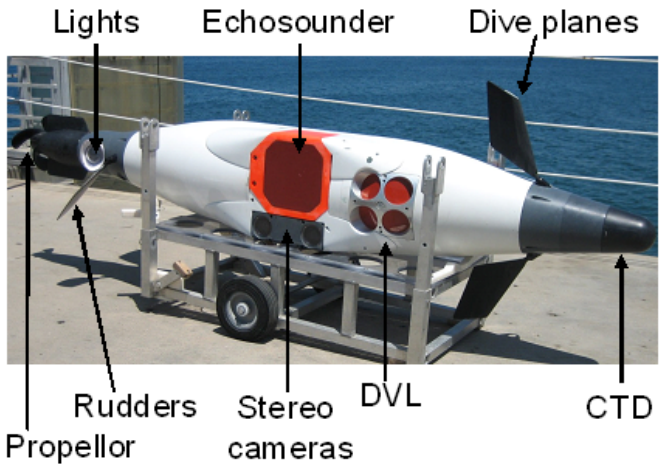


Figure 1. NOAA Fisheries AUV, on its side to show instrumentation.

The goals for the NMFS AUV Program were discussed at the Fall meeting of the ASTWG. This project's principal goals were to operationalize the AUV for surveys and

to conduct a fisheries ecosystem survey using the AUV (and completing the long sought demo project). Other goals included: refining control code; procuring and integrating a new motion controller board; procuring a new light source; supporting travel for collaborating scientists from other Centers; revising stereo camera control code; conducting a survey for rockfish (*Sebastes*) and rockfish habitat on previously surveyed bank off southern California; reprogramming the DVL; and contracting design and fabrication services for replacement parts.

APPROACH

AUV design and control software were refined or repaired via laboratory and tank testing at SWFSC, and field trials in the ocean nearshore of La Jolla, California. Collaboration between Southwest, Southeast, and Northeast Fisheries Science Centers was vital for accomplishment of several goals and ultimately the survey-readiness and survey completion.

WORK COMPLETED AND RESULTS

Accomplishments of the AUV project during FY2009 included collaborative development leading to a survey-operational AUV, and successful completion of a survey for rockfish and their seabed habitat.

<u>Collaborative development achievements</u>

- SWFSC, SEFSC, NEFSC
    - C. Thompson and J. Godlewski visited SWFSC in July
    - C. Thompson visit in Aug., and participated in a rockfish survey in Sep.
- Revised code
- Deployments nearshore
- Recovery of failed flight system computer
- Rebuild of failed payload computer
- Migrated stereo cameras to payload computer
- Attempted boat-based nearshore survey of rockfish
- Improved camera acquisition rate
- Integrated high-intensity LED light sources
- Broadcast GPS data (from GPS and DR) from flight computer via UDP using LabView VI, and read by ER60 on payload computer
- Sent EK60 depth to flight computer
- Consolidated mission data into a single file
- Aligned and reprogrammed the DVL

<u>Nearshore deployments</u>

- Location: Scripps Canyon off La Jolla, California
- 8 days of deployments over ~ 2 months
    - 17 June; 16 July; 12, 13, 17, 19, 21, 25 August

Results from nearshore deployments included multi-leg missions and collection of echosounder and stereo-camera images of fish from near Scripps Canyon (Figure 2).

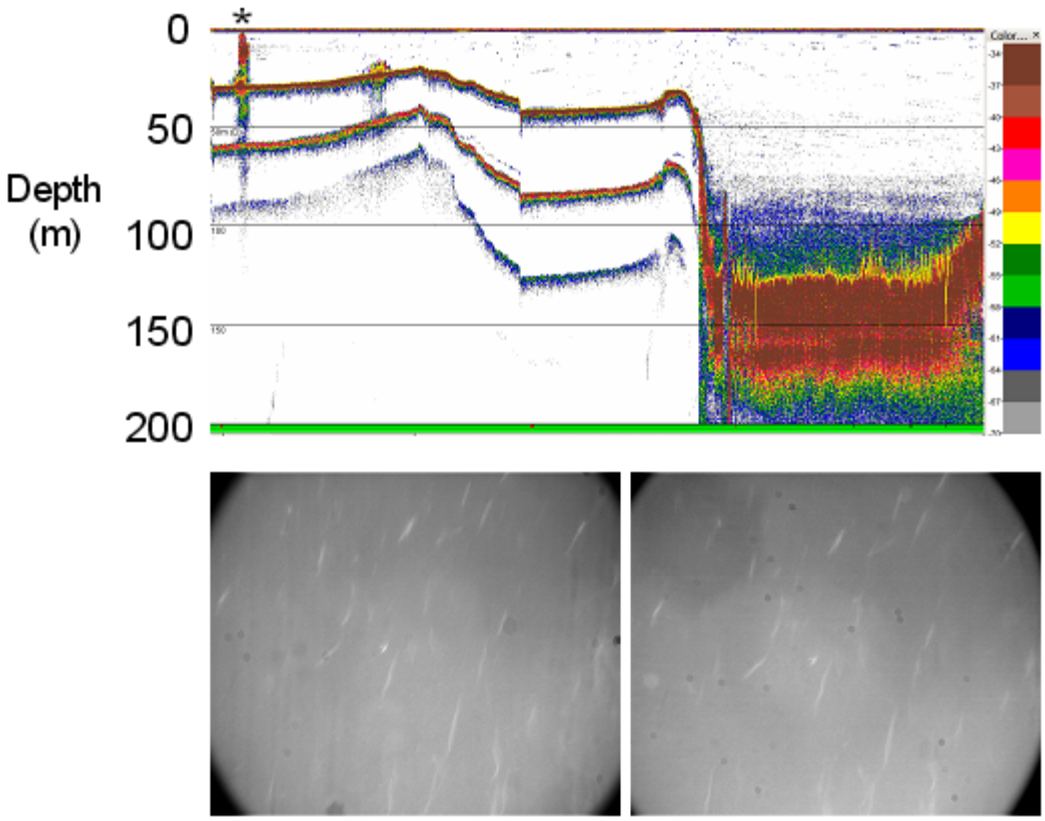


Figure 2. a) Echogram from the AUV's 38 kHz EK60, and b) left and right stereo camera images from the location in the echogram marked with the asterisk, showing a school of small pelagic fish (anchovy or sardine).

Open-Ocean Deployment and Rockfish Survey

During 21-24 September, 2009, we completed a survey of 43 Fathom Bank located at approximately 32° 39.25' N, 117° 58.25 W' and 75 km west of San Diego, California (Figure 3). The survey was conducted from the chartered vessel F/V *Outer Limits* (San Diego, California) outfitted with a hull-mounted 5-frequency EK60 echosounder array (18, 38, 70, 120, & 200 kHz), 120 & 200 kHz sidescan sonars, and Seabird CTD.

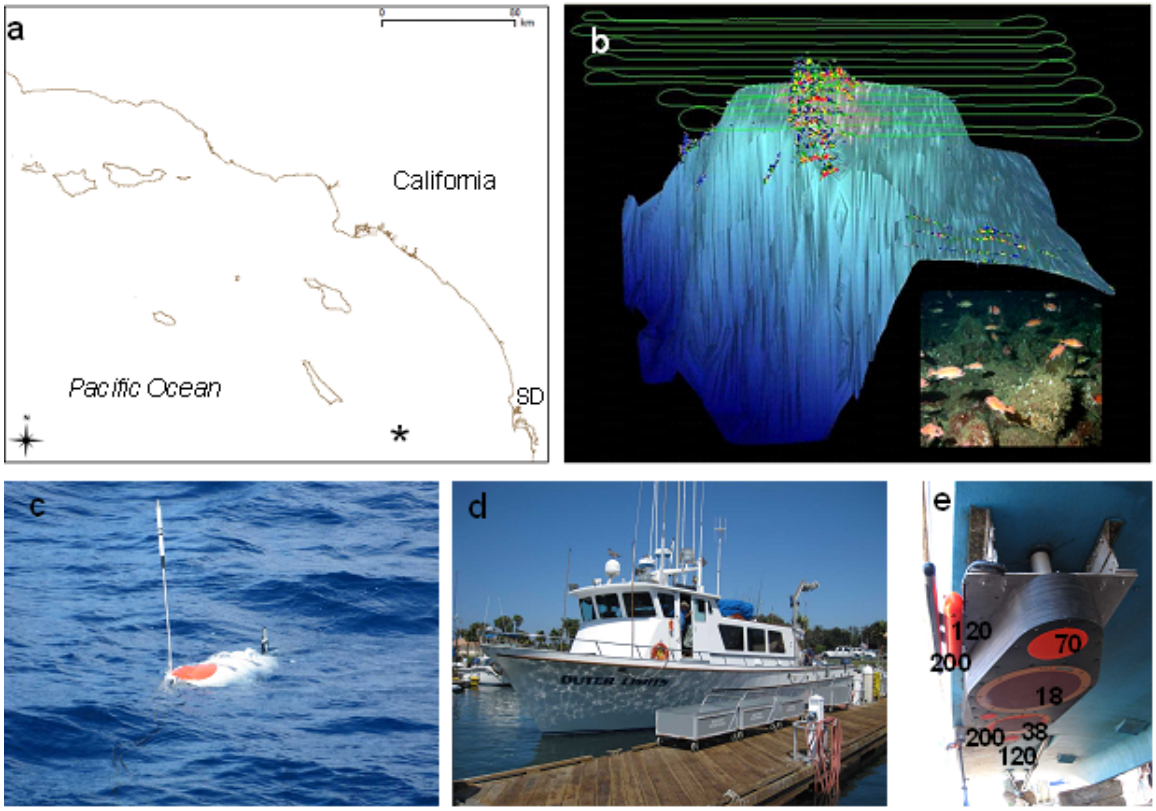


Figure 3. a) 43 Fathom Bank study area, b) bathymetry and rockfish data from previous echosounder and ROV survey, c) AUV in the ocean during the survey, d) vessel and e) hull-mounted transducer and sidescan array used during the AUV rockfish survey of 43 Fathom Bank.

The survey involved echosounder, sidescan and CTD sampling from the vessel, and echosounder, stereo-camera and CTD sampling from the AUV. The survey operations involved completing a sidescan survey using the vessel to search for hazards to the AUV (e.g. derelict fishing gear). After the sidescan survey, during night, we began the vessel-based EK60 survey. During daylight, we conducted the AUV operations, including the EK60 survey, until its batteries required charging. Simultaneously, we also conducted a vessel-based EK60 survey during the day. Overnight, we conducted a continuous vessel-based EK60 and sidescan survey. Command and control of the AUV was from the vessel via ethernet radio communications.

Appoximately 24 km of tracklines were surveyed by the AUV during the two days at sea (Figure 4). Other mission summary is provided in Table 1.

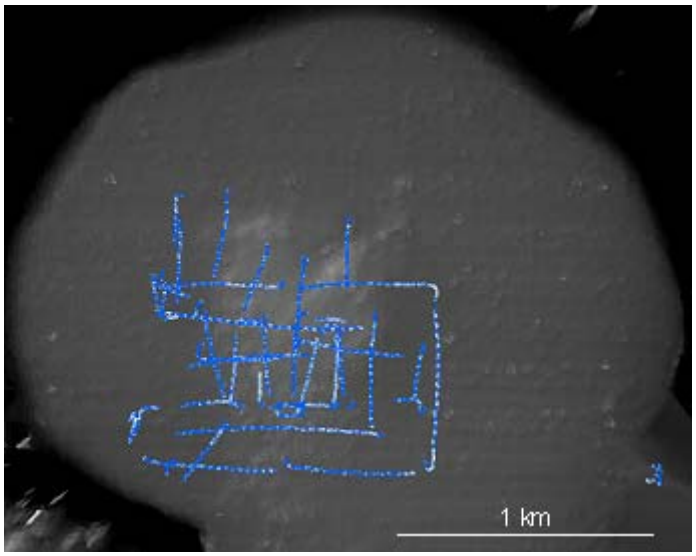


Figure 4. AUV tracklines during dives (blue) shown over a bathymetric surface from a multibeam echosounder survey of the top of 43 Fathom Bank (gray level indicates relative depth).

<u>Table 1. Summary of AUV survey missions</u>

- 18 missions
- 9 multileg missions (3 restarted because of aborted dives)
  - Two of the ML missions ~ 45 min each
  - Culminated in a ML mission with 14 legs, total duration of 1.25 hours, 10-m target depth
- Total survey distance (including surface intervals) coverage: ~ 24 km
- Typical speed: ~ 600 RPM, 1.3 m/s, 2.5 knots
- Payloads, continuously operating: EK60 (38-kHz, 1-s interval); DVL; CTD; stereo camera (3-s interval); high-intensity LED lights (continuous).

Results from the AUV survey of 43 Fathom Bank include echosounder, stereo-camera, CTD, and DVL data. Echograms from the AUV's EK60 reveal the seafloor, large rockfish aggregations over the rocky peak of the bank, and dispersed fish and plankton (Figure 5). Echograms also show that data during dives included less noise and more details from scatterer aggregations compared to surface intervals where waves and swell induced AUV motion. Consider, for example, the regions from 0 to 50 m in the first surface and dive intervals.

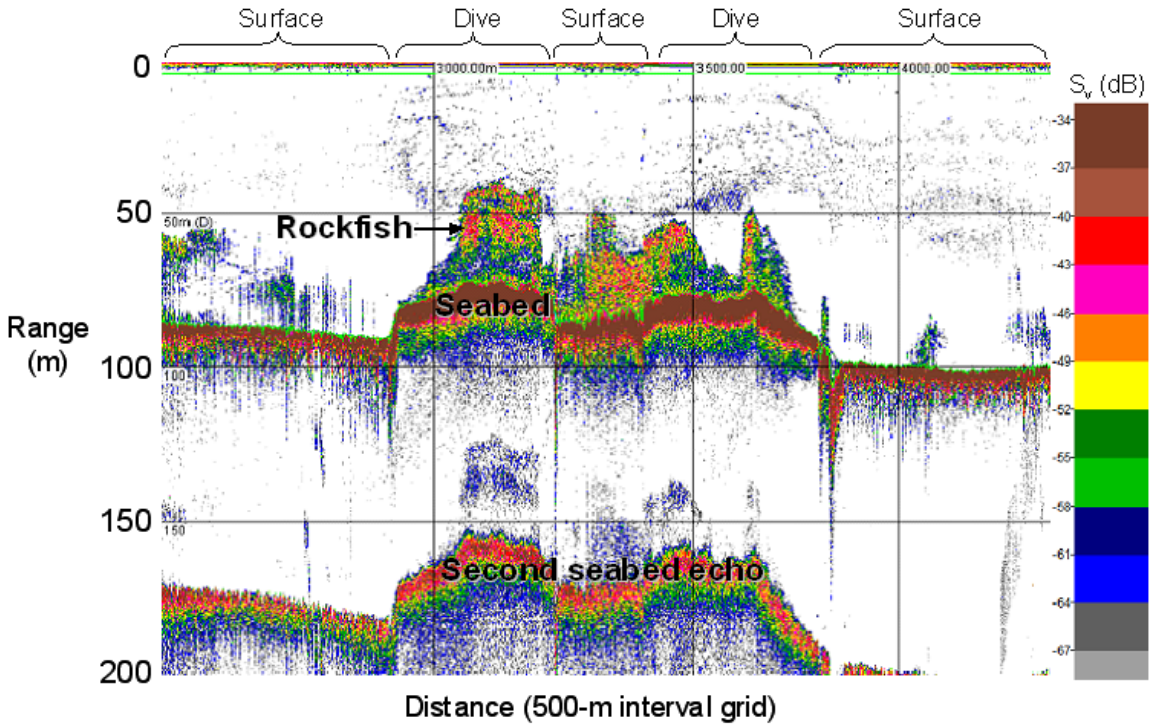


Figure 5. Echogram from the AUV's 38-kHz EK60, collected from 43 Fathom Bank, showing volume backscattering strength (S_v) versus range below the transducer and track distance.

Stereo images recorded small pelagic fish evident in the echograms (Figure 6). Motion blur occurs because the light source was operated in continuous mode and the camera electronic-shutter rate was in automatic mode and the exposure duration was too long to stop the motion. The new LED light sources allow triggering and strobing, and will solve this problem. Despite the motion blur, the lengths of these fish can be estimated from the stereo pairs.

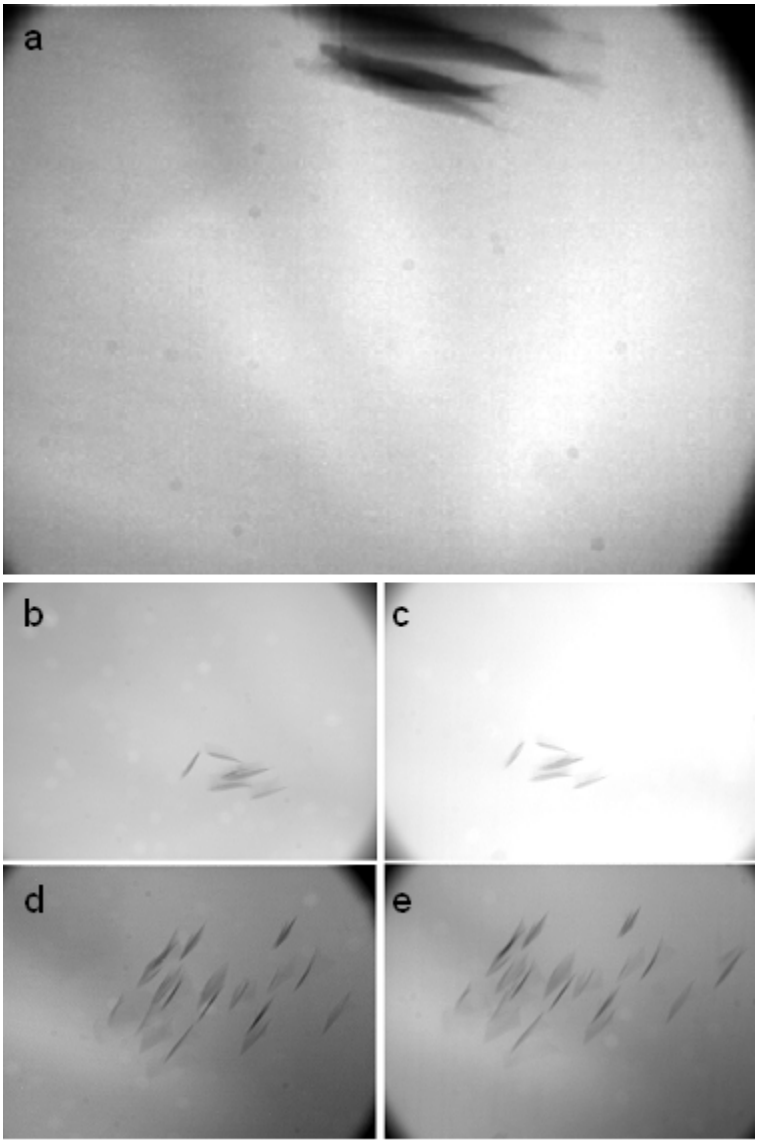


Figure 6. Images from the AUVs stereo cameras. a) Image from one of the AUV cameras showing small pelagic fish that appear in the echogram in Figure 5 near the end of the first dive segment; b-e) left- and right-camera image pairs with examples of small pelagic fish.

Using a variant of the new multifrequency biplanar interferometric (MBI) imaging method developed by Cutter and Demer (2009), the spatial location, within the beam, for each of the samples from the AUV's EK60 was calculated. An example of the biplanar interferometric (BI) solutions from the single-frequency echosounder are shown for a portion of the EK60 data in Figure 7, after filtering the background noise. The residual data represent individuals and aggregations rockfish and pelagic fish and plankton. The rockfish were distributed from the seabed to approximately 50 m above the seabed in some areas, during the daytime.

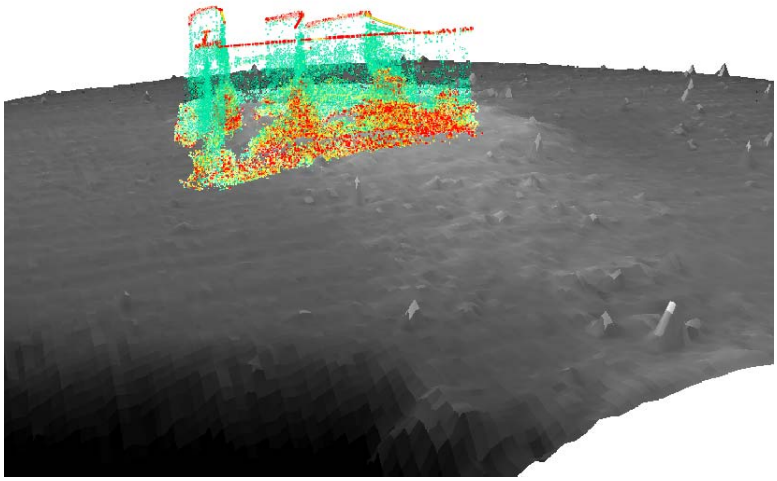


Figure 7. Bidirectional interferometric imaging solutions from the AUV's EK60 S_v data, rendered in 3-D over a bathymetric surface from an earlier multibeam survey.

References

Cutter, G. R. and Demer, D. A. Multifrequency, bi-planar, interferometric imaging. *Geoscience and Remote Sensing Letters*, 7(1):000-000, doi: 10.1109/LGRS.2009.2029533 (online 2009; print 2010).

IMPACT/APPLICATIONS

During FY2009, significant progress was made with the development of the AUV, such that it is now considered operational for ocean surveys.

TRANSITIONS

During FY2010, we plan to conduct at least two more ocean surveys using the AUV, in collaboration with other Science Centers, and augment vessel-based surveys with the AUV for comparisons with standard survey products.

RELATED PROJECTS

None.

PUBLICATIONS

None.

PRESENTATIONS
G. R. Cutter. Update on the Status of the ASTWG AUV program. ASTWG meeting, Miami, Florida, 18 November, 2009.

HONORS/AWARDS
None.

EXPENDITURES
In FY2009, ASTWG funds ($108k) were used for AUV maintenance, repair and replacement parts, supplies, contracted labor, transportation, travel and training.

Advanced Sampling Technology Working Group
2009 Progress Report to
The Office of Science and Technology

TITLE: Multi-scattering detection, enumeration, and identification of anadromous species during migrations in streams and rivers

INVESTIGATORS:

David A. Demer
Josiah Renfree
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla CA 92037

Sean A. Hayes
R. Bruce MacFarlane
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

GOALS

Surveys of anadromous species, salmonids in particular, are difficult and expensive, and their results often have high uncertainty. All forms of technology explored to date have failed to provide accurate counts of individual fish (5-20 cm) in turbulent and often large rivers. We propose using a new multi-scattering technique to detect and classify salmon by the ratio of their incoherent and coherent sound fields.

PRIORITIES

Recently, a multi-scattering technique has been developed to characterize, enumerate, and monitor the behaviors of fish swimming in tanks (Conti and Demer, 2003; Conti et al., 2007; Conti et al., 2006; Demer et al., 2003). This method detects and characterizes moving objects by the ratio of the incoherent and coherent sound fields. In stark contrast to other acoustic methods, this technique works best in reverberant conditions. It utilizes broad bandwidth signals for target identification and has the potential to overcome all of the above-mentioned logistical challenges. Therefore, we propose to adapt this technique to detect, identify species and sizes, and then enumerate anadromous salmonids during their fresh water migrations.

APPROACH

Use the multi-scattering technique to: 1) measure the scattering spectra of multiple species of salmon smolts versus their sizes; and 2) adapt the broad bandwidth multi-scattering method to the detection, enumeration, and identification of salmon smolts in streams during their spring migration. Results will be validated with data from traditional fish traps. This work will provide a solid foundation for subsequent refinement of the automated hardware, and its application to assessments of juvenile and adult fish in streams and rivers.

WORK COMPLETED

The multi-scattering technique was used to measure the broad bandwidth sound scatter from hatchery reared coho, steelhead and Chinook salmon smolts (lengths = 50-250 mm). The smolts were transported from Santa Cruz to La Jolla, CA and measured in the SWFSC's multi-scattering hyperbaric tank.

Broadbandwidth transducers were purchased for the field experiments. Laboratory experiments were conducted to refine the measurement apparatus and analysis methods before conducting the field work during the spring migration in 2010.

RESULTS

The multi-scattering technique was used to measure the broad bandwidth sound scatter from hatchery reared coho, steelhead and Chinook salmon smolts (lengths = 50-250 mm). These data (Figure 1) were used to derive empirical models of scattering cross-sectional areas versus species and lengths. Optimal frequencies and bandwidths were determined for the field measurements.

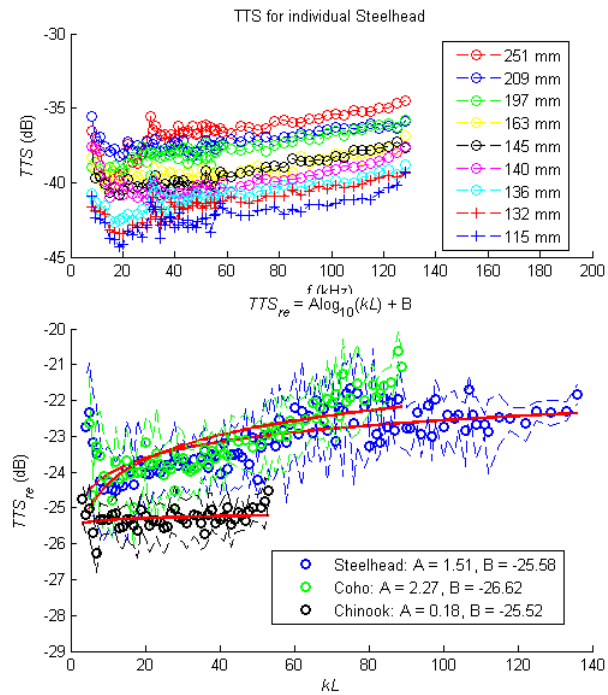


Figure 1. (a) Total scattering cross sections σ_T of individual steelhead salmon from f = 5 to 130 kHz, versus kL ($k=2\pi f/c$). Data indicate large length-dependent *TTS* which can be used for classification. (b) Reduced TTS for steelhead (blue), coho (green) and chinook salmon (black), from a pilot study. The red lines correspond to linear regressions of the data for each species.

IMPACT/APPLICATIONS

Currently NMFS and other Federal and State agencies spend tens of millions of dollars each year on counting anadromous species during their river migrations with both extensive labor and equipment costs- in spite of this, many of these efforts report low capture efficiencies and unacceptably large confidence intervals for stock estimates. This technique has the potential to robustly detect anadromous fish moving through reverberant corridors, identify their species and sizes, and thus provide accurate enumerations.

TRANSITIONS

None at this time.

RELATED PROJECTS

This project is closely related to, and is making use of the multiscattering hyperbaric tank system developed via a previous ASTWG project.

PUBLICATIONS

Renfree, J. S., Hayes, S. A., and Demer, D. A. 2009. Sound-scattering spectra of steelhead (*Oncorhynchus mykiss*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids. *ICES Journal of Marine Science*, 66: 1091–1099.

PRESENTATIONS

Renfree, J. S., Hayes, S. A., and Demer, D. A. Sound-scattering spectra of steelhead (*Oncorhynchus mykiss*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids. ICES Symposium on the Ecosystem Approach using Fisheries Acoustics and Complementary Technologies, June 2008, Bergen, Norway.

EXPENDITURES

Grant total = $88k

REFERENCES

Conti SG, Demer DA, 2003. Wide-bandwidth acoustical characterization of anchovy and sardine reverberation measurements in an echoic tank. *ICES Journal of Marine Science* 60:617-624.

Conti SG, Maurer BD, Drawbridge MA, Demer DA, 2007. Measurements of total scattering spectra of bocaccio rockfish (*Sebastes paucispinis*). *Fish. Bull.* 105:153-157.

Conti SG, Rosny JD, Roux P, Demer DA, 2006. Characterization of scatterer motion in a reverberant medium. *J. Acoust. Soc. Am.* 119:769-776.

Demer DA, Conti SG, J. DR, Roux P, 2003. Absolute measurements of total target strength from reverberation in a cavity. *J. Acoust. Soc. Am.* 113:1387-1394.

Renfree, J. S., Hayes, S. A., and Demer, D. A. 2009. Sound-scattering spectra of steelhead (*Oncorhynchus mykiss*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids. *ICES Journal of Marine Science*, 66: 1091–1099.

Northeast Fisheries Science Center FY09 Annual Report for: Remote detection and identification of marine animals to improve fish and habitat assessment using a Dual Frequency Identification Sonar (DIDSON)

(Representatives: Mike Jech, 508-495-2353, Michael.Jech@noaa.gov; Joseph Godlewski, 508-495-2039, Joseph.Godlewski@noaa.gov; Christine Lipsky, 207-866-4667, Christine.Lipsky@noaa.gov)

GOALS

Recently, the Dual Frequency Identification Sonar (hereafter DIDSON; Ocean Marine Industries, Inc.) was developed to reduce the problem of fish avoidance to artificial lighting. 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. The goals of the NEFSC projects in FY2009 were to identify several species of diadromous fish according to fish size and swimming behavior and to observe and quantify Atlantic herring (*Clupea harengus*) *in situ* behavior.

PRIORITIES

American shad and several other diadromous species do not currently use the fish ladder at Veazie Dam in Veazie, Maine, and as a result, their abundances are unknown. Our objective for this study was to observe fish that may not be inclined to move up the fishway and to positively identify American shad at the mouth the fishway using the DIDSON.

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 was mounted near the mouth of the fishway at the Veazie Dam in Veazie, Maine using a track system, so the height of the unit could be adjusted with changing tides or flow regimes (Figure 1). The DIDSON was aimed along the dam face in order to detect fish milling below the dam.

The DIDSON sonar was mounted to the NEFSC's Advanced Fisheries Tow Vehicle (AFTV) and deployed off the FRV DELAWARE II during Sept. 2009. 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 AFTV.

WORK COMPLETED

The DIDSON was deployed on June 16 (Figure 1) and recorded images continuously for a one-month period. A preliminary review of a subsample of images was reviewed to determine approximate fish length and to analyze swimming behavior. These images were compared to DIDSON images of known American shad from a concurrent study.

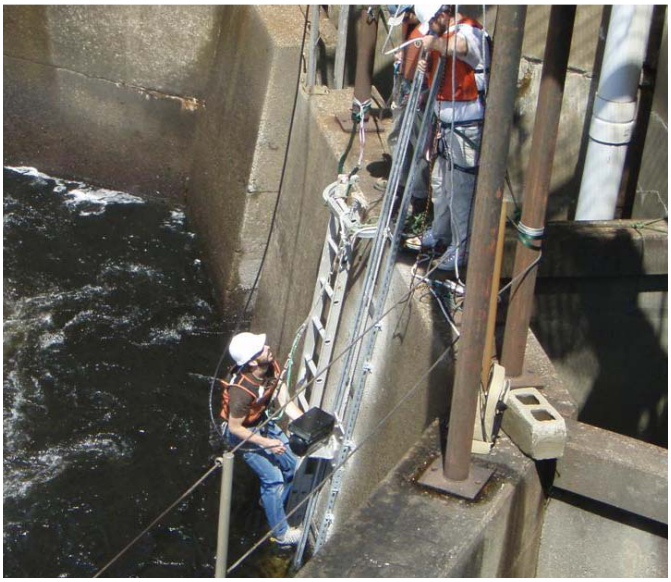


Figure 1. DIDSON being deployed by attaching to a track mount on the side of the Veazie Dam fishway.

We have incorporated a Dual-Frequency Identification Sonar (DIDSON) in the nose of the AFTV to quantify fish behavior (Figure 2).

Figure 2. AFTV being retrieved onto the FRV DELAWARE II during the Atlantic herring acoustic survey in Sept.-Oct. 2009. The DIDSON is mounted in the nose of the vehicle on a Pan & Tilt unit.

RESULTS

The images taken below the dam are highly suggestive of American shad milling below Veazie Dam. The images will be reviewed more thoroughly this winter, and we will attempt to identify other fish species in the assemblage below the dam.

The DIDSON sonar was deployed on the northern flank of Georges Bank during the NEFSC's annual acoustic survey of Atlantic herring in September – October 2009. 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.

IMPACT/APPLICATIONS

The Penobscot River is home to a variety of diadromous species, but little is known about their abundance. Since several dams will be removed from the river in the near future, there is interest in restoring these species to historic levels. In order determine the most appropriate restoration strategies for these species, baseline abundance is needed. Since this river system is home to at least two federally listed species under ESA, the ability to use many methods commonly used in fisheries research is limited. Therefore, the DIDSON is an ideal non-invasive tool that can be used to help in determining relative species abundance, migration timing, and behavior, which will aid management with restoration priorities in the future.

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.

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

Quantification of Shortnose Sturgeon in an Overwintering Site in the Penobscot River, Maine, using DIDSON (C. Lipsky, NEFSC and G. Zydlewski, UMaine), FY08, FY10

American shad in the Penobscot River-using telemetry, models and DIDSON to inform recovery. Joseph Zydlewski, Michael Bailey, Christine Lipsky and Ann Grote. FY10

A study to begin in January 2010 is aimed at understanding the factors influencing American shad recovery in the Penobscot River. Current presence in the River, areas of use and the availability of habitat after dam removals will be considered. Work in 2009 using a DIDSON (Dual frequency IDentification SONar) has produced exciting images of shad in the open river. Additionally, six American shad were successfully captured (electrofishing), radio tagged, released and tracked. Modeling efforts have produced a useful construct to assess the potential for population recovery.

PUBLICATIONS

PRESENTATIONS

Jech, J. M., and J. Godlewski. 2009. Observations of Atlantic herring using DIDSON sonar. ICES WG-FAST, Ancona, Italy, May 2009.

Progress Report- FY09 ASTWG: Evaluation of bioelectrical impedance analysis (BIA) to measure fish energy density and reproductive potential for stock assessment (Mark Wuenschel, NEFSC, Mark.Wuenschel@noaa.gov, 508-495-2276, Gary Fitzhugh, SEFSC, 850-234-6541 x214,Gary.Fitzhugh@noaa.gov, Rich McBride, NEFSC, 508-495-2244, Richard.McBride@noaa.gov)

GOALS

Develop and test modifications of BIA technology to measure energy density as a proxy for fish condition with a variety of marine groundfishes. Determine the accuracy, precision, and cost-effectiveness of such measures of fish condition. Implement this technology across seasons and species to explore BIA as an ecosystem indicator of environmental productivity and reproductive cycles. Establish linkages (correlations) between BIA measures of condition and the energy available for reproduction to provide alternative (non-fecundity) measures of reproductive potential for stock assessments.

PRIORITIES

In many fishes, the energy allocated to growth and reproduction (surplus energy) is accumulated from pulses of environmental productivity. Estimates of fish condition are typically derived from length-weight data, and assume that heavier fish of a given length are in better condition. However, methods based on whole body weight may obscure more complex (asynchronous and/or inverse) seasonal patterns of energy allocation to different organs and tissues of the body (e.g. gonads, liver, muscle) that occurs in many fishes. Recent studies have proposed bioelectrical impedance analysis (BIA) as a rapid, non-lethal method to determine the proximate composition and energy density of fishes. Our priority objective is to apply this technology and to test its ability to predict energy density in marine groundfishes. This has required equipment modifications to improve repeatability of measured values. Herein, we outline these modifications and present preliminary data demonstrating good precision of BIA estimates in relation to water content, dry weight, and predicted energy density for several species.

APPROACH

A simple device was constructed to use a commercially-available BIA system (RJL Sytems Inc.) to fishes. The system consists of a nonconductive fish measuring board, with moveable articulating electrode holders. The holders can accommodate different needle/electrodes, and allow for the easy replacement of electrodes, and adjustment of electrode depth. These properties make this system easily adaptable to different species and sizes of fishes. The device is constructed of readily available material, and the specifications listed and diagram should allow for its replication by any experienced carpenter/machinist. The performance of this system was evaluated by repeated measures on a number of individuals of various species. A metabolic condition index, based upon phase angle (degrees) was determined from the BIA measures of resistance and reactance using the following equation:

$$PHASE\ ANGLE\ (°) = \left(\arctan\left(\frac{REACTANCE}{RESISTANCE}\right)\right) \times \frac{180°}{\prod}$$

Phase angle is sensitive to body condition and may be sensitive to medium-term metabolic states (e.g., integrated over weeks) as well. The advantage of phase angle measurements in either human or animal applications is that BIA technology may be used effectively without the need for expensive calibrations and regression to estimate proximate composition. Therefore, variability in determinations of phase angle for individuals should only be a result of body mass differences where measurements may differ due to electrode placement and penetration, and not due to possible errors associated with extrapolation to proximate composition.

WORK COMPLETED

Using previously published methods for applying BIA technology to relatively small-sized freshwaters fishes, our initial attempts to apply BIA to medium to large-sized marine groundfishes identified several shortcomings which might lead to sources of error. Therefore, we designed and built a prototype BIA measuring board (below) to circumvent these problems and reduce the level of 'noise' in BIA readings.

Figure 1. Technical rendering of the newly designed BIA measuring board and probe assembly (left) and the prototype in use to measure BIA on pollock at sea aboard FSV Henry B. Bigelow.

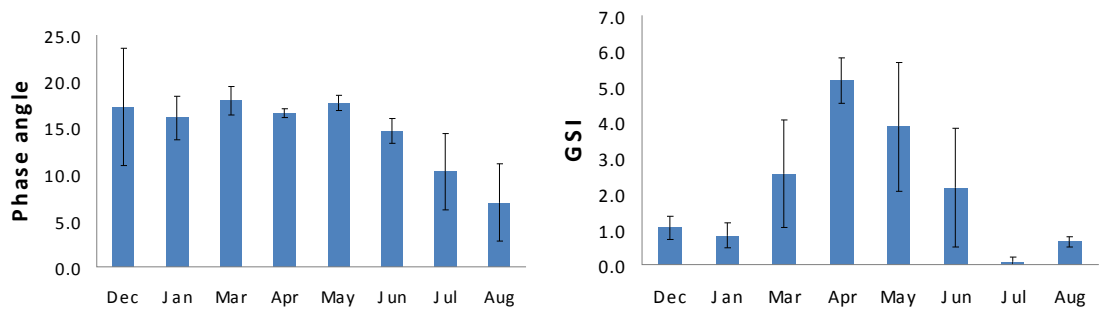
Side-by-side comparisons of previous probe configurations and our new probe and measuring board on the same individuals indicated a significant reduction in the coefficient of variation in BIA readings with the new board and probes. We have also completed repeated measures analysis on groups of fish to determine how the length of time after capture and period on ice affects BIA measures. This information further enhanced our ability to establish protocols for applying this technology to specimens sampled under various means (i.e. port samplers, cooperative study fleet etc.).

RESULTS

The newly developed measuring board and probe system produced stable and reliable readings from bioelectrical impedance analyzers, and is relatively inexpensive (and easy) to construct. This new apparatus was tested on a number of fish species, and has several advantages over earlier devices. To date, we have collected BIA data on the following species from a variety of sampling activities (surveys and cooperative study fleets); red hake, Acadian redfish, haddock, cod, pollock, winter flounder, American plaice, yellowtail flounder, Atlantic herring, tilefish, and black sea bass. Preliminary analyses demonstrated high r^2 values (0.92->0.99) for relationships of total body water, wet and dry weights predicted from BIA measures to observed weights for most species, with the

exception of flatfishes which had generally lower r^2 values. Although the r^2 values were high for many species, the slopes differed from 1. Therefore, we conclude that previously published regressions, primarily for freshwater species, cannot be applied to the groundfishes or sea basses of primary interest to the NEFSC and SEFSC. Moreover, in the case of flatfishes, a new model formulation may be needed. Nonetheless, new and useful calibration models appear attainable because constituent relationships determined in different seasons did not vary significantly for the groundfishes examined so far.

While constituent relationships (e.g. body water- body mass functions) did not differ seasonally, we did find that BIA measures are sensitive to seasonal cycles. In an examination of monthly samples of golden tilefish during 2009, BIA indicated that composition changes had occurred over the spawning cycle and were detectable among females with differing reproductive states. Phase angle decreased below 15% following the peak spawning period (GSI) and was distinctly lowered in post-spawning (resting) females (Figure 2). This trend, which suggests available energy had decreased, was not evident from other, more traditional measures of condition including body-muscle water content, and Fulton's *K*. In addition, tilefish exhibited no obvious visual cycles of fat deposition (such as mesenteric fat), which makes a tool like BIA worth full investigation for it's utility in tracking energetic condition.



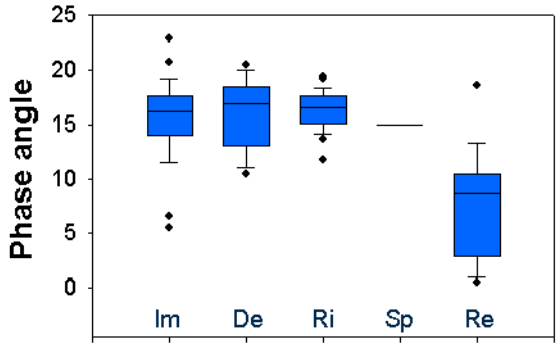


Figure 2. BIA estimated phase angle and gonadosomatic index (GSI) of female tilefish from monthly collections (above) and the relationship between phase angle and maturity classification (left, Im – immature, De- developing, Ri, ripe, Sp-spent, Re-resting).

IMPACT/APPLICATIONS

Our progress in modifying and testing this devise in the marine environment on economically-important groundfish species is encouraging. We are ready now to establish species-specific calibration curves for these species and test experimentally the effect of food consumption rate as the energetic mechanism affecting energy density as measured by BIA in black sea bass.

TRANSITIONS

We have completed the first phases of this research project, namely, equipment modifications to improve repeatability of measured values, development of protocols for using BIA (time after death etc.) and limited application to test if this technology provides useful information on the seasonal patterns of energy allocation in a variety of marine fishes. Our results indicate that this technology does indeed show promise, and is worth continued evaluation. To that end, we are now prepared to proceed (given continued funding) forward with our evaluation process. Additional phases proposed/underway include a broader field application of BIA across species and seasons, calibration and validation of BIA indices to laboratory analyses of proximate composition, and a laboratory experiment to test the correlations between BIA measures of fish condition at various points in time and the reproductive condition of those individuals. We have recently brought live specimens (black sea bass, *Centropristis striata*) into the laboratory where we will rear them under different rations through the winter-spring period of gonad development. Ongoing testing aboard NEFSC bottom trawl surveys is also expected.

RELATED PROJECTS

The Special Symposium on BIA at the most recent annual meeting of AFS culminated in a panel discussion of this technology. We participated in this discussion and have agreed to contribute to an informal working group of other NOAA (AFSC) and academic researchers using this technology. A web blog is planned to facilitate sharing of ideas, breakthroughs, and potential pitfalls as BIA is more rigorously tested and applied.

PUBLICATIONS

We have met with Shelly Dawicki (Science writer, Res. Com. Branch, NEFSC) to develop a 'science spotlight' (http://www.nefsc.noaa.gov/press_release/) on this BIA research.

We plan to submit for publication a technical note detailing the improved design and modifications of the BIA measuring board developed for this project.

PRESENTATIONS

Wuenschel, M., and R. McBride. 2009. Evaluation of bioelectrical impedance analysis (BIA) to measure patterns of condition and energy allocation in marine groundfishes. NEFSC Science Symposium. Newport, RI. January 21-23.

Wuenschel, M., R. McBride, and G. Fitzhugh. 2009. Evaluation of bioelectrical impedance analysis (BIA) to measure patterns of condition and energy allocation in marine groundfishes. Special Symposium on bioelectrical impedance analysis. American Fisheries Society. 139th Annual Meeting. Nashville, TN. August 30-September 3 (http://www.fisheries.org/afs09/program.html).

Advanced Sampling Technology Working Group
2010 Progress Report to
The Office of Science and Technology

PROJECT TITLE: Development of an Optical Sampling Trawl (OST) for use in groundtruthing species and size composition of acoustic backscatter, and fine-scale, non lethal sampling.

PRINCIPAL INVESTIGATORS: Kresimir Williams[1], Rick Towler[1], Craig Rose[1], Scott McEntire[1], David King[1], Anne Hollowed[1], Chris Wilson[1]

COLLABORATORS: W. Waldo Wakefield[2]

AFFILIATIONS: Alaska Fisheries Science Center[1], Northwest Fisheries Science Center[2]

GOALS

This project aims to design and build an optical sampling device attached to a conventional trawl to provide length and species composition of fish aggregations. Image-based sampling will enable greater spatial resolution, reduced selectivity, and provide non-lethal sampling of midwater organisms.

PRIORITIES

Primary tasks for FY09 were to: (1) Complete selection, purchasing, initial testing, system assembly, and develop camera control software enabling full field tests of the camera system. (2) Develop basic analysis software to derive manual measurement of fish lengths for comparison with traditional codend samples.

APPROACH

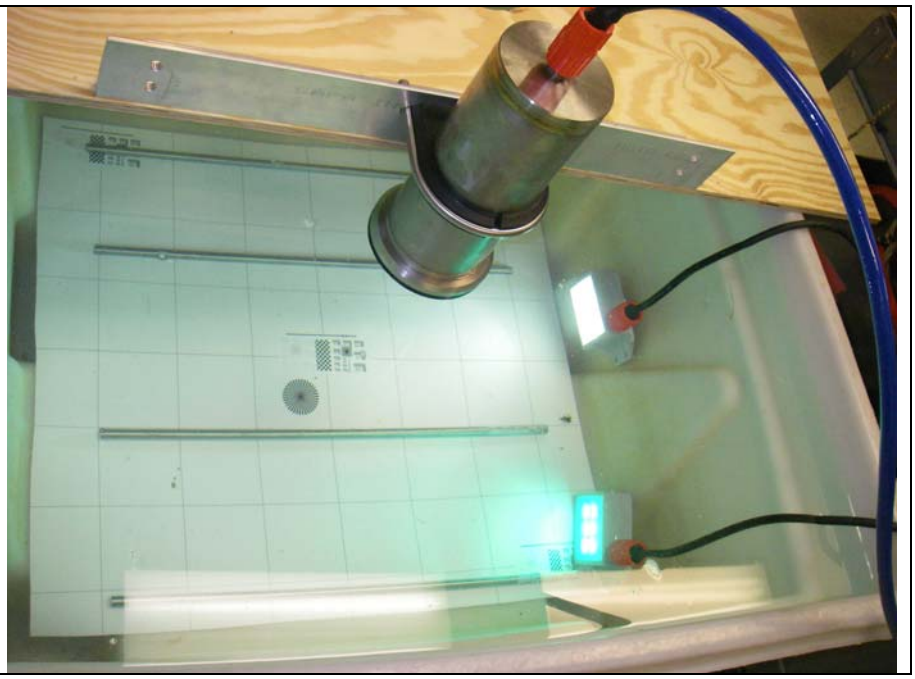
Project work will proceed though a series of sequential phases, beginning with general system design, product research, purchasing, testing, design of customized electronic components, assembly, and finally, field trials. Development of software for camera control and analysis of data will take place in parallel with hardware development.

WORK COMPLETED

System design and purchasing: Cameras, strobes, lenses, computer hardware, and underwater cables were selected and purchased after a comprehensive review of available technology. Underwater housings for the cameras, computer, and batteries were designed and manufactured to specification.
Viewport testing: Three viewport designs were compared in a small tank (Fig 1.) to determine the best option for use with camera underwater housings. Flat, plano-concave, and dome ports were compared for sharpness, distortion, and view angle.
Image writing/compression testing : Initial tests were performed to determine the approximate speed at which raw images could be compressed and written to disk by the low-power Atom-based single-board computer.
Range and lighting testing: The camera and LED strobes were tested in a large dive tank to compare LED strobes and measure performance of the system at ranges up to 6 m.

Due to funding delays, work on this project did not begin until June 2009. Consequently, most software development will take place in winter 2010, and initial deployment is re-scheduled for March 2010.

Figure 1.
Laboratory tank testing setup showing the JAI 4200GE camera outfitted with a 14mm 2.8 lens in a housing.



RESULTS

Customized camera housings, including dome mounting end caps and camera mounting chassis were designed, manufactured and immersion tested in shallow water (<1 m). Pressure housings for the computer and batteries have been designed and manufactured, with current work focusing on instrument layouts. LED lights will be used for the system because of their ability to be operated at speeds of 2-5 Hz, small size, and power efficiency. The LEDs will be pulsed (strobed) at 2 ms bursts, which will be sufficient to capture fish targets moving at 1.5 m/s though the image space without blurring. Two LED strobe prototypes were constructed (one using white and one using green LEDs) by casting the circuit board with the LEDs into an aluminum housing using clear epoxy resin, which removed the need for an o-ring-based housing and viewports (Fig. 2).

Viewport tests revealed that a dome port would be most suitable as it provided a wide angle of view while minimizing distortion and provided adequate sharpness. Domes were manufactured to specification to complement the optical design of the wide angle lenses.

Spectral outputs of different color LED strobes were compared with a theoretical seawater spectral tranmittance curve and the sensitivity of the monocrome CCD sensor used in the cameras (Fig. 3). Although green light LEDs were expected to be superior in terms of reduced absorption loss and near-peak CCD sensitivity, the white LEDs preformed better in the field (Fig. 4, upper panels). Histograms of the 8-bit pixel values (Fig. 4, lower panel) from the white square target seen in the images showed that the white LEDs resulted in a 65 % brighter image of the target at 4 m. This finding may be due

in part to an apparent higher efficiency in the white LEDs which are a newer generation product relative to the green light LEDs.

Initial tests of the image acquisition indicated that a mini-pc computer based on an 1.6 GHz Atom processor was capable of compressing and writing eight 4Mp 8-bit monocrome images per second, enabling a 4 Hz sampling rate for the stereo-system. Additional work will be done to optimize the image compression algorithms to potentially increase sampling rates.

Figure 2. View of the LED strobes. Circuit boards containing the LEDs were placed between two layers of epoxy; the bottom layer was thermally conductive to allow heat to dissipate from the LEDs, and the second was clear to allow light transmission.

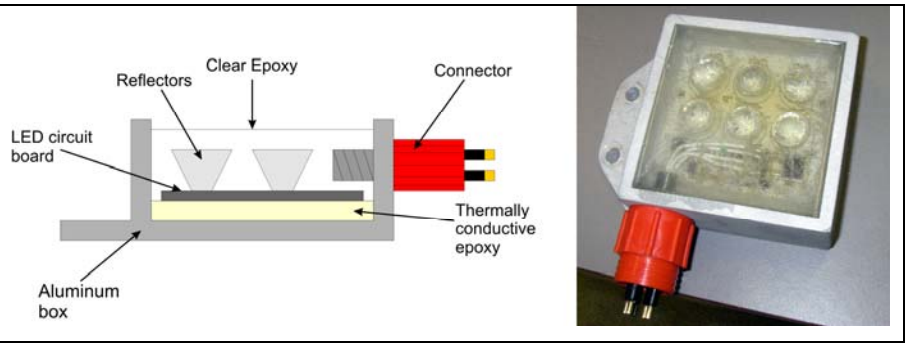


Figure 3.
A comparison of estimated spectral output from white, blue, and green LED strobes related to seawater transmittance and the spectral sensitivity of the Kodak KAI-4021 ccd. The green LED should provide optimal use of lighting in seawater.

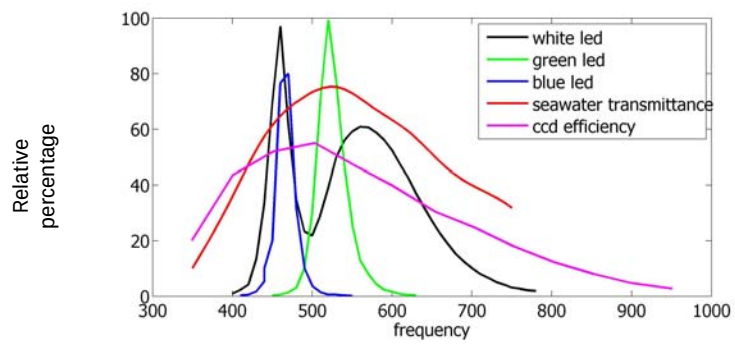
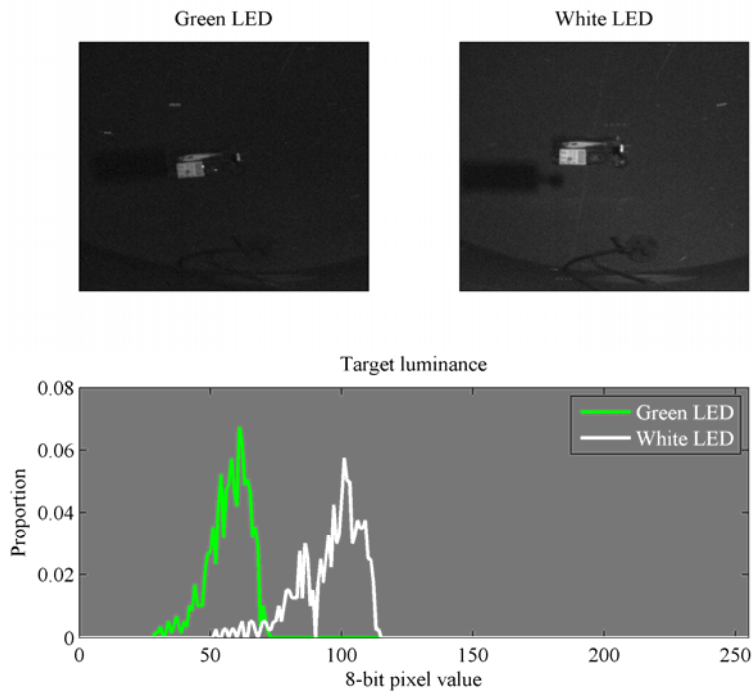


Figure 4.
Results of range and light testing in a large tank. Upper panels show a target 4 m away from the camera illuminated with a green and white strobe. Lower panel shows the brightness comparison of the white square on the target plate in terms of 8-bit (0-255) pixel intensity.



IMPACT/APPLICATIONS

None at this time.

TRANSITIONS

None at this time.

RELATED PROJECTS

None at this time.

PUBLICATIONS

None at this time.

PRESENTATIONS

None at this time.

EXPENDITURES

Total = $38,211

Advanced Sampling Technology Working Group
2009 Progress Report to
The Office of Science and Technology

TITLE

Working from top to bottom with the ME70 multibeam sounder: simultaneous water column and seafloor mapping

INVESTIGATORS

Chris Wilson
chris.wilson@noaa.gov
NOAA NMFS
Alaska Fisheries Science Center
Seattle, Washington

Tom Weber
weber@ccom.unh.edu
Center for Coastal and Ocean Mapping
University of New Hampshire
Durham, NH

David A. Demer
david.demer@noaa.gov
G. Randy Cutter
george.cutter@noaa.gov
NOAA NMFS
Southwest Fisheries Science Center
San Diego, California

GOALS

The Simrad ME70 fisheries multibeam echosounder has been installed on several of the new NOAA noise-reduced fisheries research vessels. The objective of the proposed research is to develop a standard operation mode for the ME70 so that it can be configured to simultaneously collect seafloor information for bottom habitat mapping *and* water column data for other fisheries research and survey needs (e.g., extraction of fish school/layer information).

PRIORITIES

The ME70 shows great potential for both investigations of organisms in the water column and seafloor characterization. However, optimization of sonar configurations and development of ME70 data processing routines currently falls outside of the standard operational procedures for NOAA fisheries research vessels. The objectives of this project are to develop ME70 beam configurations that can be used for simultaneous water column investigations and seafloor mapping, and to develop software algorithms and a processing pipeline for seafloor characterization during routine survey operations.

APPROACH

The ME70 multibeam sonar is user configurable in terms of number of beams, beam steering angles, beam widths, beam frequencies, and pulse length. Functional dependencies limit the users ability to change one parameter without affecting another (i.e., increasing the number of beams also increases the pulse length because each beam utilizes a unique portion of the ME70's available bandwdith). Thus, the first task is to develop a beam configuration strategy that is optimized for the dual purpose of collecting water column backscatter from fish/invertebrates and seafloor backscatter for habitat mapping. Different beam configurations are being tested as part of this work. For each one, the emphasis is slightly different: one optimizes the ability to parameterize

school morphology; one minimizes the number of beams (and potentially increases the ping rate); one makes it possibile to examine the frequency dependence in the backscatter at each beam steering angle. One common thread used for each beam configuration is the use of split-beam processing to increase the resolution of the ME70 for seafloor mapping.

After defining a useful beam configuration, or possibly multiple beam configurations optimized for different tasks, a methodolgy for processing bathymetry and seafloor backscatter will be developed. Raw ME70 data will be processed for seafloor detections and converted into file formats that can be directly loaded into standard software packages used for processing bathymetry (e.g., Caris HIPS, IVS PFMdirect) and seafloor backscatter (e.g., GeoCoder). Software routines developed as part of this process will be made available to NMFS.

Finally, field trials of the newly developed ME70 modes and processing methods will be conducted at field sites with known bottom types in the Bering Sea. These sites were selected based on information from earlier bottom type groundtruth studies and hydrographic multibeam studies conducted by the RACE Division Habitat Research Team. Water column data using the same modes will also be collected, and subsequently compared with standard split beam echo sounder (EK60) data.

WORK COMPLETED

Due to delays in the funding process and contracting requirements, only a portion of this work has been completed, with the remainder to occur during FY10.

Three different ME70 beam configurations have been developed and used to collect data for testing purposes and algorithm development. Data were also collected with a standard configuration used by IFREMER researchers aboard the R/V *Thalassa.* These data collection efforts occurred in June-July during the summer 2009 AFSC acoustic-trawl survey of walleye pollock in the Bering Sea. A portion of the time was dedicated to conducting ME70 surveys in areas that coincided with seafloor bathymetry/bottom type information previously collected by the RACE Division Habitat Research Team. Preliminary algorithms for processing the data have been developed. The data collected during this effort will be used to assess the performance of the different beam configurations, to develop and/or refine software algorithms for processing the ME70 data, and for developing a finalized processing pipeline for generating bathymetry and seafloor backscatter with the ME70.

RESULTS

Preliminary algorithms were developed to process raw ME70 data to extract seafloor bathymetry and backscatter information. Both bathymetry and backscatter were processed in near real-time during the cruise, and then imported, gridded, and visualized in Fledermaus (Interactive Visualization Systems (IVS 3D), Portsmouth, NH 03801). Figures 1-3 show representative results generated during the cruise.

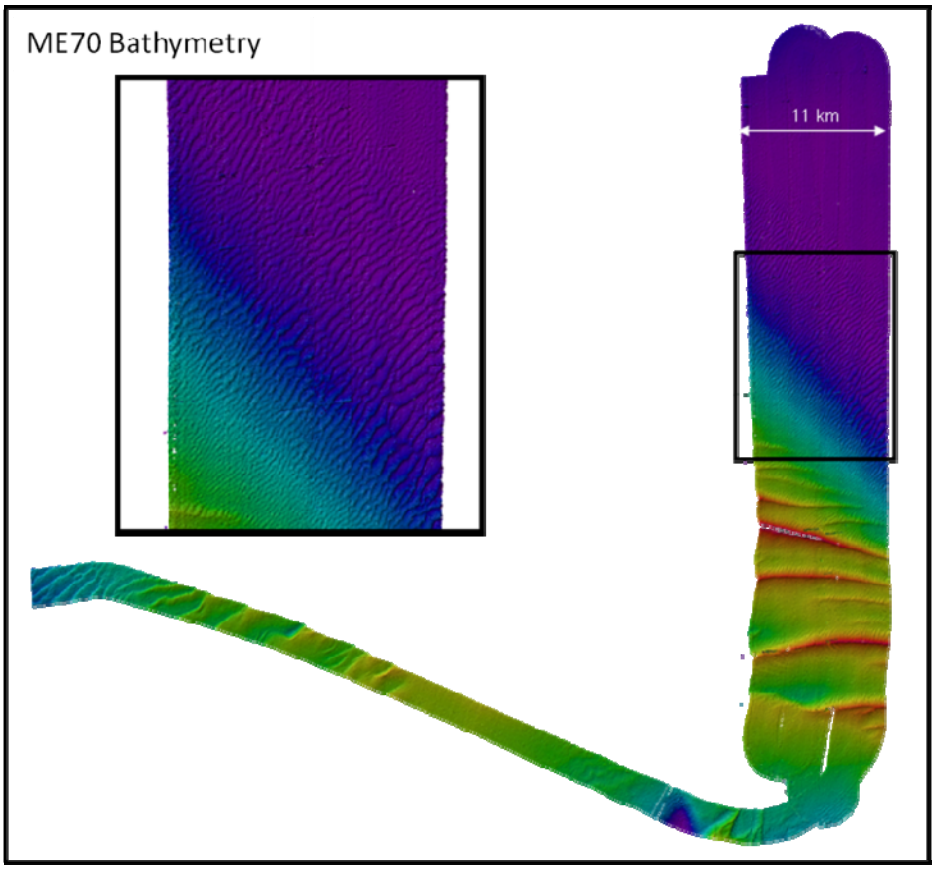


Figure 1. ME70 bathymetry collected on 19 June 2009 showing a sandwave field along the east side of Unimak Pass, Alaska. Depths vary from 45 m (red) to 90 m (purple).

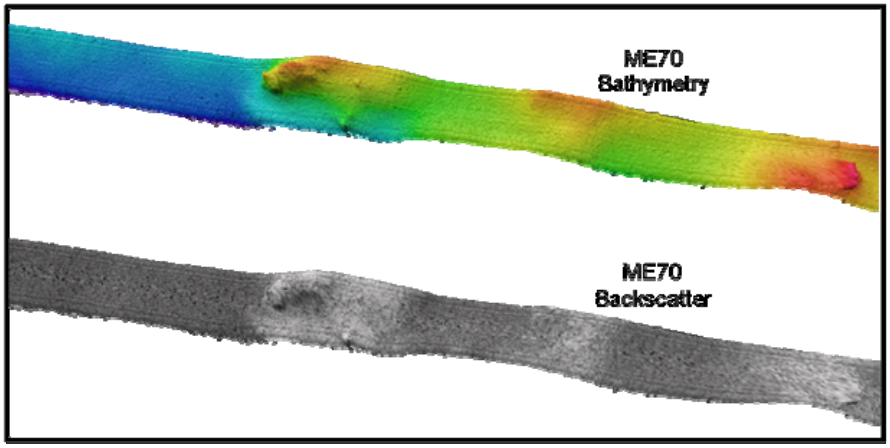


Figure 2. ME70 seafloor bathymetry and seafloor backscatter generated on 13 June 2009 during the transit between Kodiak and Dutch Harbor to begin the cruise. The change in seafloor backscatter indicates a difference in bottom type. In addition to backscatter mosaics, the angular dependence in the seafloor backscatter is also available. Both backscatter mosaics and angle dependent backscatter play crucial roles in determining seafloor type (e.g., Demer et al., 2009).

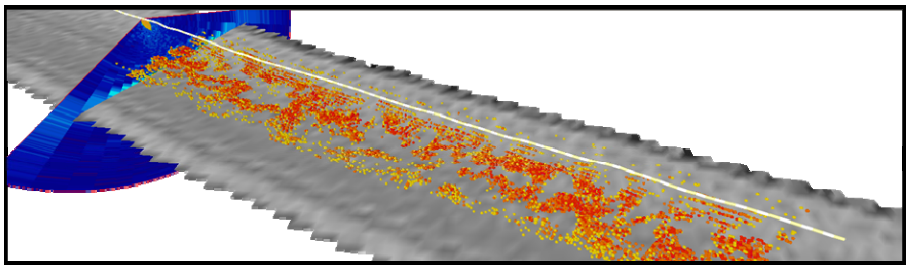


Figure 3. Euphausiid swarms detected in midwater over relatively flat, featureless Bering Sea seafloor. This image illustrates the degree of spatial resolution in the water column that is available from the ME70.

During FY10, work will focus on: 1) quantification of ME70 performance to provide bathymetry and seafloor backscatter; 2) development/refinement of software algorithms to process seafloor imagery; and 3) description of an efficient data processing protocol to generate seafloor characterization data.

IMPACT/APPLICATIONS

Processing techniques and operating methods developed in this project will be available to other NMFS ME70 users. This will enable these researchers to collect seafloor and water column ME70 data without becoming experts on the ME70 itself, as well as to process data in near real-time to make adaptive data collection decisions in the field. Results of this project will likely enable routine use of the ME70 on the new NOAA fisheries survey vessels.

TRANSITIONS

None at this time.

RELATED PROJECTS

G.R. Cutter and D.A. Demer, "Multifrequency biplanar interferometric imaging," *IEEE Geoscience and Remote Sensing Letters*. 7(1) (doi: 10.1109/LGRS.2009.2029533, online 2009, print 2010).

G. R. Cutter, L. Berger, and D.A. Demer. **"**Comparison of bathymetry mapped with the Simrad ME70 multibeam echosounder operated in bathymetric and fisheries modes". – *ICES Journal of Marine Science* (in-review).

D.A. Demer, G.R. Cutter, J.S. Renfree, and J.L. Butler. "A statistical-spectral method for echo classification". – *ICES Journal of Marine Science*, 66: 1081–1090 (2009).

PUBLICATIONS

None at this time.

PRESENTATIONS

None at this time.

EXPENDITURES

Grant total: 0 at the time of the report

ASTWG's response to Steve Murawski's queries regarding the Simrad ME70:

1) *In terms of use of the technology should we pursue purchasing of the benthic add-on package to address habitat characterization?*

ASTWG Recommendations:

It has recently been shown (Cutter *et al.*, submitted), that bathymetry data with equivalent accuracy and precision can be obtained from the Simrad ME70 operating in the standard Fisheries Mode (FM) or in Bathymetric Mode (BM; available with the bathymetric option). Consequently, the ASTWG concludes that the bathymetric option is not necessary. The ASTWG recommends that

1) resources be put towards software development; and

2) funds are provided for each Science Center to hire a multibeam echosounder specialist to maximize the utility of the Simrad ME70s.

Rationale:

The ME70 collects water column and seabed backscatter in both FM and BM. The split-aperture data collected in either mode can be processed for bathymetry and seabed classifications. The FM offers more flexibility for instrument configuration and has roughly two-times lower sidelobes levels. Post-processing methods are being developed (e.g., Bourguignon et al., 2009; Demer et al., 2009; Weber et al., 2009; Trenkel et al., submitted) and should continue to be developed for the FM data (.raw format) which allow simultaneously collected pelagic and benthic data to be processed for both water column-scatter and high-resolution seabed products (e.g., bathymetry and seabed classification). Additionally, effort should be directed towards reformatting ME70 output to a hydrographic format (e.g., .all format) for input to standard hydrographic processing software such as Caris HIPS (Figure 1).

2) *It is clear that with so many units now in service we could make a dent in our EFH requirements for mapping through casual mapping while steaming as well as dedicated cruises. Can this be combined with high resolution acoustics to determine fish biomass and species at the same time mapping habitats?*

ASTWG Recommendations:

Yes, the ME70 can collect data (.raw format) from both the water column and seabed in both FM and BM. There has been and continues to be significant progress on processing ME70-FM data (.raw format) for water column, bathymetry, and seabed classification.

Rationale:

The ME70 records data over a specified interval (e.g., from 0 to approximately 500-650 m) from 3 to 45 beams (FM) or 81 beams (BM), including both water column and seabed scatterers. The FM is much more configurable and has two-way sidelobe suppression to -70 dB, compared to BM with one-way sidelobe suppression to -35 dB. Currently, the FM has a lower maximum ping-rate than the BM, but that limitation can be mitigated with recently developed algorithms. Also, while algorithms are now available, some software development is required to process the .raw data for water column, bathymetry, and seabed classification products.

3) *With these units in service on DYSON and BIGELOW and about to be with PISCES and SHIMADA, how are they being utilized?*

ASTWG Recommendations:
At least one FTE with a specialty in multibeam echosounders should be hired at each Center; this person will be dedicated to the ME70 and responsible for maximizing its use and developing new uses.
Rationale:
The ME70 on both the FSV Dyson and Bigelow are currently underutilized because there are no ME70-dedicated operators or scientists and there is inadequate processing software and training. The ME70 on Dyson gets some attention and use for research and development though collaborations between AFSC, SWFSC and UNH. The ME70 on Bigelow is functionally not utilized due to lack of personnel.

4) *Are the Centers taking advantage of them and if not fully utilized, what are the constraints to fuller utilization?*

ASTWG Recommendations:
The primary constraint is personnel. We strongly recommend hiring one person per Science Center to utilize the ME70. The secondary constraint is software for processing the ME70-FM data (.raw), and reformatting it (.all) for input into standard hydrographic data-processing software. We recommend contracting the development of software to process and reformat the ME70-FM data (.raw) for water column, bathymetry, and seabed classification products.
Rationale:
Currently the ME70 is severely underutilized at the Science Centers and the primary constraint is personnel. The Advanced Technology position at each Science Center has paid dividends far beyond what was initially conceived. A similar model for the ME70 will undoubtedly do the same for multibeam data. The position should facilitate both water column and seabed data processing and associated research and development. These positions should be tied to the Science Centers, not the ME70s. Additional resources should be made available for requisite software development, software purchases, and training.

5) *In particular, I am interested in a recommendation on post-cruise processing of acoustic data. It is clear that some Centers do not have operational expertise to process these raw data into usable mapping products. Should we create a laboratory or center of expertise or use an existing center in NOAA to take the raw data from cruises, post process and return to the individual programs for use in data analysis?*

ASTWG Recommendations:
The ASTWG recommends a distributed but collaborative support system, much like ASTWG, that would foster growth of expertise in utilizing the ME70 at each Science Center. NMFS should provide additional resources (FTEs, software, hardware and training) to each Center which will allow optimal use of the ME70s (and other new equipment aboard the FSVs), consistent with the priorities of each Center and ship user. Additionally, we recommend partnering with NOAA's National Geophysical Data Center (NGDC) for archiving the ME70 data, as well as partnering with Integrated Ocean Coastal Mapping (IOCM) for reducing the raw data to formats that are compatible with those required by NGDC and for processing of standard data products such as bathymetric and seabed classification maps.

Rationale:

Each Center's applications for the ME70 may be very different. The ME70 was designed and purchased for studies of water column scatterers, but the data should be maximally used whenever possible. Partnership with NGDC should alleviate the burden on each Science Center's Information Technology group to manage and archive potentially large amounts of data. NGDC is archiving and providing web-based access to hydrographic multibeam data collected by NOS and others; thus NGDC has experience with multibeam data, although perhaps only as derivatives such as soundings or grids. Initially, progress on processing ME70 data should proceed through NOAA and collaborations with academic partners, and this model should continually improve information from the ME70. In cases when standard data products are produced (e.g., bathymetric data for charting), a partnership with NGDC and IOCM will be a valuable asset for disseminating this information to NOAA at large, and to the public. These partnerships must consider issues of metadata, intellectual property, and continuous improvements to methods.

6) Who should be responsible for training and upgrades?

ASTWG Recommendations:

a) Training and upgrades should generally be uniform across all FSVs, with accommodations for differences in the operations between Science Centers.
b) Hardware and software upgrades should be the responsibility of NMAO.
c) Training for ME70 operation and data acquisition should be primarily the responsibility of NMAO. Science Center personnel should also be familiar with operations, particularly the FTE specializing in this equipment.
d) Training for data processing should be the responsibility of each Science Center and resources should accompany the FTE specializing in this equipment.

Rationale:

a) The ME70's should generally be upgraded simultaneously. However, the ME70 is a new system and the acquisition software is evolving. While the system matures, upgrades should be applied to one system, tested, and then the other systems can be upgraded.
b) The ME70 is a vessel asset. NMAO has the responsibility for ensuring the ME70 is operational.
c) The ME70 is a vessel asset. NMAO has the responsibility for ensuring their personnel are familiar with operations.
d) Data processing is related to the scientific missions of the cruises. Thus training on data processing should primarily reside with the Science Centers.

Note: The above questions involve technical, scientific, procedural, and policy issues which require consideration of both the ME70 technology and NMFS' resources. The purchase of multi-million dollar acoustic equipment for each of the new FSVs should logically be accompanied by resources to be added to each Center to maximally utilize the data for ecosystem-based stock assessments.

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George R. Cutter Jr., David A. Demer, Laurent Berger, (submitted). High-resolution bathymetric mapping with the Simrad ME70, broad-bandwidth, split-beam, multibeam echosounder, ICES Journal of Marine Science.

David A. Demer, George R. Cutter, Josiah S. Renfree and John L. Butler, 2009. A statistical-spectral method for echo classification, ICES Journal of Marine Science, 66.

Weber, T., T. Clark, and C. Wilson. 2009. Simultaneous water column and seafloor mapping with the Simrad ME70. FEMME Conference, Lisbon, Portugal.

Table 1. Comparison of ME70 Fisheries Mode (FM) and Bathymetric Mode (BM) features.

ME70	Fisheries Mode (FM)	Bathymetric Mode (BM)	Comments
Beam configuration	Custom (highly configurable)	Fixed (four options)	
Beam directions	Any	Equidistant, or equiangle	
Swath width	Custom, 2°-150°	120°	
Beam widths	Custom, 2.2°-20°	Fixed*	*Approximately 2° by 3° for center beam; varies by beam direction choice.
Pulse duration	CW or LFM, 64-5028 µs.	CW, 384 or 768 µs	
Number of beams	3 to 45	81	
Number of soundings per ping	45 beam-wise, probably ~ 112*	Up to 200, typically ~ 150 per ping	* Using BM technique; perhaps more with advanced methods.
Range	3–600 m	3–600 m	Affects ping interval
Motion compensated	Yes	Yes	Up to ±10° roll, ±5° pitch, and heave
Split-beams	Optional	Optional	Split beams reduces ping-rate.
Frequencies	Configurable, 70–120 kHz	Fixed, 90 kHz	
Beamforming	Two-way	One-way	
Sidelobe levels	a low as -70 dB*	as low as -35 dB	*User-specified.
Processor control and interface	ME70 workstation	SIS workstation	
Recorded data format	Simrad .Raw	Simrad .All	
Processing	Echoview, Movies3D, and custom software	Standard hydrographic data processing software (bathymetry) and custom software (seabed classification)	Post processing software should be further developed for converting .RAW data to profile points and then reformatting to .ALL files; for seafloor classification; and for processing .RAW files for information on water-column scatters.
Water-column data	Routinely recorded	Optionally recorded	Recorded on ME70 workstation
Excess Cost	Software development + operators	~ $165 k + ~ $12 k for installation and HAT/SAT each + ~$25 k for spares + training + operators; + software development	

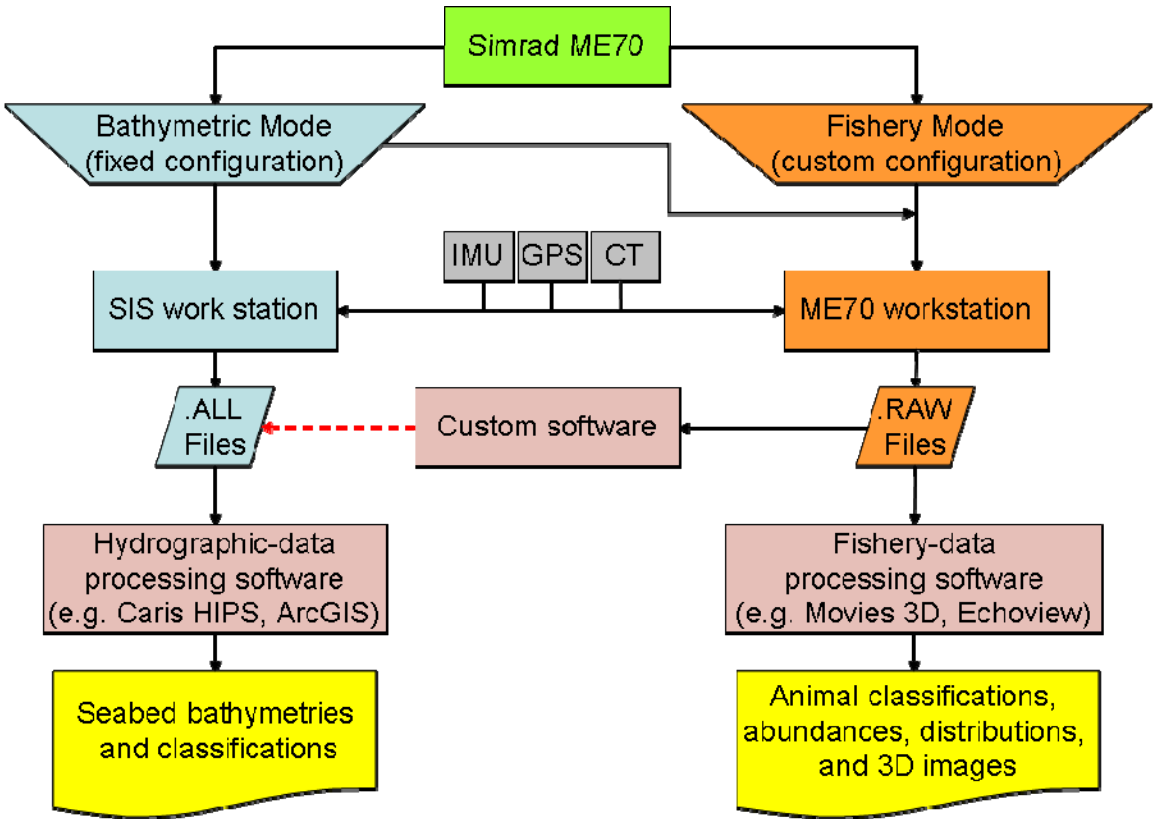

Figure 1. Data processing sequence for the ME70 in Bathymetric Mode (BM) and Fisheries Mode (FM). Ancillary data are input from the inertial motion unit (IMU), global positioning system receiver (GPS) and conductivity and temperature profiler (CT). With custom algorithms and software to derive high-resolution bathymetry data from the .Raw files and convert the results to .All format (red dotted line; to be done), high-resolution bathymetric data can be obtained from the ME70 operating in FM. This flexibility allows data to be concurrently and efficiently collected on fish and their seabed habitat.

Measurement of vessel radiated noise with moored hydrophones.

Alex De Robertis, Chris Wilson, David Demer

Introduction:
A semi-taught sub-surface mooring instrumented with hydrophones was deployed in an attempt to make measurements of radiated noise of NOAA Ship Oscar Dyson. The measurements were made to be comparable to those conducted by the US Navy at the Southeast Alaska Acoustic Measurement Facility (SEAFAC), where Dyson was noise-ranged the following day.
The primary goal of the work is to investigate whether reliable radiated noise measurement can be accomplished in the field by NOAA personnel in a convenient and cost- effective method to monitor the acoustic performance of noise-reduced FRVs.

Key Events:

- On 25 October 2009, a mooring designed to measure radiated noise of *Oscar Dyson* or other noise-reduced FRVs was deployed ca. 15 nautical miles from the SEAFAC site in Behm Canal near Ketchikan, Alaska.
- The mooring was a semi-taught sub-surface mooring deployed in 370 m of water with commercially available hydrophone recorders (Fig.1) at 61 m, 91.5 m, and 122 m. This resulted in similar measurement conditions (i.e. number of sensors, hydrophone depths, bottom depth, angle to hydrophones, etc.) as that used at SEAFAC.
- Dyson made a total of 12 runs past the mooring over 3 hours: 8 at a separation distance of 128 m, two at 90 m, and two at 225 m. Vessel speed was 93 RPM, nominally 12 knots using generators 2 and 4 as in the SEAFAC trials.
- The equipment and all data were successfully recovered.
- The vessel approach is clearly audible in the hydrophone records, and initial data processing reveals that the data is likely to be informative over at least some frequency bands. Wind speeds up to 25 knots during the measurements likely increased background noise.
- Analysis of the data is underway: AFSC will collaborate with SWFSC in these efforts. Tasks include calibration of the hydrophones used for these measurements, and quantitative estimates of vessel noise for comparison with the SEAFAC measurements.

Fig. 1 Hydrophone recorder during deployment.

Acknowledgements:
We are indebted to the Phyllis Stabeno and Hedrick “Rick” Miller of the Pacific Marine Environmental Laboratory for mooring design and deployment advice, and equipment loans. Staff at the naval Surface Warfare Center, Carderock Division provided advice regarding measurement geometry and identified a suitable mooring location. The officers and crew of the *Oscar Dyson* are thanked for their efforts during the mooring fieldwork. Scott Furnish with the MACE Program provided critical assistance during all aspects of the work. Steve Sessions (SWFSC/AST) and Kyle Beyers (NOAA Corp/SWFSC/AST) prepared the 2 of 3 Aural M2 recorders provided to this project by SWFSC/AST. Financial support from the Office of Science and Technology made this work possible.

NOAA Vessel Acoustic Management Plan Recommendations
Compiled during a workshop held 28-29 July 2009

Executive Summary

A workshop was convened 28-29 July 2009 at NOAA HQ in Silver Spring to design a noise monitoring system (acquisition and analysis) and develop protocols (measurement and mitigation) to monitor and maintain the quiet acoustic characteristics of the NOAA Fisheries Survey Vessels (NOAA FSVs) under an Acoustic Management Plan (AMP). Nineteen participants from Office of Marine and Aviation Operations (OMAO), NOAA Science and Technology, NOAA-Fisheries Science Centers, Naval Surface Warfare Center – Carderock Division, Harbinger Studios, and Lamont-Doherty discussed existing monitoring programs and developing a new Automated Acoustic Monitoring System (AAMS) to monitor vessel noise characteristics. The need for measurement instrumentation, data collection and processing, and personnel to assess and interpret the accumulated data are identified in the 15 recommendations from this workshop.

Two goals were identified: 1) develop an acoustic maintenance plan (AMP) to keep the FSVs compliant with the ICES Cooperative Report 209 1/3 octave radiated noise criteria; and 2) develop the capability to investigate the impact of tonal frequencies and loudness on the behavior of species under study. Considerable discussion was devoted to designing and developing an automated monitoring system (AAMS), as it was the consensus that automating as many of the measurement and analysis steps as feasible would result in a useful and beneficial system to assess radiated and structure-borne noise. The AAMS should be composed of accelerometers for vibration measurements, hydrophones for radiated platform noise, machinery management systems, and integration with Statistical Process Control (SPC) and Scientific Computing System (SCS) software. This system will integrate multiple sensors and statistically analyze these measurements to continuously monitor potential sound sources of underwater radiated noise. Sound level criteria and tolerances will be developed as measurements and experiences are gained. Noise mitigation strategies were touched upon, but should be further developed.

In addition to instrumentation and logistics, a long-term budget and personnel strategy must be developed and implemented to maintain a consistent level of high-quality monitoring to assess the acoustic management plan. Experiences and lessons learned from implementing an AMP on existing vessels can be applied to new fisheries and survey vessels. Acoustic expertise needs to be developed within NOAA to minimize our dependence on external resources.

Participant List (in alphabetical order):

M. Bancroft (NOAA/OAK Management), E. Bradley (NSWC-Carderock), C. Byrne (NOAA/NEFSC), D. Demer (NOAA/SWFSC), J. Diebold (Lamont-Doherty), J. Godlewski (NOAA/NEFSC), C. Hollinsworth (NSWC-Carderock), G. Eckenrode (NSWC-Carderock), L. Hurt (NOAA/OMAO), M. Jech (NOAA/NEFSC) D. Kirklewski (Harbinger Studio), J. Otis (NSWC-Carderock), J. Rix (NOAA/OMAO), A. Shimada (NOAA/S&T), J. Stricker (NOAA/OMAO), R. Thomas (NOAA/NWFSC), C. Thompson (NOAA/SEFSC), M. Webb (NOAA/OMAO), C. Wilson (NOAA/AFSC)

Introduction

Based on what is known regarding fish behavior in response to sound, it is reasonable to assume that in certain situations, fish respond to an approaching survey vessel by moving out of its path or diving to the sea floor where they would be largely undetected by standard acoustic survey methods. These, and other more subtle, avoidance reactions could thus potentially bias acoustic survey estimates of abundance.

In the mid 90s, concern over whether underwater-radiated survey vessel noise caused fish avoidance reactions, prompted the formation of an international group of experts to examine this issue under the auspices of the International Council for Exploration of the Seas (ICES). The reason for the concern was that fishes are generally most sensitive to sound less than 10 kHz, which is also the frequency range where underwater radiated vessel noise levels are greatest. Thus, the task of the working group was to review the literature and to provide recommendations for vessel radiated noise levels to potentially eliminate fish avoidance reactions near the vessel. The group was also tasked with recommending radiated noise levels for higher frequencies (> 1 kHz) to optimize the performance of shipboard acoustic survey instrumentation operating at these frequencies. The results of working group's efforts were published as an ICES Cooperative Research Report 209, which states very specific radiated vessel noise levels that must be met to eliminate fish avoidance reactions (Mitson 1995). In particular, the report stated that 1/3 octave underwater radiated noise should not exceed the hearing sensitivity of cod and herring by greater than 30 dB at a range of 20 m from the vessel. This makes a very important assumption that all surveyed fish species will not react to sounds less than 30 dB above their hearing threshold. Recent studies suggest that this may be true in some situations but not others.

Two recent vessel-comparison studies conducted with noise-reduced ships (i.e., vessels that meet the radiated noise levels outlined in Mitson (1995)) and noisier, conventional vessels illustrate the variability in fish avoidance behavior both within and among species. Ona et al. (2007) reported that the noise-reduced Norwegian vessel, *G.O. Sars* produced stronger avoidance reactions in over-wintering herring compared to a noisier, conventional vessel, but the reaction was such that no difference was detected in abundance estimates. Both ships repeatedly passed over an upward-looking bottom-mounted echosounder. The median vertical displacement of the herring layer increased 40 m as the fish moved deeper in response to the *G.O. Sars*, whereas the increase was only half this amount for the noisier vessel. No significant difference was detected in estimates of fish density between the two vessels at passage, although there were significant declines in density for both ships when comparing these estimates immediately before and after passage. This suggests that avoidance reactions existed during this experiment for both ships. The most comprehensive vessel comparison work using a noise-reduced (*Oscar Dyson*) and a noisier, conventional survey vessel (*Miller Freeman*) to date was conducted by De Robertis et al (2008, 2009, accepted, submitted) on walleye pollock in the eastern Bering Sea (EBS) and Gulf of Alaska (GOA). This work was conducted over different: seasons (winter, summer), diel periods (day, night), fish physiological states (spawning, non-spawning), fish depths (100-700 m), and large

geographical areas (Bering Sea shelf, Bogoslof Island-EBS, Shelikof Strait-GOA, Shumagin Islands-GOA). Pollock exhibited significantly greater avoidance reactions, in terms of backscatter intensity, to the conventional research vessel during winter spawning surveys in the GOA, and during the night from the Bering Sea Shelf (i.e., EBS summer survey). No significant vessel differences in backscatter strength were detected during the other spawning survey where pollock occur very deep (700 m, Bogoslof), or from the Bering Sea Shelf (i.e., EBS summer survey) during the day. Results using a surface drifting echosounder-buoy during the winter Shumagin survey also found that avoidance reactions to the conventional vessel exceeded those of the noise-reduced vessel, which provided independent confirmation to the other pollock vessel-comparison results (De Robertis and Wilson, submitted). The results of the herring study and those with walleye pollock suggest that the relationships between the stimuli that can cause avoidance reactions are complex and do not always follow predictions (e.g., the Mitson 1995 assumptions regarding fish avoidance and vessel noise levels). Thus, more work is currently planned to better characterize under what conditions fishes exhibit avoidance reactions. Because, vessel noise is the obvious candidate stimulus, it is important that regular and careful monitoring of vessel noise is undertaken to better interpret and understand the range of fish behaviors that occur in response to the vessel.

Many of the vibration sources are known and understood from years of experience at naval sound ranges and with naval vessels, so the current method of ranging is an excellent start in characterizing the vessel's noise signature, but more will be needed to understand how structure-borne noise affects radiated noise, and then how that affects fish and mammal behavior. For NOAA, the structure-borne noise relationship to radiated noise and usefulness for predicting fish or mammal avoidance can only be assessed by gathering a statistically reasonable (i.e., considerable) amount of data. This formed the crux of the workshop: can a monitoring system be implemented at a reasonable cost and with success? The consensus was that a system could be developed and implemented at a reasonable cost. The recommendations presented here are focused on developing and implementing a measurement methodology (see Appendix B) and an automated system for monitoring the vessels. The success of the program will depend on proper analysis and interpretation of the data, mitigation of vessel noise, and implementing a long-term budget and personnel strategy to maintain the quiet nature of the vessels.

The question of what protocol foreign fisheries institutes are using to monitor their research vessels was raised. Chris Wilson (NOAA/AFSC) sent emails to Norway (Egil Ona), France (Laurent Berger), UK (John Simmonds). Chris received a response from Paul Fernandes (John Simmonds) that nothing is done to monitor radiated noise of their noise-reduced vessel. To date, no other responses have been received. When others respond, their response will be forwarded to the workshop participants.

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Recommendations

1) ***Recommendation***: Install identical and consistent systems on all NOAA FSVs.
   Rationale: Installation of identical systems aboard the ships will facilitate data collection, processing, and interpretation. Failure to install identical systems may result in the introduction of "instrument-based" variability in recorded data among the vessels, and negatively impact NOAA's ability to evaluate the status of each ship and the impact of machinery dependent noise on the behavior of species that react to specific radiated noises and/or vibrations. In addition, common instrumentation will facilitate an "economy of scale" for purchasing new and replacement parts, as well as facilitate sharing information and results.

2) ***Recommendation***: Configure and install an 8-channel measurement system for each FSV to automatically monitor key vibration locations as well as the hull-mounted hydrophones (Automated Acoustic Monitoring System – AAMS).
   Rationale: As outlined in the NOAA Vessel Acoustic Management Protocol, vibration measurements are a key component of monitoring machinery and maintaining an acoustically quiet vessel. Approximately 70 locations have been identified to measure structure- and machinery-borne vibration (Figures A1 and A2, Appendix A). In addition to the vibration measurements, three hydrophones have been mounted on the hull to measure platform-induced noise. Because the noise characteristics of the vessel can change when generator and engine configurations are altered and other pumps and machinery go on-off line, it is important that we have the ability to acquire these measurements continuously or at least at short periodic intervals.

   To initiate development of a monitoring system that integrates automated measurements with the ship's Machinery Control Systems (MCS) and Shipboard Automated Maintenance Management System (SAMMS), we recommend initially

configuring and installing an 8-channel system that will automatically monitor up to eight accelerometers and up to three hull-mounted hydrophones (total of eight channels) simultaneously (Option 1 in Table A1). This system should consist of 8 accelerometers, cables, and 8-channel signal analyzer. The analyzer (0 to 50 kHz) will have the capability to output narrow-band power spectra, 1/3-octave power spectra, and time-series to a serial or TCP/IP port. The analyzer will also have the capability of being upgraded with more channels as the need arises. Detailed specifications need to be developed for the accelerometers and analyzer (see Appendix A).

We recommend a consistent system among the NOAA vessels. Due to the sound range scheduling of the FSVs in FY09 and FY10, it will be beneficial to install the system as soon as possible to take advantage of collecting the data during sound range periods. Analysis of these data should provide information for the optimal locations for monitoring.

While eight locations are sufficient to begin developing an AAMS, additional sensors will be required to full monitor and maintain the AMP. Table A2 (Appendix A) outlines options (options A2-4) for implementing a "full-blown" AAMS in support of the AMP and the least expensive (option A5) option for manual monitoring.

3) ***Recommendation***: Integrate data from the Automated Acoustic Monitoring System (AAMS) with the Scientific Computer System (SCS).
Rationale: SCS acquires data from all shipboard sensors via serial or TCP/IP protocol and stores the data in files with a common format. In addition to acquisition, SCS can perform rudimentary calculations on the data and has methods to visualize (i.e., graphs, gauges, plots) the data in real time. Because SCS already exists on the vessels and there is expertise on the vessels (survey techs) and on land (OMAO), integration of the automated measurement system with SCS should be straight forward.

To accommodate integration of these data into SCS, it will be necessary to enlist the services of an OMAO SCS programmer. The salary for a full-time OMAO programmer is $140K per year. The scope of the work will be determined after the installation of the hardware and the scale of the integration is evaluated. We recommend initiating discussion with OMAO electronic and software divisions (e.g., Frank Colohan and Doug Perry) to develop the scope of work for data integration and visualization.

4) ***Recommendation***: Develop and implement an "Acoustic Management Plan" database.
Rationale: Maintaining the quiet acoustic characteristics of the NOAA FSVs will require collecting data from multiple measurement and maintenance systems. These data will need to be connected for efficient evaluation and assessment of changes in the noise signature. For example, if an unusual signal is detected in one of the hydrophones, easily searching the engineer logs to see if any machinery was added or replaced or was running would be beneficial. Relational database formats are superior for data storage where multiple data sets need to be linked.

A database for the automated measurements should be implemented. This database may need to be developed "from scratch" or acquired and potentially modified from an existing database (i.e., from the Navy). SCS has the capability to store sensor data in a database format. It will be beneficial to involve OMAO electronics and software divisions (e.g., Frank Colohan and Doug Perry) for developing and implementing this database. This database needs to be linked to the SAMMS and MCS databases (see Recommendations 4 and 5).

5) ***Recommendation***: Link Shipboard Automated Maintenance Management System (SAMMS) database with Automated Acoustic Measurement System (AAMS) database.
Rationale: SAMMS is used by the engineering department for monitoring and maintaining equipment and machinery. This system is utilized through Azima DLI, which maintains logs and measurements in a database format. We recommend linking this database with the AAMS database and the MCS data. This connection should be done through SCS so that scientists and ship personnel can develop methods to query and evaluate sources of vessel noise.

   Because the SAMMS database is in association with Azima DLI and their database may be proprietary, DLI may need to be part of the development of the overall data storage scheme. It will be beneficial to involve OMAO electronics and software divisions (e.g., Frank Colohan and Doug Perry) for developing and implementing this database. This database needs to be linked to the Automated Measurement System and MCS databases (see Recommendations 3 and 5).

6) ***Recommendation***: Link the Machinery Control System (MCS) with SCS.
Rationale: A new MCS software package is currently being specified and procured for the FSVs. We recommend that this software have electronic logging capabilities and be able to output data via serial or TCP/IP protocols so that it can be linked to SCS. It will be beneficial to involve OMAO electronics and software divisions (e.g., Frank Colohan and Doug Perry) for developing and implementing this database. This database needs to be linked to the SAMMS and Automated Measurement System databases (see Recommendations 3 and 4).

7) ***Recommendation***: Review and implement NOAA FSV Acoustic Management Plan protocols.
Rationale: A draft Acoustic Management Plan (AMP) has been developed for the NOAA FSVs. This AMP was modified from a protocol provided by Naval Surface Warfare Center – Carderock Division. Modifications were made to be specific to NOAA vessels. A summary of the AMP activities, scheduling, and responsibilities is found in Table 1.

   Comments to this draft should be completed and delivered to J. Rix (OMAO) by mid-August 2009.

Table 1. Summary of Acoustic Management Plan (AMP) activities, scheduling, and responsibilities.

Survey/Inspection	**Periodicity**	**Ship Operating Condition**	**Responsible Party**
House Keeping Survey	Monthly	Dockside or Underway	Ship's Force
	Quarterly	Dockside or Underway	Independent Inspector
Sound Short Survey	Monthly	Dockside or Underway	Ship's Force
	Quarterly	Dockside or Underway	Independent Inspector
	As needed – when rotating or reciprocating equipment has been worked on and/or acoustic insulation has been disturbed	Dockside or Underway	Ship's Force
Hull Vibration/ Platform Noise/ Sonar Self-noise Surveys	Quarterly	Underway with standard machinery lineup at 11 knots and as a function of speed	Ship's Force
Diesel Generator Vibration Survey	Quarterly	Underway with diesel generator set to at least 50% load or typical load when in standard machinery lineup at 11 knots	Ship's Force
Mount Height Survey	Semi-annually	Dockside	Ship's Force ("Go-No Go" gauge)
	Annually	Dockside	Independent Inspector (calipers and micrometers)
Machinery Vibration Survey Exclusive of Gensets	Semi-annually	Underway with standard machinery lineup at 11 knots	Ship's Force
Radiated Noise Acoustic Trials on an approved acoustic range	5 years (following special survey drydockings)	Underway with standard machinery lineup at 11 knots and other key speeds	Approved acoustic range and personnel, and an independent inspector
Underwater Inspection/Hull Cleaning (if warranted)	Semi-annually	Dockside	Approved divers and an independent inspector
Transducer Cleaning	Monthly – during proficiency dives	Dockside	NOAA divers

8) ***Recommendation***: Assess and implement Statistical Process Control (SPC) software.
Rationale: The Automated Acoustic Measurement System (AAMS) will have the capability to collect a large amount of data, which will need to be evaluated and potentially "flag" unusual events. In addition, evaluation of these data will require connection to the machinery databases and logs (e.g., SAMMS and MCS). Statistical process control (SPC) is an efficient strategy for continuous monitoring of processes. SPC uses measurements of input variables and control charts to detect whether the process observed is under control. In this case, all major noise sources and a number of selected locations on the ship should be fitted with accelerometers, microphones, and hydrophones and the data should be continuously and automatically monitored for statistical anomalies. Self-noise hydrophones, echosounders and multi-beam sonars in passive mode, and microphones in the engine room are some examples. Additionally, other non-acoustical measurements that might affect the ship's radiated noise (e.g. barnacle growth and fuel efficiency which may indirectly indicate sub-optimal operation), should also be control charted. Anomalies would be immediately investigated and remedied using the basic tools of quality management

We recommend SPC output be directed to the on-board SCS. SCS should have the ability to alert shipboard personnel (e.g., scientific staff, engineering department, the bridge) when the SPC software "flags" an event. For example, if the SPC detects an unusual vibration, it should flag this event and then SCS should e-mail the scientific staff as well as the engineering department for further evaluation. In addition, AAMS and SPC output should be up/offloaded to land-based diagnostic support.

9) ***Recommendation***: Purchase a hand-held vibration data collector (DLI ViPRe model) for each vessel.
Rationale: The hand-held units will supplement the automated system (AAMS) by being able to verify automated measurements, sample additional locations, and appraise "flags". The cost of each unit is approximately $13K.

10) ***Recommendation***: Purchase a vibration data collector calibrator (DLI Model PR-1 Precision Reference Generator) for each vessel.
Rationale: Instrument calibration is required to maintain a consistent level of high-quality data and calibrations must be performed at regular intervals. The PR-1 allows ship's force to verify the calibration of the ViPRe on the vessel, rather than sending it to DLE for annual calibration checks. This minimizes the likelihood of damage or loss during shipping. Currently, OMAO owns 2 PR-1's that are shared among the fleet. Each vessel should carry its own calibrator for real-time diagnosis of accelerometers and monitoring of vessel noise. The cost of each unit is approximately $2K.

11) ***Recommendation***: Develop in-house expertise of acoustic monitoring and management.
Rationale: Currently the expertise for monitoring, evaluating, and maintaining the underwater radiated vessel noise characteristics resides external to NOAA. This puts NOAA at a disadvantage for real-time diagnosis, evaluation, and mitigation of vessel

noise, and hence potentially at a financial disadvantage because all effort, even the most simple, must be outsourced. Maintaining a consistent level of high quality data and monitoring and evaluating the noise levels in real time requires dedicated effort, which is optimally done by personnel committed to maintaining the quiet vessels.

We recommend NOAA develop the in-house expertise to monitor the acoustic maintenance of NOAA FSVs. This expertise will require dedicate personnel, which can be obtained through new hires or position changes. These personnel will be responsible for administering the acoustic management plan as well as overseeing data analysis and developing, in collaboration with the Science Centers, noise-level criteria and thresholds. We do not foresee developing the in-house infrastructure for large efforts such as sound ranging, but do see the need for developing resources for monitoring, evaluating, and managing underwater radiated vessel noise.

12) ***Recommendation***: Incorporate the acoustic management plan in the design and construction of new vessels.
Rationale: As NOAA learns from its efforts of monitoring and managing acoustically quiet vessels, these lessons should be incorporated into the design of new vessels. For example, experience with the number and locations of accelerometer measurements and hull-mounted hydrophones can be directly translated to new construction as well as upgrading existing vessels. In addition to hardware and instruments, software and network capabilities need to be identified and incorporated in the design and construction of new vessels.

A budget strategy should be developed to incorporate the acoustic management plan in the design and construction of new vessels. Budget analysts must be made aware of the necessity and requirements for maintaining an acoustically quiet fleet.

13) ***Recommendation***: Develop and implement a long-term budget strategy for maintaining acoustically quiet vessels.
Rationale: Funds are required to implement any monitoring and management plan. From inception to year-to-year maintenance, nothing can be done without funds. A budget strategy needs to be developed so that the acoustic management plan can be developed, implemented and maintained over the life of the vessel without interruption. Budget analysts must be made aware of the necessity and requirements for maintaining and acoustically quiet fleet.

14) ***Recommendation***: Provide measures of variability (e.g., standard deviation, error bounds) when presenting acoustic data.
Rationale: Without knowing the range of variability or probability density function (PDF) of a variable or parameter, it is impossible to evaluate whether a measurement is within tolerance or outside of the “normal” range. Variability can be expressed as a standard deviation or variance, or as error bounds or estimates. For example, underwater radiated noise levels measured at a sound range should include a measure of variability so that subsequent sound range results can be compared and whether there has been a change in underwater radiated noise assessed.

15) ***Recommendation***: Develop criteria for monitoring and managing narrowband tonals. ***Rationale***: This workshop participants agreed that the current state of knowledge about how narrowband (i.e., 1 Hz band) tones affect fish behavior is not well understood (if at all), and so did not address this directly. The ICES WGFAST (Working Group – Fisheries Acoustics, Science and Technology) is beginning to address this issue through study groups. This issue should be elevated to possibly another workshop when more studies have been conducted. In addition, the Science Board should elaborate on their expectations for corrective action in the event that an FSV falls out of compliance with ICES radiated noise criteria (including time frames, funding streams, etc.)

Appendix A. Specifications for Instrumentation System

Table A1. Item list and costs for automated measurement system. Five options are presented: automated monitoring of 70 locations with no multiplexing of acquisition (option 2); automated monitoring of 70 locations with multiplexing acquisition (options 3 and 4); automated monitoring of 8 locations with no multiplexing of acquisition (option 1); and manual monitoring of accelerometers and downloading data (option 5). Software integration is common to all options.

		Cost ($K)
1) 8-channel system (8 sensors and 8 acq. channels)		
Accelerometers		
8 accelerometers	$1K per sensor	8.0
Cabling		8.0
Misc. install		5.0
Data Acq. for 8 channels		
1 accel./channel (no multiplex)	~$3K per channel	30.0
Computer, storage		5.0
TOTAL (per vessel)		**56.0**
2) 70-channel system (70 sensors and 70 acq. channels)		
Accelerometers		
70 accelerometers	$1K per sensor	70.0
Cabling		30.0
Misc. install		10.0
Data Acq. for 70 channels		
1 accel./channel (no multiplex)	~$3K per channel	210.0
Computer, storage		5.0
TOTAL (per vessel)		**325.0**
3) 70-channel system (70 sensors and 16 acq. channels)		
Accelerometers		
70 accelerometers	$1K per sensor	70.0
Cabling		30.0
Misc. install		10.0
Data Acq. for 16 channels		
5 accel./channel multiplex		45.0
Programmable junction box/multiplexer		10.0
Computer, storage		5.0
TOTAL (per vessel)		**170.0**

4) 70-channel system (70 sensors and 4 acq. channels)		
Accelerometers		
70 accelerometers	$1K per sensor	70.0
Cabling		30.0
Misc. install		10.0
Data Acq. for 4 channels		
~18 accel./channel multiplex		20.0
Programmable junction box/multiplexer		10.0
Computer, storage		5.0
TOTAL (per vessel)		**145.0**
5) Manual Monitoring		
Hand-held accelerometer		20.0
Computer, storage		5.0
Calibrator		2.5
1 person to do 70 locations, ~2 hours		
TOTAL (per vessel)		**27.5**
Software Integration with SCS and shipboard network	$140K per programmer per year	**140.0**

Instrumentation (also see Appendix B)

<u>Accelerometers</u> (8 for permanent mounting, 8 for roving measurements, 2 spares)
- Piezoelectric accelerometers minimum mounted resonance frequency 18 kHz (approximately 6 kHz useful, 10%, frequency range)
- Electrically isolated base
- CCLD (4-20 ma 28 V powering) (Deltatron, Isotron, ICP, other manufacturer designations)
- 10-32 UNF threaded stud mount
- µDot electrical connection
- Accelerometer Calibration Exciter
- Cementing studs – do NOT stamp or mark – use cable markers instead!

<u>Permanent Cabling</u>
- Terminated in isolated (insulated with shoulder washer – usually in the design of the BNC bulkhead connector itself if chosen properly) BNC connections in either a rack panel or (better) water proof (via glands) junction box with removable cover (quarter turn fasteners – like Dzus fasters)

- The analyzer front-end will have another cable harness coming from it (BNC to BNC) which is a multicore cable connecting through another gland on the junction box hence, when the analyzer is in “continuous” or on-line monitoring mode, there is a secure and watertight connection from the analyzer front-end through to the accelerometer (expect that the µDot connection will need to be covered with silicon caulking, or RTV, in order for it to be waterproof itself).
- For off-line, or roving, measurements, the multicore cable from the analyzer front-end simply gets disconnected and the other cables (roving) connected as desired.
- Double-shielded construction

Roving Cables (Qty 10 – eight “live” and two spares)
- µDot to BNC
- Length? Longest needed. If measuring the eight points which have the greatest distance apart, add 10 (ten) feet. A standard (for all ten) length might be on the order or 30 – 50 feet (10 – 16 meters).

Spectrum Analyzer System for Structureborne, Airborne, and Underwater (Hydrophone) Measurements

- Frequency range: DC – 50 kHz (50 k Hz range to accommodate hydrophone measurements and high frequency noise per earlier studies)
- One-third octave band analysis 1 Hz – 20 kHz, with filters that meet ANSI S1.11-1986, Order 3 Type 1-D, eight channels REAL TIME (i.e. simultaneously, no data loss)
- FFT with exactly 1 Hz resolution capability up to at least 2 kHz (i.e. for example 3200 line frequency span 3.2 kHz, or 6400 lines 6.4 kHz span). The main point is to have a means to compare data from various sources with the same resolution. Furthermore, any analyzer system should be able to provide narrowband (FFT) resolution of 1% of the frequency of interest, For example, a 0.1 Hz resolution would be needed for accurate assessment of a 10 Hz tone, but for a 2 kHz tone, a 20 Hz resolution would be sufficient. In the field of Sound and Vibration, a resolution of 1% for FFT analysis is generally considered to be a reasonable expectation for what is termed “narrowband” analysis. This can be accomplished over a wide frequency range by zooming various frequency ranges to cover a wider band than the maximum line count allows for a given analyzer brand. This would, for some analyzer brands, simply mean multiple virtual analyzers simultaneously run in order to cover a wide frequency range with the 1% maximum bandwidth (resolution) requirement met. For other analyzer brands, it would mean multiple “passes” or analyses.
- FFT and One-third octave band analysis for all eight channels always in real time for 20 kHz (highest TOB) and 50 kHz FFT frequency ranges.
- Hardware inputs BNC with CCLD (ICP) 4-20 ma (28 V) powering.
- Strongly recommended but optional (because it is only available from Brüel & Kjær, OROS and possibly a few others) would be to have the one-third octave band AND FFT measurements made simultaneously.
- Recording of raw time data to hard drive for later analysis (for example FFT calculation when not available real time).

- Easy expandability (i.e. without having to send system back to vendor for physical retrofit) from base 8 to 70+ channels.

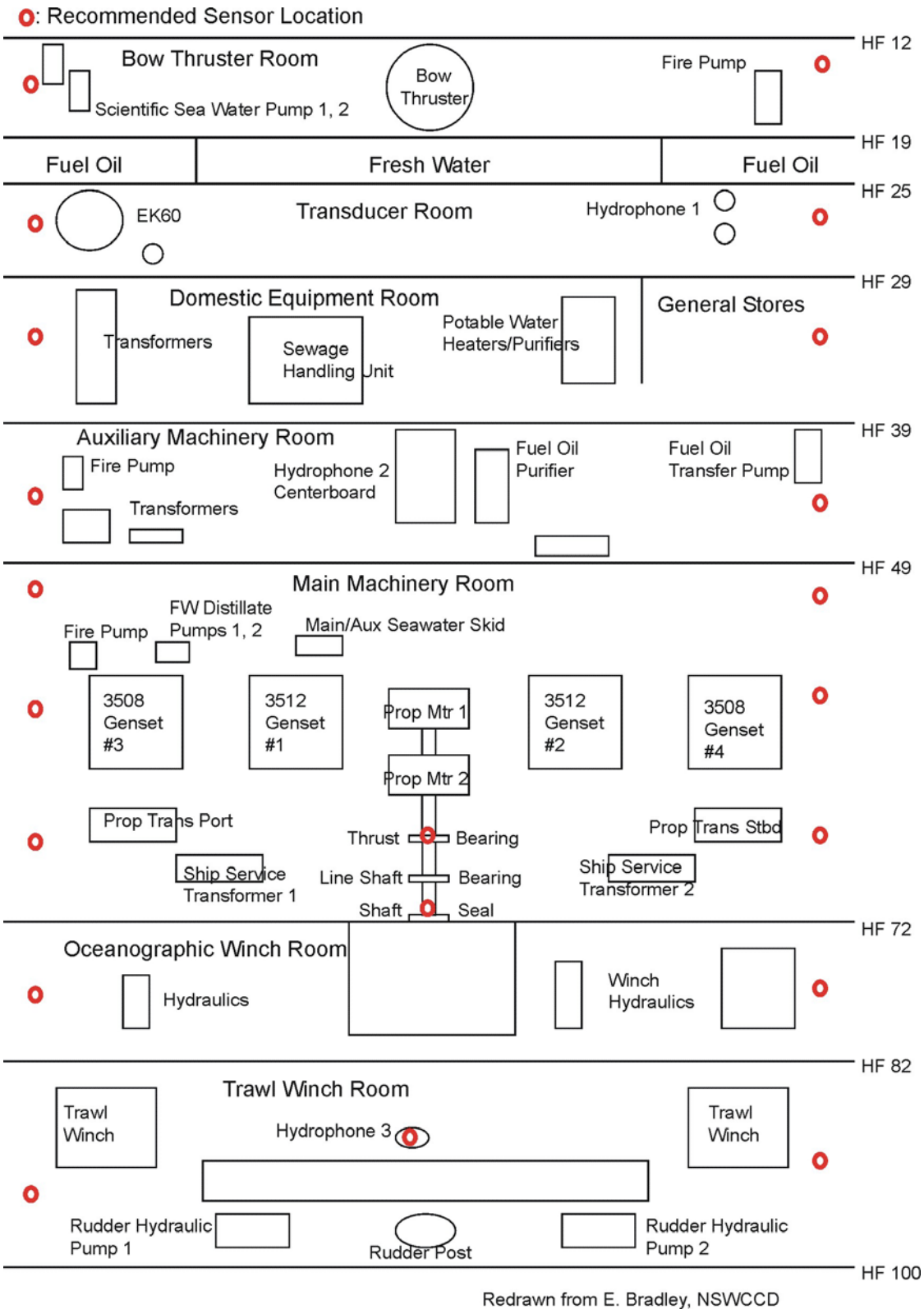

Figure A1. Locations of vibration sensors (redrawn from E. Bradley, NSWCCD).

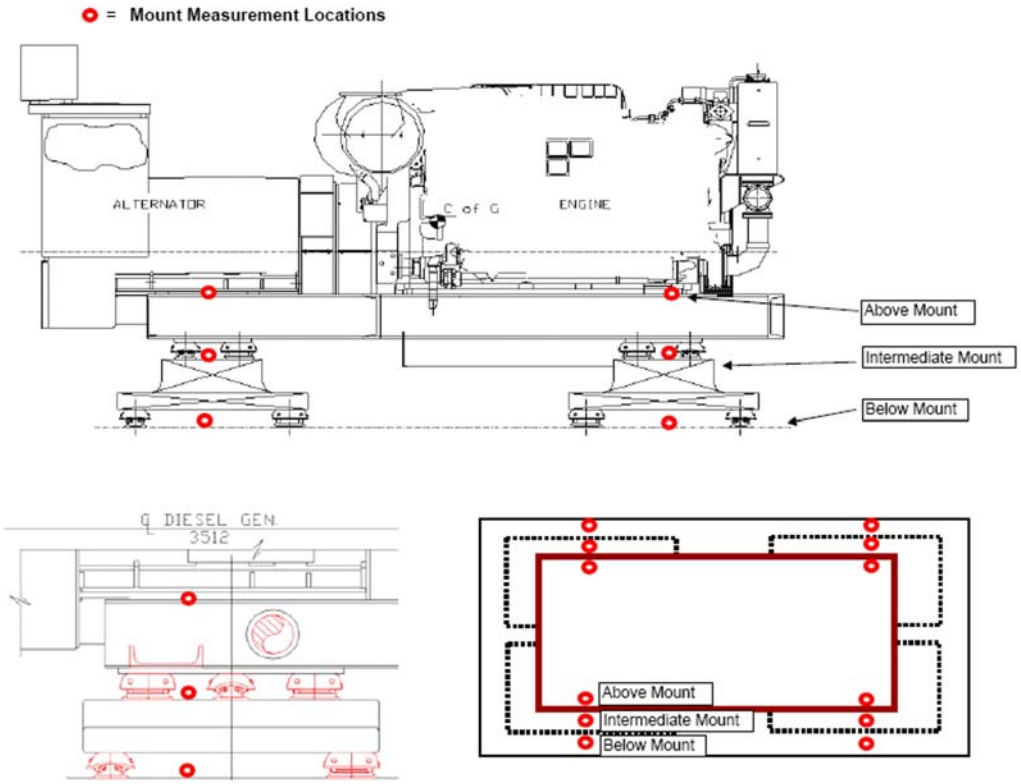

Figure A2. Locations of mount measurement locations (from E. Bradley, NSWCCD).

Appendix B.

Comments Regarding NOAA Fisheries Advanced Sampling Technology Workshop

Silver Spring, MD

July 28 and 29, 2009

August 3, 2009

for

NOAA
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543

Prepared by

Duff Kirklewski
Harbinger Studios
P.O. Box 208
Bellingham MA, 02019
508.966.3329
harbinger@rcn.com

Executive Summary

On Tuesday and Wednesday July 28 and 29 a workshop on vessel noise monitoring was held at NOAA Fisheries in Silver Spring Maryland by the NOAA Fisheries Advanced Sampling Technology Working Group. The purpose was to gather managers, engineers and scientists with experience in various related disciplines throughout NOAA, the Navy, and other ancillary organizations to discuss the need and implementation plan to determine how to correctly measure, assess, and mitigate radiated noise from newly designed and built research vessels (FSV's). While these vessels have been designed to be quieter than their predecessors, there is still some concern regarding the degree and nature of observed fish avoidance relating to these specific vessels.

In order to more fully understand the issues and multiple parameters that influence fish behavior around a nearby vessel, both radiated and structureborne (vibration) noise will be studied more closely. This dictates the need for measurement instrumentation, data collection and processing, and personnel to assess and interpret the accumulated data. Furthermore, noise mitigation strategies need to be developed when radiated noise levels are found to exceed those desired to keep fish avoidance at a minimum. During the two day workshop, these subjects were discussed in great detail with many viewpoints expressed. In the end, a tentative direction was agreed to which included instrumentation of one or more vessels with an eight channel structureborne measurement system to collect and archive data along with subsequent post-processing in order to better determine the true impact of various component (machinery types) sources of increased radiated noise from the vessel.

The following discussions are only the opinion of the writer, who is outside of the NOAA and Navy organizations, in the hopes that some of the important details of the workshop discussions be revisited when the final draft RFP/RFQ for the instrumentation system along with careful consideration of the various caveats for various measurement and data processing methodologies.

Initial Considerations

Ideally, the subject research vessels would radiate no noise at all, or perhaps just less than the threshold of hearing of any fish that biologists might want to approach without "being discovered". Unfortunately, things that vibrate, like ships and motors, usually cause acoustic noise. Furthermore, a ship, which during initial ranging measurements is found to meet or exceed noise radiation expectations, will probably exhibit degradation over time, causing the radiated noise levels to increase. These increases in noise levels may cause fish to avoid the vessel and if the fact that the radiated noise has increased is not discovered for some time, some (if not all) of the data regarding fish counts collected for a given mission should be considered tainted. Since this scenario is unacceptable, an effort will be made to attempt to correlate in some manner radiated noise to

structureborne noise so that, in the event of an increase in structureborne noise, the influence on fish avoidance might be quantified.

If it were possible, the original ranging of the vessel would include a comprehensive and exhaustive measurement and correlation of both the radiated vessel noise (underwater sound measurements using hydrophones) and the structureborne noise (vibration measurements of rotating/reciprocating machinery and ship structures taken on the ship). This study would then yield a list of resonant frequencies and tones, or set thereof as is the case for harmonic families, found in the radiated noise which can be traced to be the root cause of the correlated frequencies seen in the structureborne noise measurements. The best case scenario would be to have an actual correlation/coherence function measured for each set of accelerometer/hydrophone pairings but the physical implementation of such a system is not feasible at this stage in current electronics due to cost and cabling limitations. So, without the ability of the sample-accurate cross spectrum measurements (again, between accelerometer and hydrophone) needed for these functions, it may be possible to carry out a simpler measurement set out just using simultaneously, but separately, measured accelerometer and hydrophone signals. These data sets can then be compared in order to see if components (spectral attributes such as tones, harmonic series, and resonant peaks) show up that are common to both structureborne and underwater measurements. Once these are identified and documented, the last and most difficult step would be to determine the amplitude linearity of each. This would help to aid in predicting more accurately the effect of increasing tone levels (due to an incipiently failing bearing for example) on radiated vessel noise and, ultimately, increased and maybe unexpected, fish avoidance.

It is the writer's understanding that the Navy engineers at the ranges have been able to determine many (most?) of the sources (from vibration) of the radiated noise, so while there will be a few more corollaries to learn (the remaining unknown radiated tone/resonance peak sources), the current method of ranging in such detail is an excellent start in characterizing the vessel's noise signature. The structureborne noise linearity in its relationship to radiated noise and usefulness for predicting fish avoidance can only be assessed by gathering a statistically reasonable (considerable) amount of further data. This forms the crux of the subject workshop and study: how can this be implemented at a reasonable cost and with success?

Goals and Limitations

If money were no object and the Navy engineers had open schedules and infinite time, the easiest and best approach would be to hand it to them and have them characterize the ship under multiple conditions, send the ship out for six months or a year collecting a tremendous amount of data in parallel with normal operations, and then re-range the ship after each mission to process the data and build a better assessment of the correlation between the structureborne and underwater radiated noise. After some time, perhaps two or three years, they will have built a model which could take into account even a few various line-ups that would give the biologists a baseline from which to have an intimate

knowledge of the exact ship noise radiating conditions for any given fish counting mission.

Since the idea of infinite time and money is only abstract, some compromises must be made. If these can be made with minimal recurring cost, it is possible that data can be collected for begin to build an extensive database from which a number of questions might be answered. What are the significant and/or insignificant changes in frequency and/or amplitude that cause increased fish avoidance? Is the fish avoidance linearly related to some frequency or amplitude change? What frequencies do the fish react to? How does the diesel engine vibration affect the radiated vessel noise? … the generator? … the pump? … the ship structure itself? … the propeller? … ship speed (i.e. NOT RPM, but speed itself)? Some of these have already been studied, but the database that could be built from simply logging measurements periodically (minutes, hours?) could help to answer some of the more difficult questions. The most important, of course, is to find a way to correlate structureborne to underwater radiated noise in some repeatable manner within reasonable certainty. Whether or not this can be accomplished remains to be proven, but if the database can be built up for a reasonable cost (i.e. not much more effort needed than the normal ship operations), it will be well worth it, even if the data does not get assessed and post-processed until some time after due to budget or time constraints.

One Possible Measurement Methodology

There are many techniques that could be used to collect and assess the data needed for vessel noise determination. Only one will be presented here for the sake of brevity.

The first step needed to assess the influence of structureborne noise on vessel radiated noise is a baseline of both of these for the vessel after the initial ranging performed when the vessel was commissioned. This will yield most, if not all, of the spectral components and families (harmonics) found in the structureborne measurements that show up in the underwater radiated noise signature. Each of these “correlated” components may show up at various accelerometer locations, giving an idea where to best mount accelerometers during missions in order to collect more data and populate the database. As a starting point, the eight “best” locations should be using for the permanently mounted accelerometers for continuous, online, structureborne noise monitoring. In addition, provision should be made for another set of “roving” accelerometers in order to supplement these eight for further data collection. The locations of the eight permanent accelerometers should be set by the Navy range engineers as they did the original ranging and understand the locations and correlations the best. They can also advise and list the remaining locations and suggest the amount of points which make the best sense to monitor in a roving manner.

From the initial baseline above, new data can be collected in order to reinforce the original correlations and to add to and perhaps find those radiated frequencies from which no structureborne source could initially be established. The data which will need to be collected (and passed on after ranging by the Navy ranging engineers) must include

both one-third octave band and FFT (narrowband) spectra for both the structureborne and underwater hydrophone measurements. This will enable a comparison between the initial ranged baseline (from Navy data) to ongoing collected data. Depending on the capability of the instrumentation used, the collected data may be limited to one-third octave band data but the writer cannot stress enough the need to, at a minimum, also collect the raw time data on some continuous (periodically/automatic as opposed off-line by “hand”) basis so the FFT spectra can be at least post-processed. Some analyzer manufacturers have instrumentation capable of simultaneous one-third octave band and FFT (AND raw time data streaming to disc) data collection. Using this instrumentation would preclude the need to post-process raw time data in order to calculate the FFT spectrum for tonal assessment.

The suggested method would be to install an eight channel spectrum analyzer system with eight permanently installed accelerometers at locations determined by the initial ranging measurements as noted above, and eight more accelerometer/cable sets for measurement of the other locations of interest. The permanent locations can be measured on a continuous basis (perhaps every ten minutes or every hour) and the other eight can be measured at will (perhaps every day). This scenario will require that the analyzer be taken out of continuous mode (or that the existing DLI analyzer be used for the “roving” points) and then restored to operation each time. This, of course, will make the system “not fully automatic” and someone on ship will need to be trained enough in order to configure the analyzer in and out of continuous mode. Perhaps the eight channel analyzer ought to be left dedicated to continuous monitoring with the DLI used for the other locations. This will only work well if the DLI system can be configured to measure the exact same frequency resolution as the “permanent” analyzer and the data input into the SCS system.

The collected data would be transferred to the SCS system on a live, ongoing, periodic basis. Should an issue come up where troubleshooting is necessary, the spectral data could be viewed by land based personnel for assessment and the spectrum analyzer put into a manual mode (by a properly trained tech) onboard ship. Measurements could be made by the advice of the land-based engineer(s) with further data uploaded to SCS as needed. From this, it would be possible for remote assessment and troubleshooting and possible mitigation. If this is problematic, at least data will be collected which could be used to troubleshoot once the ship gets back to port.

There are three, perhaps more, readily seen difficulties with this scenario. The first difficulty is the need for someone aboard the ship to have the knowledge and training necessary to run and operate the spectrum analyzer. The level of expertise required to just collect data by changing the mode of operation of the analyzer is not trivial. It would be better to have the analyzer dedicated to continuous measurement of the eight initial points only with additional data collection taken using the DLI system. Unfortunately, the DLI system may not afford the capability of one-third octave band data (FFT is more desirable in the end, however), but DLI may be able to accommodate that.

The second difficulty is the determination of structureborne measurement locations, thresholds for troubleshooting or mission “abandonment”, and determination of when each location ceases to be significant. This can only be done by the collection of data which can be reduced along the way and then used during the next vessel ranging survey. Significant changes can also be used to trigger an alarm so that the mission can be aborted or delayed so tainted data is avoided, but the exact amount of change needed to set these thresholds cannot be easily determined a priori. This is where the use of an outside (Navy, NOAA, or other signal processing “expert”) signal processing consultant is imperative. As more data is collected, it will be easier to set these thresholds. The same consultant can also assess the significance of each measurement point once enough data is collected and can provide assistance and guidance for troubleshooting and mitigation using the spectrum analyzer system.

The third difficulty is the interface with the SCS system. Not only do the spectra need to be uploaded on a (pseudo) continuous basis into the SCS database, but the surrounding ship ops conditions at the time also need to be available and time-stamped in such a way as to provide an accurate “state of all ship systems” snapshot for any time a significant structureborne event occurs. While the data format for the spectral (and time) data are not particularly complex, the exact way that they get transferred (OLE linking? UFF file export?) from the spectrum analyzer (and potentially DLI unit for additional data) is not known at this time. It may be a simple file exchange or potentially a convoluted conversion requiring a number of steps and dedicated software. Even if this interface fails or is not “doable”, most spectrum analyzers will provide data in widely accepted formats so, in a worst case scenario, analyzer data can be stored natively and retrieved at a later date for post-processing.

Recommended Instrumentation

Specifications for Instrumentation System, Eight Channels

<u>Accelerometers</u> (8 for permanent mounting, 8 for roving measurements, 2 spares)
- Piezoelectric accelerometers minimum mounted resonance frequency 18 kHz (approximately 6 kHz useful, 10%, frequency range)
- Electrically isolated base
- CCLD (4-20 ma 28 V powering) (Deltatron, Isotron, ICP, other manufacturer designations)
- 10-32 UNF threaded stud mount
- µDot electrical connection
- Accelerometer Calibration Exciter
- Cementing studs – do NOT stamp or mark – use cable markers instead!

<u>Permanent Cabling</u>
- Terminated in isolated (insulated with shoulder washer – usually in the design of the BNC bulkhead connector itself if chosen properly) BNC connections in either a rack

panel or (better) water proof (via glands) junction box with removable cover (quarter turn fasteners – like Dzus fasters)
- The analyzer front-end will have another cable harness coming from it (BNC to BNC) which is a multicore cable connecting through another gland on the junction box hence, when the analyzer is in "continuous" or on-line monitoring mode, there is a secure and watertight connection from the analyzer front-end through to the accelerometer (expect that the µDot connection will need to be covered with silicon caulking, or RTV, in order for it to be waterproof itself).
- For off-line, or roving, measurements, the multicore cable from the analyzer front-end simply gets disconnected and the other cables (roving) connected as desired.
- Double-shielded construction

Roving Cables (Qty 10 – eight "live" and two spares)
- µDot to BNC
- Length? Longest needed. If measuring the eight points which have the greatest distance apart, add 10 (ten) feet. A standard (for all ten) length might be on the order or 30 – 50 feet (10 – 16 meters).

Spectrum Analyzer System for Structureborne, Airborne, and Underwater (Hydrophone) Measurements

- Frequency range: DC – 50 kHz (50 k Hz range to accommodate hydrophone measurements and high frequency noise per earlier studies)
- One-third octave band analysis 1 Hz – 20 kHz, with filters that meet ANSI S1.11-1986, Order 3 Type 1-D, eight channels REAL TIME (i.e. simultaneously, no data loss)
- FFT with exactly 1 Hz resolution capability up to at least 2 kHz (i.e. for example 3200 line frequency span 3.2 kHz, or 6400 lines 6.4 kHz span). The main point is to have a means to compare data from various sources with the same resolution. Furthermore, any analyzer system should be able to provide narrowband (FFT) resolution of 1% of the frequency of interest, For example, a 0.1 Hz resolution would be needed for accurate assessment of a 10 Hz tone, but for a 2 kHz tone, a 20 Hz resolution would be sufficient. In the field of Sound and Vibration, a resolution of 1% for FFT analysis is generally considered to be a reasonable expectation for what is termed "narrowband" analysis. This can be accomplished over a wide frequency range by zooming various frequency ranges to cover a wider band than the maximum line count allows for a given analyzer brand. This would, for some analyzer brands, simply mean multiple virtual analyzers simultaneously run in order to cover a wide frequency range with the 1% maximum bandwidth (resolution) requirement met. For other analyzer brands, it would mean multiple "passes" or analyses.
- FFT and One-third octave band analysis for all eight channels always in real time for 20 kHz (highest TOB) and 50 kHz FFT frequency ranges.
- Hardware inputs BNC with CCLD (ICP) 4-20 ma (28 V) powering.
- Strongly recommended but optional (because it is only available from Brüel & Kjær, OROS and possibly a few others) would be to have the one-third octave band AND FFT measurements made simultaneously. This is unique to B&K, OROS, and possibly a few others whereas for other vendors, one will have to measure them separately. For the Data

Physics system, the data can be recorded to disc and played back to re-analyze the tones using FFT analysis, but recording the time data continuously or even periodically (without need to) will use up a considerable (if not unacceptable) amount of disc space. This means that the continuous monitoring will be done in one-third octave bands (per the Navy's suggestion) which arguably is the correct way to monitor continuously. However, should a non-stationary (i.e. not steady state or constant) change or event take place which is problematic, the analyzer will have to be switched (manually?) into the FFT mode and restarted to gather tonal (constant bandwidth, narrowband) data. If the event changes or disappears, the cause cannot be troubleshot or found. IF the TOB (one-third octave band) AND FFT data were taken simultaneously during the online (continuous) monitoring, this manual step and potential loss of important data would not happen. Since the Navy apparently does not have experience with this capability, they have lived with this limitation. Note that this is an assumption on the part of the writer and may not be correct.
- Recording of raw time data to hard drive for later analysis (for example FFT calculation when not available real time).
- Easy expandability (i.e. without having to send system back to vendor for physical retrofit) from base 8 to 70+ channels.

Other Future Possibilities

The establishment of a deep database and subsequent data collection will yield a clearer picture of the relationship between structureborne and radiated noise. If the correlation(s) become clear and well-defined, even for limited frequencies, the correlation between fish avoidance and radiated noise can be further studied. If it is found that there is little or no correlation between radiated noise and fish avoidance, something of value has still been learned.

Beyond fish avoidance studies, the proposed spectrum analysis setup can also aid in both maintenance troubleshooting and mitigation effectiveness assessment. This will be possible only if the analyzer is used in it's native manual mode with parameters set up and changed according to the particular need. Furthermore, many modern spectrum analyzers contain (as standard or optional modules) additional troubleshooting tools such as cepstrum analysis, order tracking and analysis, signal enhancement (time averaging), phase demodulation, and cross-spectra functions. While these tools are limited to very special applications, they are often capable of identifying problems when most other analysis means fail.