Report from the Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping Workshop

Anthony R. Marshak, Laura Kracker, and Rebecca Peters

U.S. Department of Commerce
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Table of Contents

Executive Summary

Five NOAA Fisheries (NMFS) Survey Vessels (FSVs) (*Bell M. Shimada, Henry B. Bigelow, Oscar Dyson, Pisces, and Reuben Lasker*) have onboard ME70 Multibeam Echosounders[1]. ME70s allow for quantitative acoustic surveys of marine organisms in the water column and near the seafloor, and for the acquisition of bathymetric and seabed backscatter data to assist in seafloor mapping. Although there have been successes over the past decade in the mapping applications of the ME70, unforeseen complications have arisen. Scientists intending to use the ME70 for mapping encounter technological issues, especially if their knowledge and experience is limited. The likelihood of correcting these issues onboard is dependent on the level of expertise of the science party and the ship crew, as well as land-based support from the vendor and other experts. Likewise, the quality of the data collected affects its usefulness for developing seafloor maps, and obtaining the best data possible is highly dependent on the proficiency of the mapping team, as well as system readiness. Additionally, there is a wide range of intended uses of the ME70 among NOAA ships and PI's of individual projects. As a result, standard procedures do not exist among ships for seafloor habitat mapping with the ME70.

The ME70 serves as a useful system for acquiring bathymetric and seabed backscatter data for seafloor mapping, but more familiarization with the system is needed for effective use. Given the variety of issues encountered when using the ME70, along with the increased need for benthic habitat maps to improve fishery independent surveys, research, and management, a two-day workshop entitled, "Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping" was held at NOAA Headquarters in Silver Spring, Maryland during November 15-16, 2017 with these objectives:

- Share knowledge and applications of the ME70 for seafloor mapping.
- Evaluate the efficacy and applicability of using the ME70 to meet various scientific objectives.
- Develop recommendations on how to improve use of the ME70 along with a framework to develop standard operating procedures (SOPs) for ME70 seafloor data collection and processing.

Products from the workshop included the identification of three overarching needs, and developing strategies to addressing them:

1. There is a need for the development of a knowledge repository where past/existing information for the ME70 can be centrally located and accessible by the ME70 user community.

2. There is a need to identify and resolve gaps in expertise for calibration, data acquisition and post-processing data from ME70 operations.

3. There is a need for a proposed determination of roles and responsibilities of those using ME70 (i.e., ship staff, survey technicians, and scientists).

[1] Simrad ME70 multibeam echosounder. Mention of trade names does not imply endorsement by the National Oceanic and Atmospheric Administration.

In summary, agreed upon frameworks for developing SOPs and an information repository for the acquisition and processing of bathymetric and seabed backscatter data when using the ME70 for seafloor mapping and habitat characterization were proposed. Additional cross-NOAA efforts to enhance cooperative training and educational opportunities for scientists and technicians were recommended toward resolving gaps in expertise for system calibration, and for data acquisition and post-processing. A proposed determination of roles and responsibilities for ship staff, survey technicians, and scientists in application of the ME70 toward seafloor mapping was also agreed upon by workshop participants.

Additionally, twelve specific recommendations were developed toward improving the utility of the ME70 across the survey fleet:

Short-term:

1. Decide on the optimal ME70 standard configuration, and provide recommendations on alternative ME70 configurations.

2. Decide on the calibration procedures (i.e., patch and sphere calibrations) and the frequency of calibration needed. Calibration typically takes about 12 hours, and is normally conducted before each survey or annually.

3. Identify the key expertise requirements for at-sea ME70 operations and post-processing, and provide training as needed.

4. Resolve whether NMFS should support a sustainable capacity that is in-house or collaborate with NOAA's Office of Coast Survey (OCS) to use their expertise in obtaining seafloor maps wanted by NMFS scientists.

5. Develop a knowledge repository where current ship SOPs can be housed along with an expert contact list for reference by users and experts.

6. There needs to be support to acquire up to date software for Caris, Fledermaus, and Matlab.

7. Identify the key scientists and gaps in expertise requirements from each NMFS Science Center who will be devoted to ME70 (or other acoustic bathymetric mapping) operations and provide the necessary acoustic training to this potential pool of expertise.
    a. For example, OCS holds a three-week acoustic training program, which they have offered to open to fishery survey technicians and the NMFS science community.

8. NOAA's Office of Marine and Aviation Operations (OMAO) should work on conducting pre-season ME70 system readiness through calibration days.

Mid-term:

1. Support research (white papers) to utilize ME70 capabilities (information from Dave Demer SWFSC, Tom Weber UNH, and other international experts should be incorporated) to provide recommendations on ME70 beam configuration, and to resolve

frequency and beam limitations and multispectral aspects.

2. Provide recommendations for standard ME70 configurations for automated data acquisition and post-processing, and promote collaborative research.
    a. Have Caris build automation models for data processing rather than having a full SOP (Caris and QPS have offered to do this).

Long-term:

1. Each region should discuss what their data requirements are to determine what may be the best tool for gathering the type of information that is needed.
    a. This also requires the identification and allocation of staff for training in acoustic operations to support seafloor mapping and habitat characterization.

2. Talk with OMAO and NMFS Leadership to potentially add in complementary systems such as the EM2040 and other systems currently used by OCS. There should also be consideration of the future of the ME70 system, with the pros and cons of the system in mind, but also that additional training of the user community is needed to allow for the application of the ME70 system toward more effective habitat mapping.

A successful ME70 mapping program requires a suite of expertise - from systems integration, to planning, processing, troubleshooting, metadata and archival. OCS has developed much of the expertise that NMFS would need, and is willing to take steps toward supporting this application. However, to be fully successful both OCS and NMFS should identify a robust and reliable strategy for resourcing and coordinating this support. Based upon workshop conversations, efforts to engage NOAA cross-line office leadership in facilitating more effective use of the ME70 system for habitat mapping, strengthen user familiarity through collaborative trainings, develop ship-specific standard operating procedures, and develop an information repository are in progress.

Acknowledgements

The authors thank the members of the "Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping Workshop" steering committee for their organization and planning efforts. Nathan Bacheler, Margaret (Peg) Brady, Vincent Guida, Bob McConnaughey, Michael Parke, Charles Thompson, Waldo Wakefield, and Mary Yoklavich all contributed significantly toward the development of the agenda, in suggesting participants and speakers, and in identifying topics and areas for conversation during the two-day workshop. Conversations with Samuel Greenaway (NOAA Office of Coast Survey, OCS), and Michael Gallagher and William Michaels (NOAA Fisheries Office of Science and Technology, OST) throughout the planning of the workshop were also very helpful toward familiarizing the steering committee with the broad uses of the ME70 system, and toward effectively organizing and conducting the workshop. We additionally thank Stephen Brown, Kenric Osgood, and Ned Cyr (OST) for their support of the workshop, and in providing resources for its successful completion. Comments from the workshop steering committee and participants in improving the quality of this report are greatly appreciated. Additional thanks is expressed to Avi Litwack and Kelly Mayo for their assistance in making this document fully compliant with Section 508 web publishing standards.

Background/Overview and Purpose of the Workshop

The scientific Multibeam Echosounder, ME70 was designed and developed for midwater fisheries applications by SIMRAD, a subsidiary of Kongsberg Maritime, in collaboration with IFREMER (French Research Institute for Exploitation of the Sea). This multibeam system is installed on five NOAA Fisheries (NMFS) Survey Vessels (FSVs) (*Bell M. Shimada*, *Henry B. Bigelow*, *Oscar Dyson*, *Pisces*, and *Reuben Lasker)* to allow for quantitative acoustic surveys of marine organisms in the water column and near the seafloor. The ME70 is capable of providing estimates of fish and plankton abundance and distributions, quantifying aggregations in three dimensions, detecting single targets and estimating target strength, and providing bathymetric information. There are two modes the ME70 can operate in, Fisheries mode (FM) or Bathymetric mode (BM). The BM operates a bottom detection algorithm, allowing for the production of bathymetric maps and characterization of the seafloor. The only NOAA vessel with BM incorporated into its ME70 system is the *Henry B. Bigelow*.

The ME70 is a multibeam system specialized for fishery applications such that each of the 45 split beams can provide quantitative measures of target strength. The beams can be configured individually and set to a frequency between 70-120 kHz. The shape of individual beams can be configured (alongship and athwartship), with a minimum beam width of 2 degrees and a maximum swath width of 140 degrees (Trenkel et al. 2008). Other features of this system include two-way side lobe suppression and short pulse lengths. The ME70 can be optimized either for surveying the midwater environment or the seafloor to address a variety of research questions. As configured on NOAA FSVs, these systems run in FM only (with the exception of the *Henry B. Bigelow*). Without the BM it is necessary to implement an independent bottom detection algorithm to collect seafloor soundings and assign an estimated depth value. Specifically, when the ME70 is operating in FM, depth soundings can be extracted using customized Matlab code developed by Tom Weber - University of New Hampshire (UNH). This coding approach was also recently integrated into commercially available Hypack software. The bottom detect data can be further processed through bathymetric software (such as Caris Hips and Sips or Fledermaus/Quimera). Additionally, a beam configuration designed by UNH has been shared among the vessels and used extensively for seafloor mapping to ~450 m depths.

The ME70 has been used in a broad range of fisheries and seafloor mapping and habitat characterization applications within NOAA. These efforts have been facilitated by:

- The availability of a broadly applicable beam configuration,
- Matlab code for bottom detection developed by scientists at the UNH/NOAA Joint Hydrographic Center,
- A concerted effort to document and share procedures among ME70 users on the FSVs,
- Support from the NOAA Office of Coast Survey (OCS) and others.

For nearly a decade, the ME70 has been used for a variety of purposes including cursory mapping to guide fish survey site selection and coral ROV surveys; characterization of seafloor features related to the distribution of fish habitat; and hazard detection on fish trawl surveys. In spite of the fact that the ME70 was not originally installed on the NOAA FSVs for seafloor mapping, the UNH-developed bottom detection algorithm and beam configuration has allowed for the processing of soundings from the ME70 sonars operating in FM to support various

management and research applications on NOAA FSVs. Additionally, several northeast bottom trawl surveys have used the ME70 while operating in BM. Early on, these fisheries and habitat applications were led by investigators (with guidance from UNH, OCS and other partners) to address program needs and were not specifically focused on acquiring hydrographic quality survey data. Recent interest in providing survey data external to OCS and improving the quality of seafloor data collection on FSVs for habitat characterization has led to greater interest by NMFS and the NOAA National Centers for Coastal Ocean Science (NCCOS) in using the ME70s on FSVs.

Since the installation of the ME70 on the survey vessels within NOAA's fleet, the system has been used for mapping in multiple survey programs. For example the ME70 has been and is currently being used on the NOAA ship *Pisces* during the Southeast Fishery-Independent Survey (SEFIS) and the Southeast Area Monitoring and Assessment Program (SEAMAP) Reef Fish Survey. Data collected from the ME70 during an acoustic/trawl survey in the Gulf of Alaska on the *Oscar Dyson* have also been analyzed to evaluate trawlable and untrawable habitats in the Gulf of Alaska. In addition, an extensive mapping campaign in the Channel Islands National Marine Sanctuary (CINMS) has relied heavily on the ME70. A list of missions that used the ME70 for seafloor mapping are compiled below in Table 1:

Table 1. Selected NOAA Fisheries Survey Vessel (FSV) missions during which the acoustic ME70 system was used to collect seafloor data.

NOAA FSV	Cruise(s)	Investigator(s)	Affiliation
FSV *Henry B. Bigelow*	HB1801, HB1802, HB1806	Michael Jech	NOAA Northeast Fisheries Science Center, NEFSC
FSV *Oscar Dyson*	DY0909	Patrick Ressler	NOAA Alaska Fisheries Science Center, AFSC
		Tom Weber	University of New Hampshire
FSV *Oscar Dyson*	**Acoustic trawl stock abundance survey of walleye pollock in the Gulf of Alaska** (DY0901, DY0904, DY0909, DY1001, DY1002, DY1006, DY1103, DY1201, DY1203 DY1207, DY1302, DY1303, DY1307, DY1506)	Chris Wilson	AFSC
FSV *Pisces*	**Southeast Fishery-Independent Survey, SEFIS** (PC 1102, PC1204, PC1304, PC1402, PC1603)	Nathan Bacheler, David Berrane, Warren Mitchell, Matt Wilson	NOAA Southeast Fisheries Science Center, SEFSC

NOAA FSV	Cruise(s)	Investigator(s)	Affiliation
		Laura Kracker	NOAA National Centers for Coastal Ocean Science, NCCOS
	South Atlantic Deep Coral Survey (PC1103)	Andy David	SEFSC
		Laura Kracker	NCCOS
	South Atlantic MPAs and Deepwater Coral Habitat Areas of Particular Concern, HAPCs (PC1203)	Stacey Harter	SEFSC
		Laura Kracker	NCCOS
	Deepwater Coral MPAs (PC1303)	Stacey Harter	SEFSC
		Laura Kracker	NCCOS
	SEFSC Caribbean Reef Fish Survey (PC1505)	Brandi Noble, Charles Thompson	SEFSC
	Southeast Area Monitoring and Assessment Program, SEAMAP Reef Fish Survey (PC1106, PC1201, PC1202, PC1302, PC1305, PC1306, PC1401, PC1404, PC1601)	Brandi Noble, Charles Thompson	SEFSC
FSV *Bell M. Shimada*	**Acoustic trawl stock abundance survey of walleye pollock in the Gulf of Alaska** (SH1001)	Chris Wilson	AFSC
	Joint U.S.-Canada Integrated Acoustic and Trawl Survey of Pacific Hake and Pacific Sardine, SaKe (SH1103, SH1204, SH1507)		NOAA Northwest and Southwest Fisheries Science Centers, NWFSC, SWFSC
	California Current Ecosystem Coastal Pelagic Species (CPS) Survey (SH1405)	David Demer et al.	SWFSC

NOAA FSV	Cruise(s)	Investigator(s)	Affiliation
	Channel Islands National Marine Sanctuary (SH1503, SH1606, SH1705)	Chris Caldow	NOAA National Marine Sanctuary Program
		Juliet Kinney	UNH Joint Hydrographic Center
		Laura Kracker, Will Sautter	NCCOS
		Erin Weller	NOAA Office of Coast Survey, OCS
	SH1709	Dianna Waters	SWFSC
		Jodi Pirtle	NOAA Fisheries Alaska Regional Office, AKRO
FSV *Reuben Lasker*	**Mapping and Visual Surveys of Seafloor Habitats and Fishes** (RL1606)	Mary Yoklavich	SWFSC
		Laura Kracker	NCCOS
		Kayla Johnson	OCS
FSV *Reuben Lasker*	**Summer California Current Ecosystem Coastal Pelagic Species Survey** (RL1606)	David Demer et al.	SWFSC

Although there have been successes when using the ME70 for seafloor mapping, complications may also arise that can affect its utility. Scientists intending to use the ME70 for mapping encounter technological issues, especially if their knowledge and experience is limited. The likelihood of correcting these issues onboard is dependent on the level of expertise of the science party and the ship crew, as well as land-based support from the vendor and other experts. Likewise, the quality of the data collected affects its usefulness for developing seafloor maps. Obtaining the best data possible is highly dependent on the proficiency of the mapping team, as well as system readiness. Specifically, confirmation and documentation to assure that the ME70 and related systems are appropriately configured. Scientists planning to use the ME70 have often received assistance from personnel at OCS and NCCOS to assist with system integration, data collection, and data processing to produce seafloor maps. Additionally, there is a wide range of intended uses of the ME70 among NOAA ships and PI's of individual projects. As a result,

standard procedures do not exist, or at best are lax, among ships for seafloor habitat mapping with the ME70.

Despite these issues, the ME70 provides a workable opportunity for acquiring bathymetric and seabed backscatter data for seafloor mapping. Given the variety of issues around using the ME70 for seafloor mapping, along with the increased need for benthic habitat maps to improve fishery independent surveys, research, and management, a steering committee (**Appendix B**) was formed to plan a two-day workshop to bring together ME70 users and experts. The workshop entitled, "Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping" was held November 15-16, 2017 in Silver Spring, MD with these objectives:

1. Share knowledge and applications of the ME70 for seafloor mapping;
2. Evaluate the efficacy and applicability of using the ME70 to meet various scientific objectives;
3. Develop recommendations on how to improve use of the ME70 along with a framework to develop standard operating procedures for ME70 seafloor data collection and processing.

The workshop provided a venue for users to share their experience, including successes and challenges encountered when mapping with the ME70. Participants were able to share their expertise and provide insight and advice regarding issues encountered. The workshop agenda and list of participants are provided in **Appendices A and B**. Targeted products from the workshop included recommendations to improve the usefulness of the ME70 across the fleet, a framework for developing standard operating procedures, and an information repository when using the ME70 for habitat mapping. This workshop was also conducted in accordance with Recommendations 5.1 and 5.2 of the Update to the Marine Fisheries Habitat Assessment Improvement Plan (Peters et al. 2018).

Applications of the ME70 Toward Seafloor Mapping and Habitat Characterization

The workshop began with introductory presentations from two experts (Dr. Tom Weber, UNH; Samuel Greenaway, NOAA OCS), each having extensive familiarity with the ME70. Both presentations are summarized below.

Habitat (Seafloor) Mapping with the ME70 Fisheries Mode

Presenter: Dr. Tom Weber, University of New Hampshire Center for Coastal & Ocean Mapping/Joint Hydrographic Center

Dr. Weber gave a technical overview of the ME70, detailing its two survey modes (Fisheries, FM and Bathymetry, BM) and their applications and tradeoffs. Unlike traditional bathymetric multibeam systems based on the Mills-Cross design, the ME70 uses a configurable planar array. A Mills-Cross design implements beams at the intersection between a transmit beam and multiple receive beams (Jung et al. 2018). In this design, the transmit beam is wide in the across-

track dimension but narrow along-track, while the receive beams are oppositely configured. Conversely, a planar array can form transmit and receive beams that are of the same dimensions both across and along track.

A planar array can also give phase-based location of a single target within the beam using the split-beam methods associated with scientific single-beam systems such as the EK-60. This target location is critical to fully calibrate these systems using the target-sphere methods as described by Foote (1982) in general and Ona et al. (2009) specifically for the ME70. For bathymetric applications, this two-way beamforming has the additional advantage of suppressing sidelobes. However, this unique planar array also presents data challenges with slower associated ping rates, a relatively wide minimum beam opening angle (2 degrees, as compared to 0.5 in cases of commonly used bathymetric systems), and large channel counts that can become unmanageable when acquiring and processing data.

Given these characteristics, the ME70 is not optimized for high resolution seafloor mapping, as it was primarily designed to detect midwater fish schools. More recently, efforts have been made to apply this system toward detecting fishes close to the seabed without influence from seafloor echo, and toward bathymetric mapping. However, the expectation that the ME70 can provide highest-resolution data for seafloor mapping is unrealistic. Hydrographic multibeam echosounders operating at similar frequencies as the ME70 (~100 kHz), such as the Kongsberg EM710, have much higher resolution, faster ping rates, better along-track and near-nadir resolutions, and far better range performance than the ME70. An EM710, for example, will give full 120+ degree across track coverage to depths of nearly 1,000 meters and maintain a swath greater than 2 km to depths exceeding 2,000 meters. The ME70 can give 120 degrees of coverage to about 150 meters and cannot resolve any depths over 500 meters. However, because of the one-way side lobe suppression of these bathymetric systems, the data from the water-column typically has much higher side lobe interference. As discussed previously, these systems cannot be readily absolutely calibrated for target strength based applications. While the lower resolution data obtained by the ME70 may limit specific object detection, this may not be limiting for broader large-scale habitat characterizations. In some applications, the ability to concurrently acquire data on both the bathymetry and water-column targets using a calibrated system may additionally be of interest. Ultimately, the utility of these technologies varies at the scale of interest and the ME70 is still applicable toward mapping seafloor bathymetry.

While the technology is user-configurable and can be manipulated by individuals toward specific uses, doing so requires time and experience to configure the system properly. Dr. Weber reinforced that extensive familiarity with the ME70 system by a given user is also needed for its optimal use, highlighting the need for training and additional on-board expertise for its maximum effective use.

Mapping with the ME70: A Coast Survey Perspective

Presenter: Lieutenant Commander (LCDR) Samuel Greenaway, NOAA Office of Coast Survey (OCS)

LCDR Greenaway gave an overview of NOAA OCS support of the ME70, especially its hydrographic mapping applications, and advice toward its utility for habitat characterization interests. OCS has been assisting on FSVs to help in advancing scientific approaches with onboard multibeam technologies and providing support to researchers.

When determining the correct mapping system for a given project, the scientific questions being posed should ultimately drive one's choice of system. Ideally, scientists should determine what their purpose of investigation is, the information that they wish to gather, and then what the best tool for obtaining that information would be. In practice, however, the availability of onboard system options for a given vessel and their associated data resolutions have driven this decision making. If, for example, a scientist needed to resolve depths on features on scales of 0.5 meters in 300 meter depths, the only way of currently meeting that requirement is a high frequency multibeam system operating on a deep-tow or autonomous underwater vehicle (AUV) flying within 60 meters of the seafloor. If one is interested in examining large-scale substrate patterns at up to 150 meters depth while concurrently acquiring calibrated watercolumn data on pelagic fish, a multibeam echosounder such as the ME70 is likely the only single system that can meet this requirement. Additionally, bathymetric data with a horizontal resolution of 100 meters is considered suitable for regional-scale habitat models and maps.

OCS has developed clear and very detailed specification for acquiring data for charting (see: https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/hssd-2018.pdf). However, OCS is committed to using the best available data for updating the charts – irrespective of the original purpose of the work. Under the concepts of the Integrated Ocean and Coastal Mapping program, OCS will also collaborate with other communities – both to broaden the applicability of data OCS acquires for charting and to assist others in mapping applications.

OCS has learned that building a robust mapping program requires a significant commitment of resources. On a technical level, properly setting up a multibeam system for mapping requires an operational familiarity with the multibeam itself, but also a full integration with ancillary sensors, positioning systems, and reconciliation of various reference frames. This is a specialized field of technical expertise that includes vessel vertical control, hardware and software integration, and system qualification. Specific factors including physical offsets for a ship's reference frame, tidal correctors, and time synchronizations must additionally be considered. All of these elements require specific expertise and are generally not available from one vendor. In fact, only a small team of individuals within OCS typically has the full set of experience to reliably integrate and qualify these types of systems.

Executing a successful mapping mission requires more than a working well-integrated system. Planning, acquiring, troubleshooting, processing, analyzing, and documenting mapping work are each specialized skills. Mastery of these fields occurs over many years of application and training. None of these components is unusually difficult, but neither is any of it trivial. For

example, basic training for hydrographic survey technicians to support OCS missions is a three-week course, while establishing competency requires 12+ months of continued on-the-job training. Individuals are generally trained to produce bathymetric maps, while more applied uses and calibrations of the system or those on other ships may require other specialists with expertise beyond the abilities of OCS trained personnel. Currently, OCS is not staffed to put a surveyor on any given FSV with the expectation that they have full expertise for that particular FSV. Training and retention of survey technicians also presents challenges, although system readiness can be done upfront and standardized on an annual basis to qualify and check all elements.

In short, NMFS could build a ME70 mapping program, but to do so successfully requires much more than a set of standard operating procedures for the system. It would require building a suite of expertise - from systems integration, to planning, processing, troubleshooting, metadata and archival. OCS has developed much of the expertise that NMFS would need, and is willing to take steps toward supporting this application. However, to be fully successful both OCS and NMFS should identify a robust and reliable strategy for resourcing and coordinating this support.

NOAA Regional Examples of Using the ME70 and Other Acoustic Technologies for Seafloor Mapping

Examples of the user experience in applying the ME70 toward seafloor mapping were presented for the six NMFS regions, in addition to efforts being undertaken by NCCOS and the National Marine Sanctuary Program (NMS) in the CINMS. While users varied in their level of experience, application, and approach in using the technology, common interests in obtaining and processing seabed backscatter and bathymetry data and in enhancing fisheries, sanctuary, and spatial ecological research were observed.

NMFS Alaska Region – Applications of ME70 Acoustics in Alaska to Assess Seafloor Trawlability and Rockfish Availability to Bottom Gear

Presenters: Sarah Stienessen (AFSC), Tom Weber (UNH), Chris Rooper (AFSC), Jodi Pirtle (AKRO), Darin Jones (AFSC), and Chris Wilson (AFSC)

Beginning in 2008, the NOAA Alaska Fisheries Science Center (AFSC) has been using the ME70 aboard the *Oscar Dyson* in collaboration with UNH, especially toward classifying trawlable and untrawlable habitats. The following case studies were highlighted at the workshop:

- 2010 Snakehead Bank Case Study - as published by Weber et al. (2013).
- 2011 Trawlable/Untrawlable habitat (T/UT) models developed for Gulf of Alaska - as published by Pirtle et al. (2015).
- 2013 Extended T/UT study with combined acoustic-optical approach to add more eastward sites.
- 2015, 2017 Continuation of T/UT study with combined acoustic-optical approach.

Initially 8% of the Gulf of Alaska shelf was classified as untrawlable by captains of chartered fishing vessels using standard AFSC bottom trawl survey protocols, with much of the rockfish composition and abundance for the region unknown. Through use of a combination of acoustic technologies (Simrad EK60 Scientific Echosounder, ME70), and ground-truthing with cameras, investigators have been able to map fine scale trawlability and other habitat features; determine rockfish species and abundance; and estimate availability of select rockfishes to bottom trawls (Q = gear efficiency).

In carrying out the first objective (i.e., mapping), ME70 bottom classification data were ground-truthed with camera image data to parameterize a model for predicting trawlability. Data were collected on bottom depth, rugosity (bottom roughness, using Vector Rugged Measure - VRM), relative elevation (using Bathymetric Position Index - BPI) and bottom hardness (using oblique incidence backscatter - Sb oblique). Opportunistic nighttime mapping operations followed the daytime acoustic pollock survey during 2013 and 2015 study periods where lowered stereo camera deployments along survey grids took place to determine trawlable and untrawlable sites. When applying data from the ME70 toward bottom characterization, the Sb oblique backscatter model provided the best and most significant results toward identifying trawlable habitats. Tentatively, adding two more years of data to their model suggested that VRM and BPI may not

always be suitable for trawlability prediction, and that other factors that explain trawlability should additionally be considered.

Other work has been conducted at the AFSC using single-beam echosounders to acoustically derive estimates of bottom type for informing habitat models and complement ME70 information. Weber et al. (2013) concluded that the spatial resolution of the ME70 system was insufficient to provide a useful estimate of the rugosity level, and that a system with higher frequencies and resolution (i.e., a hydrographic system or side-scan sonar) might provide more useful results because of the significance of oblique backscatter (Sb). Additionally, a recent project in the Gulf of Alaska is evaluating the utility of a hydrographic multibeam echosounder (Kongsberg EM710) for discriminating trawlable and untrawlable areas.

Additionally, the ME70 can be used to examine or enhance:

- Seafloor effects on survey bottom-trawl performance and efficiency in trawlable habitats.
- Stock assessment surveys in untrawlable habitats using combined acoustic-optical methods.
- Habitat predictor variables in species distribution models to refine Essential Fish Habitat.
- Fishing-Effects Model seafloor characterization to assess impacts to Essential Fish Habitat.

Overall, these studies have allowed for a composite of substrate and habitat information to be collected when using the ME70 together with other technologies. Ultimately, the utility of these data are dependent on the spatial scale of the defining features. The predictive habitat model in development is being applied toward stock abundance surveys and population assessments. It is important to note that continuous substrate information helps to provide the best model, particularly when using oblique incidence backscatter information, demonstrating the complementary utility of the ME70.

NMFS Southwest Region - Acoustic Multibeam Echosounder Technologies for Seafloor Habitat Mapping

Presenters: Diana Watters and Mary Yoklavich (SWFSC); David Demer (SWFSC)

The NOAA Southwest Fisheries Science Center (SWFSC) habitat ecology team has conducted research on understanding west coast rockfishes and their deep water (>50 m) habitats. Their work is focused on these and other demersal species that are associated with complex rocky habitats, including deep-sea corals. As most of their work occurs in untrawlable habitats, they have relied on manned subs, AUVs, and towed camera sleds to perform visual surveys. They have additionally used other technologies including multibeam echosounders, to examine deeper water regions of the California shelf and slope. Their group has been able to produce high resolution seafloor habitat maps to support:

- More efficient fish and coral survey designs
- Stock assessments
- EFH designations
- MPA design and monitoring
- Models of species distribution and abundance

For example, work by Wedding and Yoklavich (2015) used both visual survey data and gridded seafloor mapping information (5 meter resolution bathymetry) to develop predictive models regarding the abundance and distribution of rockfishes. Generalized Additive Models (GAMs) were based upon depth, slope, and hard/soft substrate complexity as derived from collected data, which allowed for the creation of predictive density and biomass maps from environmental covariates. Ultimately, these predictive maps can be applied toward:

- Estimating total biomass in study areas
- Quantifying habitat capacity
- Prioritizing habitats for conservation
- Evaluating potential risks to rockfish stocks, and
- Informing EFH consultations

The team has also been using the ME70 for mapping the northern Channel Islands seafloor in collaboration with NMS and NCCOS. They have leveraged time aboard Untrawlable Habitat Strategic Initiative (UHSI) cruises to allow for this mapping, together with AUV ground-truthings. Overall, they have been able to map portions of the Sanctuary (302 km^2) located south of Santa Rosa and Santa Cruz islands, ranging from 28 to 502 meters depth.

Additional work by David Demer and colleagues from the SWFSC Advanced Survey Technologies program has been focused on applying the ME70 split-beam configuration toward acoustically classifying the seabed and determining fish-habitat associations. Their team has made advances in deriving bathymetric data toward determining seabed slope and in examining seabed heterogeneity. These efforts have allowed for enhancements of fish surveys in geographically defined regions, allowing for complementary higher resolution sampling with ROVs and AUVs to define acoustic classifications as primary and secondary bathymetric substrate types. Additional simultaneous measurements using the EK60 and ME70 together have allowed for the creation of habitat probability maps where certain species may be found.

Overall, this team and staff at the SWFSC have emphasized that the utility of the ME70 is very strong, is not being used to its full potential, and its uses should continue to be explored further to enhance fisheries ecological research.

NMFS Northwest Region – Using Acoustic Multibeam Echosounder Technologies for Habitat Mapping

Presenter: Dezhang Chu (NWFSC)

At the NOAA Northwest Fisheries Science Center (NWFSC), the ME70 has been used to collect seafloor data during its 2010-2011 NWFSC hake and 2012 killer whale surveys, in addition to the 2012 NWFSC/SWFSC “Sake” (sardine/hake) survey. Approximately 1 TB of data have been collected, which potentially could be applied toward identifying seafloor topography and classifying features. However, the Center has generally been unable to process these collected data. Investigators have only been able to replay or view data. They are also constrained by other work demands and limited expertise to be able to process data in a timely manner or integrate the information with other acoustic data (e.g., EK60 data). There are additional challenges in

calibrating system backscatter, proper beamforming for habitat classifications, and in attempting to work toward automatic seafloor classification. Investigators also continue to improve their data processing capabilities, but have generally been limited in the utility of the system toward these interests. Participants from other regions, including IFREMER, remarked on challenges in calibrating beams for improved detection, especially when attempting wide swath angles.

Overall, while progress has been made in acquiring ME70 acoustic seafloor information, its application toward habitat characterization remains limited due to constrained staff and resources.

NMFS Pacific Islands Region – Example Sonars Used for Habitat Mapping

Presenter: Michael Parke (PIFSC)

In the Pacific Islands region, two Research Vessels (R/Vs) used by NMFS investigators house multibeam echo sounders, but not the ME70. The R/V *Hi'ialakai* contains two sonars, the EM3002 and EM300. The EM3002 has full swath width accuracy to the latest International Hydrographic Organization (IHO) standard that is 10x a given water depth (EM3002D) of >200 meters, including sonar heads for 500 or 1500 meter depth ratings. The EM300 has a swath width of up to 5.5x a given water depth. It operates from a depth range of 10 to 7000 meters with up to 864 soundings per ping and built-in yaw, pitch, and roll compensation and stabilization. Aboard the R/V *Ahi*, the Reson SeaBat 8101 multibeam sonar is used with both phase and amplitude bottom detection, a 150 degree swath coverage (which can be upgraded to 210 degrees), and operates at up to a 600 meter swath width and at 5 to 300 meters depth. Beginning in 2008, the Pacific Islands coral matrix program presented opportunities for mapping using these instruments, producing successful merged bathymetric maps for areas such as Baker Island (U.S. Minor Outlying Island) and Tutuila Island (American Samoa). However, these efforts have not been without challenges.

Attempts to obtain better environmental information to enhance deepwater bottomfish stock assessments have been limited to sporadic, non-systematic data collection opportunities, leaving many areas unmapped. Data acquisition is constrained by non-standardized sea trials, lack of detection of faulty sonar heads and/or roll bias for certain instruments, poor sound velocity with inadequate CTD (Conductivity, Temperature, Depth) measurements, and imprecise differential GPS positioning. Ongoing data deficiencies include limited mapping extent, poorly constrained vertical control, and inaccurate horizontal positioning. These limitations are mainly due to rotating personnel, equipment failures, and data deficiencies. Additionally, more effective integration of onshore and offshore personnel, improved survey plans, and post-cruise data processing are needed.

Certain limitations have been moderated through successful scientific collaborations with the University of Hawaii, using their R/Vs that house Kongsberg EM122 (12 kHz) and EM710 (70-100 kHz) multibeam sonars. There has been additional co-development by NMFS and the University of Hawaii of 5 meter resolution bathymetry and seabed backscatter synthesis for the Main Hawaiian Islands. These collaborative efforts have allowed for the collection of more accurate benthic information that is being applied toward stratifying sampling for both shallow

water and deep water fish surveys and planning ROV missions to survey deep water corals. Additionally, this allows for complementary collection of substrate information that can be tied to simultaneously collected biological data necessary for characterizing species habitats. However, the resolutions at which these data are collected must be better reconciled to allow for the creation of more accurate predictive species-habitat maps. Currently, these efforts are further constrained by the lack of scientific consensus regarding the preferred data resolution for habitat mapping, with suggested ideal resolutions ranging from 1 to 60 meters.

Overall, while progress has been made in acquiring seafloor bathymetric and backscatter information, further refinement of data collection and analytical methods will allow for their more effective application toward habitat characterizations.

NMFS Southeast Region – Using the ME70 for Habitat Mapping in the Southeast Region

Presenters: Brandi Noble and Nate Bacheler (SEFSC)

In the Southeast region, the FSV *Pisces* is used for three primary projects during which complementary seafloor information is collected using the ME70:

- SouthEast Area Monitoring and Assessment Program (SEAMAP) Reef Fish Survey
- SouthEast Fishery-Independent Survey (SEFIS)
- Characterizing the South Atlantic Bight Marine Protected Area (SAB MPA)

These projects are focused on conducting fisheries-independent reef fish surveys in highly complex, mostly shelf-edge environments that are not well suited for traditional gears. Therefore, they are assessed with stereo-video cameras, vertical line gears, traps, and ROVs. Ultimately, this information is used to obtain an index of relative abundance for federally managed reef fishes. Since 2012, the ME70 has been used for nighttime mapping operations during the SEAMAP Reef Fish Survey. This survey targets natural reefs located in depths from 15 to 200 m in the Gulf of Mexico and U.S. Caribbean, but they are primarily located on the shelf-edge break. The SEFIS trap-video survey is conducted throughout the South Atlantic region from North Carolina to Florida and examines hardbottom reefs ranging from 15 to 120 meters depth. The survey was greatly expanded in 2010 with additional points from fishermen, and further expanded from 2011 onward into ME70 mapped and ground-truthed areas. Additionally, the SAB MPA survey conducts work throughout the east coast extending from southern North Carolina to central Florida (50-250 m depth). Their sampling area has benefited significantly from mapping efforts conducted by the U.S. Navy off northern Florida. Characterization efforts have since been expanded by NMFS using ROVs during the daylight hours and nighttime mapping using the ME70.

Using the ME70, the SEFSC derives habitat presence/absence information, and has increased and refined information on mapped substrate distributions collected during its fisheries-independent surveys. As of the workshop, 5405 linear nautical miles and 1972 km^2 have been mapped during the SEAMAP survey as compared to just 319 linear nautical miles using side-scan sonar technology. An additional ~150-200 km^2 have been mapped during each SAB MPA survey, which has been coordinated with SEFIS efforts toward ultimately mapping the complete coverage of the South Atlantic outer shelf. Efforts to improve habitat and fish index precision are

ongoing with complementary gears (i.e., trap, camera, ROV, and hooked line), with information being applied toward more rigorous survey designs and improving information on site-specific habitat relationships for managed species. Mapped information has also facilitated higher-resolution habitat classification efforts using geocoder for sediment analysis. Additionally, bathymetric information is being incorporated into benthic terrain models and seabed backscatter data are applied toward identifying hard bottom areas.

Data resolution was initially limited during early use of the ME70 in 2011. However, the information collected was still useful toward identifying simple substrate delineations and in focusing reef fish survey sampling sites. From 2014-present, higher quality information at greater resolutions has been collected. These improvements are ongoing with system use.

Although advances continue to be made using mapping technologies and standard operating procedures (SOPs) have been developed, SEFSC scientists have nevertheless identified many challenges that they continue to encounter in using the ME70. These include a particular lack of fishery biologists with proper acoustic training, limited expertise within working groups, and a need for self-initiated coordination among a very limited ME70 user community. SEFSC representatives noted that mapping in the southwest region has been accomplished through SWFSC collaboration with OCS, and NCCOS (Biogeography Branch). It was suggested that having a NOS liaison with specific ME70 knowledge would also be very beneficial toward resolving knowledge limitations and in facilitating NMFS mapping efforts. Individuals feel constrained in terms of contacts upon which they can rely when questions arise. Additional operational challenges include working with ship operators with limited mapping experience, needing to manually enter survey lines into an autopilot, and integration of Hypack for survey and mapping operations. Much mapping with the system includes making on-the-fly changes, which requires the bridge to use the same software the lines were created in (Hypack) instead of Rose Point software that is used during normal operations. Additional issues with software compatibility and a lack of standardization among other FSVs can create challenges when communicating with ME70 users from other regions.

Overall, while improved data resolution and survey applications have been observed in the southeast region, system troubleshooting and limited staff expertise has created challenges when applying the ME70 toward habitat characterization efforts.

NMFS Northeast Region – ME70 Bottom Mapping in the Northeast Region

Presenter: Vince Guida (NEFSC)

Habitat characterization attempts for the northeast region have been made possible through the use of single-beam and multibeam sonar equipment aboard the FSV *Henry B. Bigelow*. Earlier mapping efforts included using single-beam EK60 sonar data to map Maryland coastal reefs (25-40 m depth) that serve as important black sea bass habitat at a coarse 20x20m resolution. With the addition of the ME70, it was anticipated that detailed maps at higher quality and resolutions could be created. However, the data that were initially obtained were not very useable even with qualified staff available for its processing. When returning to investigate black sea bass habitats with the EK60, scientists were successful in creating imagery at an exaggeration of 100 fold at

4x1 km horizontal and 10 meters topographical resolution. This information was very useful for informing where concentrations of black seabass occur, given their affinity for sandwave areas of 1-3 m height. In additional collaborations with the Bureau of Ocean Energy Management (BOEM), the NEFSC has worked to map benthic substrates that are proposed as wind energy areas extending from off North Carolina to Massachusetts. These efforts have been complemented by use of AUVs available through partnerships with the National Institute for Undersea Science and Technology (NIUST) that were equipped with Simrad EM2000 multibeam sonars. These devices were operated for ~15 hours and produced maps from approximately 50 meters from the bottom. While the equipment requires an expert crew of six skilled operators, its higher resolution and ability to operate over a large depth range are of great utility. These efforts allowed for the creation of detailed ultra-high resolution (2 meter) maps for Hudson Canyon that were useful for identifying tilefish burrows and methane blowout locations. Scientists have been challenged in obtaining similar resolutions with the ME70, which produced much coarser imagery in the same tilefish locations at 110-140 m depth. Along these locations, 123.6 km^2 of substrate were mapped over a 24 hour period (~5.0-5.5 km^2 mapped per hour), but at much less detail than with other technologies.

While initially using the ME70 in conjunction with Olex software to scout bottom trawl locations, recurring patch test issues and unsuccessful calibration attempts to account for heading and ship roll limited its overall utility and caused significant losses of scouting time. Distorted multibeam data were being produced, which were of little use to scientists and required resurveying due to inaccurate offsets that led to the creation of false bathymetric data. Additionally, other difficulties presented included the loss of bottom detection, mechanical issues, communication errors among systems, display and data archiving errors, and challenges to maintain constant operation with the system unexpectedly turning off. Loss of bottom detection repeatedly occurred while performing CTD casts or trawling, with the solution being to correct by creating an artificially forced bottom using the software. Additionally, estimates of bottom hardness directly under the ship were initially erroneous, which skewed hardness values for the rest of the swath. These challenges led to the creation of questionable data, but since 2011 they have largely been resolved with improved expertise. The ME70-Olex system is now regularly used for scouting, and was successfully used in 2012 to map the southern New England slope at depths up to 500 meters and for identifying canyons.

Attempts to complement ME70 information with video have proven successful, especially given that the *Bigelow* can support camera vehicles to examine fish habitats, deep coral distributions, and tandem mapping and sampling of fishes in known areas. Although certain challenges have persisted, scientists remarked that the ME70 has provided much useful information over time, especially as users have become more familiar with the technology. Future efforts include using the ME70 to continue examining fisheries shelf habitat, Gulf of Maine and mid-Atlantic deep sea coral distributions, and conducting efforts to map, classify substrate, and sample fishes in tandem.

Overall, while use of the ME70 toward obtaining high-resolution habitat information was initially limited, the system has produced useful habitat information that can be complemented with other higher resolution technologies.

NOAA Office of National Marine Sanctuaries - ME70 Mapping in the Channel Islands National Marine Sanctuary (CINMS)

Presenter: Chris Caldow (NMS)

Staff from the NOAA Office of National Marine Sanctuaries (NMS), together with members of the NCCOS Biogeography Team have been using the ME70 to map the CINMS since 2014. Previously, a dearth of high resolution benthic information had been available throughout the region, with ~60% of the sanctuary characterized by lead line or single-beam data. As the region is at risk of potential oil spills and other anthropogenic effects such as ocean noise (the impacts of which are influenced by ocean substrate/hardness), it is important to document the habitats that may be affected by these stressors, understand the role they play in supporting living marine resources within the sanctuary boundaries, and apply this information in the context of improved species assessments.

As a result of the southern California mapping initiative, 12.6% of the southern California region has been mapped, with NMS contributing to a significant amount of the mapping effort. To date, ~80% of CINMS has been mapped and these efforts were made possible through extensive partnerships with NCCOS and assistance from OCS to ensure that the ME70 aboard the FSVs *Ruben Lasker* and *Bell M. Shimada* could be used for mapping the region. Beginning in 2014, ~42% of the NMS was mapped surrounding San Miguel, Santa Rosa, Santa Cruz, Santa Barbara, and Anacapa Islands. Relying on input from partners, including The Nature Conservancy, U.S. Navy, BOEM, academic institutions, and NMFS, priority mapping areas were identified. Efforts progressed from 2015-2017 aboard the two FSVs and the R/Vs *Nautilus* and *Rainier*.

While successful overall, issues have arisen in terms of user familiarity with survey techniques, hardware and software troubleshooting, wiring, communication, and needed updated surveys of the ships to meet OCS standards. Some concerns have been alleviated by relying on other partners such as BOEM and the U.S. Geological Survey (USGS) for supporting additional ship time with other sonar systems. As in other regions, staff have also remarked on the limited expertise available and difficult learning curve toward mastery of the technology for mapping.

International Approaches When Using the ME70 for Seafloor Mapping

Two examples of applying the ME70 toward seafloor mapping in European waters (Norway and France) were presented during the workshop.

Use of the ME70 multibeam echosounder in Norway

Presenters: Egil Ona (Norwegian IMR) and Dezhang Chu (NWFSC)

Investigators at the NWFSC have been recently collaborating with scientists from the Norwegian Institute of Marine Research (IMR) toward using the ME70, among other echosounders and sampling equipment (including EM300, EM302, EM305, EM710, TOPAS profiler, AUVs, camera, and video), to characterize seafloor habitats within the Norwegian Exclusive Economic

Zone (EEZ). Together with NOAA, IMR, The Geological Survey of Norway (NGU), and the Norwegian Mapping Authority these efforts have been conducted under the Norwegian Mareano project (www.mareano.no/en/maps/mareano_en.html) toward producing interactive maps.

Complementing this work, the ME70 is being applied toward examining demersal and semi-demersal fish stocks. However, because the autocorrelation of density along the ship track is very high, and extra information cannot be gained from certain beams in the athwartship direction, they have made efforts to decrease the volume to the acoustic deadzone through development of broadband echo sounders. Additionally, the increased sampling potential provided by the ME70 may help to reduce this coverage uncertainty, which was applied during a regional survey of sand eel (Teleostei: Ammodytidae) grounds. Application of the ME70 toward estimating abundance of lesser sand eel (*Ammodytes marinus*), which burrow in sandy substrates and can form large feeding shoals, has proven effective despite their patchy distribution. Using zig-zag or parallel transects, expanses of the Norwegian southwestern EEZ were surveyed at greater sampling volume and resolution, and less acoustic deadzone, than would be possible with another echosounder such as the EK60. Full scientific data outputs were obtained that permitted estimations of fish school diameter with lower coefficients of variation.

Additionally, given a full split-beam calibration of each beam toward improving accuracy, a 3-dimensional reconstruction of the sand eel schools was created and tied to mapped substrate information. Using Simrad TD50 multibeam visualization software, this information can be captured and processed in real-time, allowing for new knowledge regarding schooling behavior to be gained during the survey. Overall, surveying this stock with the ME70 may readily reduce the sampling effort needed to reach an acceptable uncertainty for stock biomass estimates, especially with improved resolution of preferred substrate. As of 2017, two IMR vessels (R/V *Fridjof Nansen* and R/V *Kronprins Haakon*) have installed the ME70 onboard, and a Simrad Large-Scale Survey System (LSSS; Korneliussen et al. 2006) is being built for post-processing both fish school and associated bathymetric information. These advances will help optimize future stock surveys, while also allowing for interpretation of large datasets.

Seafloor-backscatter processing of ME70 (bathymetry option) data: Application to continental shelf mapping of the Bay of Biscay and Irish Sea

Presenters: Xavier Lurton, Ridha Fezzani, and Laurent Berger (IFREMER Underwater Acoustics Laboratory)

From 1999-2005, IFREMER worked closely with Simrad and IMR to develop the ME70, which was first installed and commissioned aboard IFREMER's R/V *Thalassa* and has been operational since 2007. The technology has been used for biological and stock assessment cruises in the Atlantic, English Channel, and North Sea. A second system was installed on the R/V *L'Europe* (Mediterranean). Worldwide, ~30 systems are currently installed on vessels or have been ordered for the collection of both midwater and seafloor data. Efforts to conduct seafloor mapping in the European Union (EU) are supported by the European Commission Joint Research Centre Data Collection Framework, in addition to EU state organizations and oceanographic institutions (e.g., IFREMER, Spanish Institute of Oceanography, UK Centre for Environment, Fisheries and Aquaculture Science), national collaborators, academics, and fishing organizations. All of these

efforts fall under the context of the EU Common Fisheries Policy. Over time, long-term, large-scale commercial species abundance data have been collected toward quantifying the spatial distribution of fish stocks. Additionally, environmental and acoustic data applied toward mapping seafloor habitat features are collected during surveys to improve scientific knowledge of fish biology and biodiversity, and to enhance fisheries science and management.

Seafloor habitat data have been collected using the ME70 (BM) onboard the IFREMER ship R/V *Thalassa* to relate species biology to physical properties of the seafloor (using bathymetric and seabed backscatter data) and toward defining, characterizing, and predicting features of essential habitats. The ME70 is also being applied toward mapping the seafloor in relation to monitoring fishing activities, examining bottom-trawling effects on habitats, and developing fishing strategies as related to bathymetry and sediment type. Regionally scaled habitat mapping efforts have been ongoing throughout the Bay of Biscay and Irish Sea since 2008 and are conducted over a six week period per year. Seabed backscatter data are applied toward enhancing fish stock assessments and characterizing seafloor habitats, with 213 surveys having been conducted within 169 gridded sites (5500m x 2000m; line length 3500 m). However, little seafloor ground-truthing has been performed to complement these efforts.

Additionally, while information is being gathered it is still not at a high enough resolution to identify or distinguish reef habitats, but data can be extrapolated to obtain information regarding topography for a given area. Efforts are also underway to link collected information with geological and biological analyses, improve coverage and grid resolution, and to extend mapping operations into the English Channel. With a large dataset being accumulated over a 10-year period, improved calibration techniques are being developed and investigated, including between both survey modes (FM and BM) to allow for improved seafloor data collection and calibration. Incorporation of complementary sensors, including the EM2040, is also being considered to enhance mapping resolution. These efforts are ongoing, working toward more effective use of the technology and providing examples on how to improve mapping resolutions and techniques.

Data Processing Examples

Presenters: Matt Wilson (QPS), Josh Mode (Teledyne Caris), Will Sautter (NOAA NCCOS), and Xavier Lurton (IFREMER)

Demonstrations and data processing examples were given by QPS and Teledyne Caris software representatives, and users familiar with bathymetric and seabed backscatter data processing methods using Caris and Fledermaus (FMGT) software. This effort allowed for workshop attendees to become more familiar with available environments in which to process and clean acquired data, and to learn about recent advances in software development. For example, new efforts by QPS have worked toward deeper and more sophisticated data extraction algorithms, guided workflows, and automatic reprocessing through the Qimera design platform. It was recommended that some of these details regarding data processing, along with input from industry representatives should be included in SOPs. This information would be greatly complemented by efforts to broaden accessibility of software and allow for NOAA-industry

cooperative advances to automate workflow components of onboard data visualization and processing.

In addition, communication with and referral to products put forth by the Marine Geological and Biological Habitat Mapping (GEOHAB) backscatter working group were recommended. These products include documents on backscatter measurements and rules for seabed backscatter acquisition and processing that were recommended to be included in a knowledge repository or SOP.

Ideas for Developing an ME70 Knowledge Repository and/or Standard Operating Procedures for Habitat Mapping

Following overviews and presentations regarding the applications of the ME70 toward seafloor mapping, a conversation took place toward developing a knowledge repository and Standard Operating Procedures (SOP) for more effective use of the ME70 system in seafloor mapping and habitat characterization aboard NOAA FSVs. A draft SOP based upon commonly applied methodologies was introduced and its applications for the NOAA user community were discussed and refined.

Presenters: Laura Kracker (NCCOS), Will Sautter (NCCOS), and Tony Marshak (NMFS Office of Science & Technology, OST)

Current workflows and documentation for ME70 operations are often ship or program specific, with little standardization between work groups or projects. Currently, there is no formal means of maintaining information on processes and procedures associated with mapping using the ME70. Standard Operating Procedures (SOP) currently do not exist across NOAA vessels for applying the ME70 toward habitat mapping operations. Development of a standard workflow or information repository would be very beneficial for establishing best practices, consistency, and for sharing of information across the ME70 community. The shortcomings or difficulties encountered by the user community could be minimized through the creation of an organized repository, development of SOPs, and improved communication among ME70 users and experts.

Ultimately, the goals of this conversation were:

- To provide insight toward assembling the right teams with collective habitat mapping expertise.
- To outline the need for proper documentation and guidance toward effective use of the ME70 for habitat mapping.
- To discuss support for NOAA scientists using the ME70 to quantify seafloor habitats.

A commonly used workflow developed over time by the FSV ME70 users was presented and compiled by staff from the NOAA National Centers for Coastal Ocean Science (NCCOS).

Components for habitat mapping include:

1. Acquisition Platform with known system configuration to account for motion, sound speed, etc. to produce the highest quality data possible.

2. Bathymetric Surface and Seabed Backscatter Surface Information.
3. Derived morphometric layers from the bathymetry as model inputs.
4. Ground Validation of Habitat Types.

The setup of the acoustic lab aboard FSVs generally include the following equipment for data acquisition and display to the ship bridge (Figure 1):

1. EK60 echosounder for fisheries and depth data acquisition, and display to bridge.
2. ME70 for bathymetry and seabed backscatter data acquisition, and display to bridge.
3. Hypack software for line planning and ME70 data acquisition, which is duplicated to the bridge.
4. Direct line to the bridge for continuous voice communication.

Each ship may have a unique configuration, but the basic system components include location of the transducers, GPS antennas on the masts, granite blocks (as central point of reference), and Inertial Motion Units (IMUs) and a POS_MV system to detect and measure motion, position, heading, heave, pitch, and roll. Data fed through the POS_MV sends data streams with position and motion corrections to the acquisition computer. Position and correction information may also be applied to the data in post-processing, but it is imperative that the system configuration be well understood as a starting point toward minimizing problems regarding data acquisition and processing. Specific details of each ME70 system have been published for the FSVs *Reuben Lasker* and *Bell M. Shimada* in integration reports by NOAA OCS and Office of Marine and Aviation Operations (OMAO) (Greenaway 2016, Greenaway and Devereaux 2017)

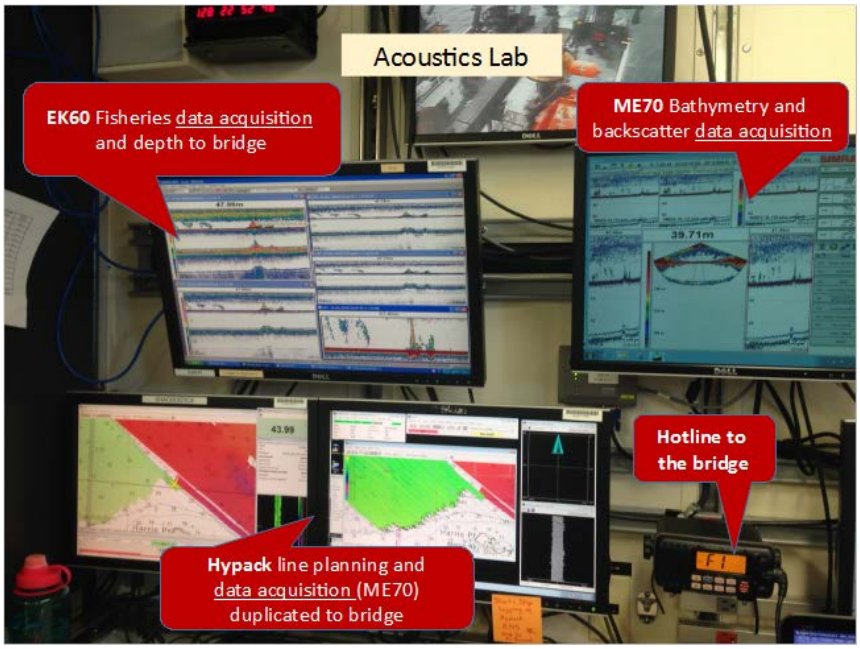

Figure 1. FSV acoustics laboratory set-up for habitat data acquisition.

A recommended mapping team and workflow were suggested for habitat mapping with the ME70. For habitat mapping surveys on multi-task missions a team of experts for either nighttime or 24 hour operations would include:

1. **Chief Scientist** - Outlines objectives for the overall mission and designates general mapping area. Coordinates daytime operations with nighttime mapping. In most cases is running a multi-task mission, with mapping often supporting or complementing daytime operations.

2. **Mapping Team Lead** - Oversees multibeam echosounder data collection and processing. Develops line plans and coordinates with the bridge. Should be well versed in systems components and configuration.

3. **Ship Survey Technician** - Acquires multibeam echosounder and sound velocity (Conductivity/Temperature/Depth - CTD, Expendable BathyThermograph - XBT, Underway CTD) data. Maintains log of survey lines as collected. Manages data acquisition, understands acquisition settings, and troubleshoots issues. An **Electronics Technician** would also be needed to provide hardware support and attend to software and networking workstations, etc.

4. **NOAA Office of Coast Survey (OCS) Physical Scientist (or Contract Hydrographer)** - Sets up and manages data processing in Caris (or other software), conducts patch test, quality controls (QCs), and cleans the data. Produces descriptive report and submits data to NOAA OCS hydrography branch.

5. **Mapping Analyst** - Assists with Caris and bathymetry data processing, QCs, and oversees data management and backups. Runs *raw2gsf* data conversion for processing and viewing.

6. **Backscatter Analyst** - Processes seabed backscatter data using Fledermaus software, conducts QCs, and creates mosaics.

7. **Fisheries Acoustician** - Operates and processes water column fish acoustic sonar data (typically from EK60 echosounder) and works with ME70 team to synchronize sonar systems (i.e., *k-synch*).

Note: The above is an ideal team with certain roles overlapping. If shorthanded, some tasks can be duplicated further by one of the recommended team members. If conducting 24 hour mapping, additional support and/or trading off tasks would be required. It is also important to note that many NMFS cruises occur where mapping is performed as a secondary objective to the main cruise, where no personnel (except survey technicians with cursory interaction) are available to interact directly with the ME70 during a given survey. Therefore, more strategic collaborative efforts among users and experts, across NOAA line offices, and the incorporation of trained personnel for acoustic mapping efforts are essential toward the effectiveness of this proposed team and workflow.

Proposed Data Processing Workflow

Working together with coupled ME70 (seabed backscatter and bathymetric data collection) and EK60 echosounder (fisheries data collection) systems, and Hypack data output in FM would posit the following proposed data processing workflow (Figure 2):

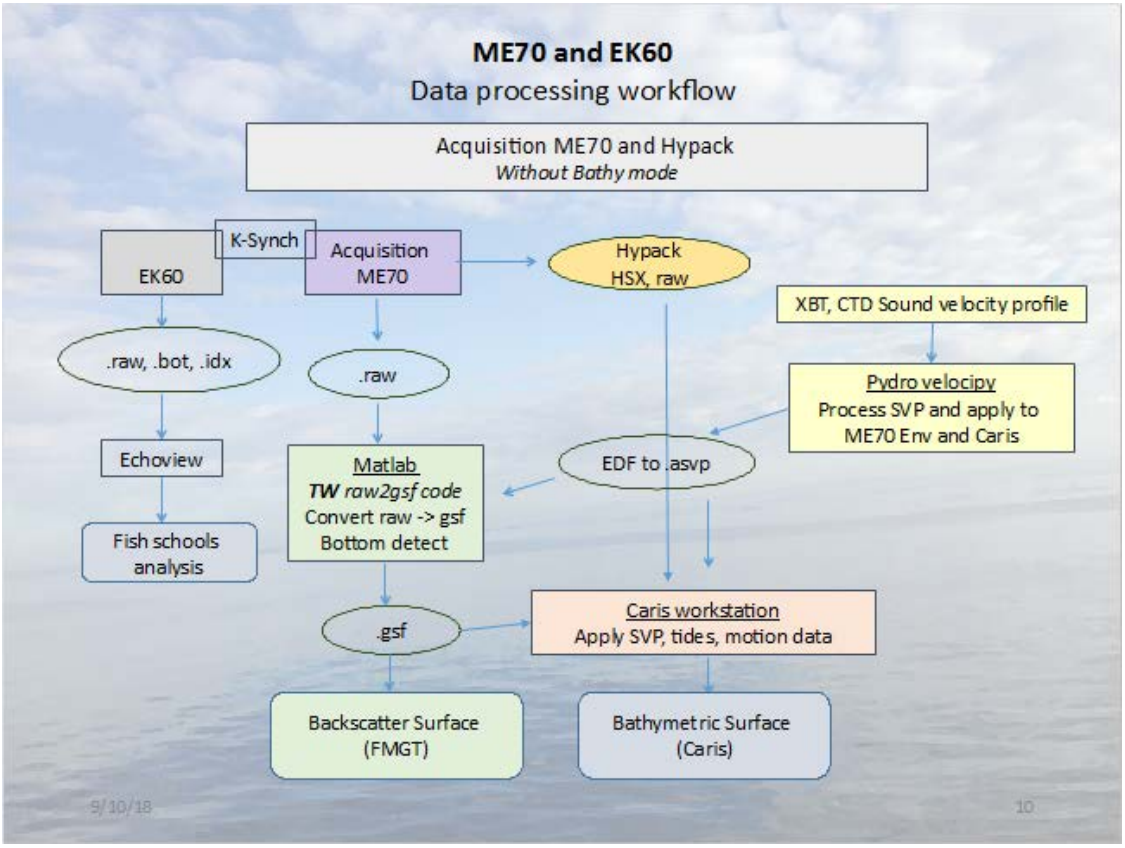

Figure 2. General data acquisition and processing workflow when using the ME70 to obtain seabed backscatter and bathymetry. Synchronized data acquisition (*k-synch*) using both the EK60 (*.raw*, *.bot*, *.idx* data formats) and ME70 (*.raw* data format) echosounders, with EK60 fish school data examined and analyzed using Simrad Echoview software. ME70 data are processed with Tom Weber's Matlab code (*raw2gsf*) that converts ME70 *.raw* data to *.gsf* format to allow for bottom detection for input into Caris (bathymetry) and Fledermaus (seabed backscatter). In this workstation, sound velocity profile, tides, and motion data are additionally applied.

Proposed Standard Operating Procedure (SOP)

Early, draft versions of SOPs have been developed by experts at NMFS Science Centers, NCCOS, and OCS for use aboard FSVs (particularly the *Pisces*). Importantly, newer ship-specific system integration testing and documentation have been produced for the *Reuben Lasker* and *Bell M. Shimada*. Currently, ME70 SOPs are informal collections of instructions at varying degrees of detail and accuracy that have been handed down by users, but have not been formalized or comprehensively reviewed. A proposed schematic showing previous guidance

documents produced by the ME70 community is available in a shared google drive called "ME70 HYPACK Workflow" (https://drive.google.com/drive/folders/0B7ULgfuKkFI9SlVjUTRSUnk4SHc?usp=sharing) These documents roughly align with the onboard workflow, but are in need of extensive updating. They have been used as much of the basis for the below proposed SOP (Figure 3):

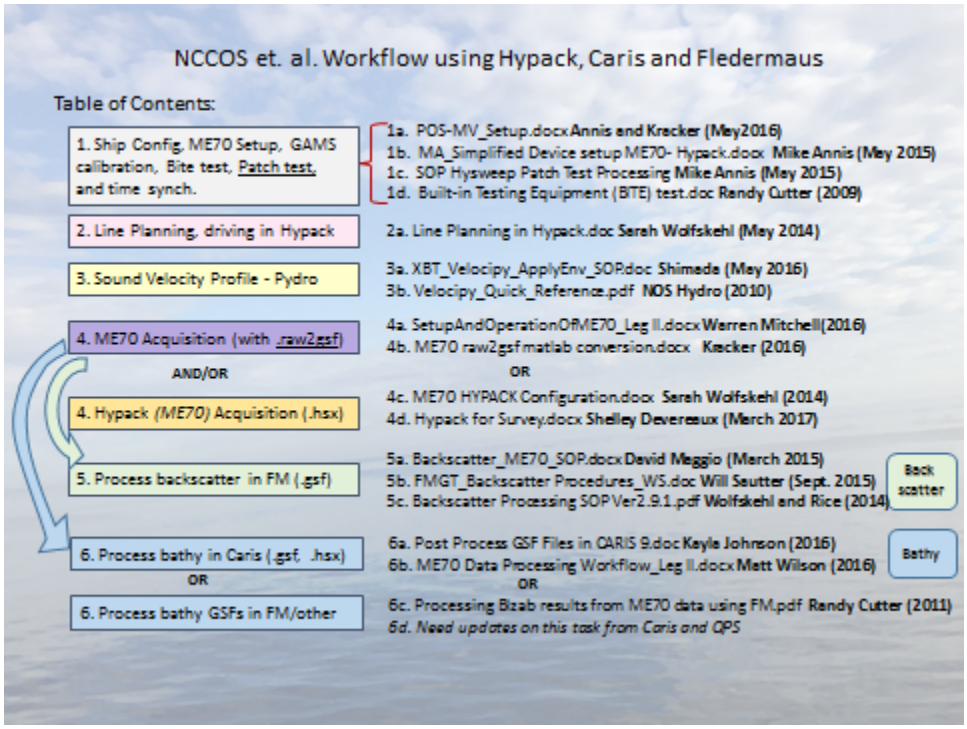

Figure 3. Proposed Standard Operating Procedures (SOPs) for obtaining and processing seabed backscatter and bathymetric data on NOAA vessels as matched to available informal digital guidance documents.

1. Ship Configuration. Refer to documents regarding setup and configuration of ship-specific systems. Additional tasks include bite tests, patch tests, GAMs (GPS Azimuth Measurement Subsystem) calibration and testing time servers.

2. Line Planning, Driving in Hypack. Helpful in 'painting the bottom' and communicating with the bridge.

3. Acquiring Sound Velocity Profiles (SVPs). Acquired at minimum every 4 hours, incorporated into the data acquisition and data processing steps.

4. Data Acquisition. Consists of two paths:
    a. Raw files (*.raw*) obtained from the ME70. Files are taken directly from the ME70 system to which a bottom-detection algorithm is applied to convert information into *.gsf* format (*raw2gsf*) to bring *.gsf* files into Caris and/or Fledermaus (FMGT).

b. ME70 acquisition ingested in Hypack. Bottom detection is built into the Hypack framework using Matlab code produced by Tom Weber (UNH) but requires additional testing.

5. Data Processing. Currently users rely on a *raw2gsf* conversion to *.gsf* files for processing in Caris and Fledermaus.

Issues still to be addressed related to this workflow and ME70 operations in general include troubleshooting, building updated system documentation, and hosting and maintaining a repository of SOPs. The following questions were discussed during the two-day workshop regarding the **development of SOPs**, **identifying overarching needs**, and in developing **recommendations** for more effective use of ME70s on NOAA FSVs:

- Where does the responsibility for maintaining SOPs lie?
- What audience (level of detail) should the SOPs address?
- Should SOPs be associated with separate tasks and specific to each ship?
- Can new software development simplify operations?
- Should there be dedicated teams to undertake these efforts?

Overarching Needs and Workshop Recommendations for Effective ME70 Use in Habitat Mapping

Overarching Needs:

1.) A knowledge repository should be developed where past/existing information for the ME70 can be centrally located and accessible by the ME70 user community.

Workshop participants agreed that priority components of the NCCOS proposed SOP should be made available in an FSV ship-specific repository that is focused on:

- **Ship Configuration, Setup, and Testing**
- **Sound Velocity Profile - Pydro**
- **Hypack (ME70) Data Acquisition in *.hsx* format**
- **Data QA/QC and Post-Processing**

The workflow initially put forward by NCCOS was discussed and mutually agreed upon. Workshop attendees emphasized the importance of including information regarding substrate model descriptions and existing frameworks for habitat classification information (*i.e.*, Cowardin or CMECS). Building on SOPs and ME70 integration information that currently exist for the FSVs *Lasker* and *Shimada*, as put together by Sam Greenaway and OCS, there is a framework toward creating a compiled repository of existing information regarding the application of the ME70 toward seafloor mapping. Among ship users and guidelines, there are currently standard procedures and calibrations, ranges, and basic aspects for ME70 use upon which one can build a ship-specific repository that can be housed online.

Current FSV and ship-specific documents contain detailed information in terms of offsets and recommended patch test values, in addition to methods for utilizing Hypack, documenting sound velocity profiles, and data acquisition methods that can be put into Caris or other processing software, including Fledermaus. As currently existing SOPs and information exist, it was determined that its compilation in an online repository with standardized templates would best serve the ME70 user community in making information more accessible and relevant toward habitat mapping interests, with regular updating by the ship users and community as related to their determined roles (**see Overarching Need #3**). This is especially necessary, given the high turnover of survey technicians and other crew members, and currently small group of ME70 experts and user community.

One point of concern raised was that system calibration for hydrographic bathymetric mapping requires obtaining a measure of absolute depth. In some aspects of fisheries research, however, the split-beam capabilities of the ME70 are emphasized as opposed to the absolute depth, with acoustically classified data aligned with seabed types that influence the presence or absence of fish species. These research procedures have different requirements and are more focused on species and bottom typing, for which specific applications of the ME70 should be additionally included in a knowledge repository or SOP. Emphasis on the importance of seabed backscatter data, its applications, and improved resolution was also mentioned as a priority toward classifying benthic substrates, particularly when ground-truthing or refining fisheries surveys. In particular, it should be understood that habitat is not necessarily limited to high-resolution

bathymetric and calibrated seabed backscatter information. Additional information regarding calibrated split-beam capabilities beyond hydrographic standards, obtaining absolute backscatter, recommended pulse rates, and scales of interest that can allow for follow-up ground-truthing are also important areas of consideration.

It was recommended that while obtaining seabed backscatter and bathymetric data are primary priorities, additional special cases and methods for higher resolution species-habitat classifications derived from these data types should be included as subfolders and supplementary SOPs in the repository as based on the expertise of user community members. This additional information would be useful to provide insight on how to collect data with the ME70 toward certain research objectives and fisheries applications. Of particular sub-interest are cruises that would be specifically targeted toward:

- Opportunistically mapping the seafloor and applying the collected information toward other operations - such an effort would require fast generation of highest resolution maps.
- Systematic dedicated mapping campaigns where a bathymetry and seabed backscatter mosaic is important, but the obtaining of high-resolution data is not as high a priority.
- A dedicated acoustic cruise for habitat species assessments that may be based on another multibeam sonar.

It was also noted that additional training for post-processing is needed to reconcile and ground-truth time-stamping of the ME70 system, Hypack, and acquired bathymetry and seabed backscatter data. Licenses for certain post-processing software including Matlab, Caris, and Fledermaus are also not universally available throughout NMFS, which presents major hurdles and should be resolved. Additional available information from GEOHAB (http://geohab.org/publications) and the user and software community should also be incorporated into the knowledge repository, including recommended models and advances toward automation of aspects of data processing and acquisition. Methods and beam swath information stipulated for calibrating and using bathymetric and seabed backscatter data in FM versus BM should also be included.

2.) There is a need to resolve gaps in expertise for calibration, data acquisition and post-processing data from ME70 operations.

A perceived primary identified bottleneck regarding ME70 user expertise for system calibration, and in data acquisition and post-processing, has been a lack of past prioritization and allocation of staff time for acoustic training and operations. Limited staff time dedicated to developing the skills required for data acquisition and processing is a serious impediment to meaningful implementation of the ME70 for habitat research. Identifying and training a current and future pool of experts for calibration, operations, and post-processing should emerge as a priority for more effective use of onboard ME70 systems.

Participants from NMFS, OCS, and OMAO recommended the development of cooperative training opportunities for the ME70 user community. Examples may include opening OCS

trainings regarding hydrographic mapping and system operations to the ME70 user community or creating additional trainings toward fisheries research objectives.

Having this additional expertise would allow for staff and a wider user community to be able to determine optimal ME70 configurations, data needs, and to apply the ME70 system or other complementary systems toward addressing habitat science and mapping interests. As there is common perception that the ME70 is being underutilized as to its full potential, it would also permit more advanced application of the technology toward these interests and broader exploration of its potential for habitat mapping. The inclusion of complementary systems on FSVs including the EM2040 would also be advantageous toward enhancing the collection of finer scale information, especially in terms of coverage, swath width, resolution, and range, but should not be considered as a replacement for the absolute calibrated data acquisition potential of the ME70. Past efforts using the ME70 have been successful toward quickly mapping locations to allow for more stratified sampling, ground-truthing, or higher resolution examination of fish-habitat associations. Continued use of the ME70 together with other technologies including the EK60 for simultaneous information regarding fish-substrate relationships was also encouraged, provided that acoustic staff or additional trainings for using acoustic technologies are available. Scientists were encouraged to seek support for training opportunities if intending to use the ME70, and to independently educate themselves as much as possible, while additional dialogue to facilitate trainings was encouraged among staff and leadership from NMFS, OCS, OMAO, and NCCOS. Creation of a formalized support network within the user community to assist other users would also be of great benefit. All participants at the workshop agreed to serve as members of this expert network, and recommended that ship-specific personnel be included.

Post-processing gaps could also be better addressed through agency-industry agreements with Caris and other software developers to allow for the building of automated models for data processing. Caris is also working on offering online training, and has offered to work with NOAA toward collaborative opportunities.

3.) There is a need for a proposed determination of roles and responsibilities of those using ME70 – Currently proposed as:

Ship's Responsibility:

- Ship equipment support and configuration (e.g., network, time sync)
- Bite test (i.e., system functionality test, transducers connectivity, etc.)
- System offset calibration (i.e., GPS and X, Y, Z offsets) should be conducted annually or before each survey as needed.

- Patch test calibration (i.e., motion sensor, gyro) should be conducted annually or before each survey as needed, and should be conducted collaboratively with scientists relevant to the survey configuration requirements.

Survey Technicians Responsibility:

- Sound velocity – however, the CTD profile is the scientists' responsibility and the specifics for these breakdowns should be included in the science plan.

- Manage Data Acquisition - Keep acquisition logs, manage data storage, assist in primary acquisition with ME70.

Scientists' Responsibility:

- ME70 configuration will be dependent on operational requirements, however an optimized standardized ME70 configuration will need to be determined for some situations.
- ME70 beam calibration (i.e., sphere calibration) will be needed for fisheries water column acoustic operations.
- Data acquisition and post-processing.
- Resolve gaps in ME70 expertise, including attending and offering trainings in ME70 calibration, data acquisition, and post-processing data.

Workshop participants agreed that the above breakdown of roles and responsibilities among ship staff, survey technicians, and scientists for effective use of the ME70 was most preferred given available resources. Participants agreed that much of the overall system support and calibration should be provided by ship staff, while survey technicians would be responsible for assisting with the sound velocity profile and with ongoing CTD casts. However, it was also noted that current ship personnel do not have the expertise for some of these tasks. NOAA OCS and OMAO would likely have to partner to provide this support. Additionally, staff and scientists are recommended to refer to documents provided in the current google drive and knowledge repository for several of these tasks in current cases of limited expertise. The scientists are responsible for running the ME70 system, beam calibration, all data acquisition and post-processing efforts, and in becoming familiarized with operating the system. Survey technicians may be available to assist with certain troubleshooting efforts, but given their high turnover and limited staff, it was recommended that the ME70 user community work closely together toward providing additional in-person or remote troubleshooting support to each other, and in creating the knowledge repository to ensure better familiarization with the system and common user issues. Scientists are also encouraged to take advantage of training opportunities provided by OCS staff and to work together within centers and across the agency to allow for more applied training of ME70 use for habitat mapping interests and for familiarity with hydrographic methodologies.

It was also reinforced that continued dialogue among NMFS, OMAO, and OCS staff and leadership should happen to designate and formalize these recommended responsibilities. For a given cruise, efforts to also allow for more advanced notice of scheduled onboard ship crew members' and survey technicians' familiarity with the ME70 system would also be preferred in allowing scientists to plan their research teams more effectively. In addition, logged information regarding team use of the ME70 equipment, settings, and maintenance/troubleshooting concerns during a given cruise should be recorded and made available to the user community on a given ship.

A standardized mission log should also be developed and written by user personnel to communicate how the ME70 was operated and troubleshot as necessary to allow for continuity and communication among users on a given ship. It was recommended that the system currently used by OMAO for distributing information regarding support, personnel, and equipment use

and logs for a given ship should be formally used and its availability publicized to all current and potential ME70 users.

Specific Workshop Recommendations:

Following conversations and identification of overarching needs, specific short-term, mid-term, and long-term recommendations were additionally developed and encouraged to be followed upon and communicated to NMFS, OCS, OMAO, and NCCOS leadership for endorsement.

Short-term:

1. Decide on the optimal ME70 standard configuration, and provide recommendations on alternative ME70 configurations.

2. Decide on the calibration procedures (i.e., patch and sphere calibrations) and the frequency of calibration needed. Calibration typically takes about 12 hours, and is normally conducted before each survey or annually.

3. Identify the key expertise requirements for at-sea ME70 operations and post-processing, and provide training as needed.

4. Resolve whether NMFS should support a sustainable capacity that is in-house or collaborate with OCS to use their expertise in obtaining seafloor maps wanted by NMFS scientists. Initial conversations have additionally suggested using a hybrid of adopting OCS systems and the availability of their expertise and trainings.

5. Develop a knowledge repository where current ship SOPs can be housed along with an expert contact list for reference by users and experts. This knowledge repository would create a better network/access to tools and resources needed to operate the ME70.

6. There needs to be support to acquire up to date software for Caris, Fledermaus, and Matlab – OCS already has an enterprise agreement with Caris to acquire up to date versions of Caris and they can put NMFS on this agreement too (could potentially funnel funds from NMFS to OCS to support hardware and software.)

7. Identify the key scientists and gaps in expertise requirements from each NMFS Science Center who will be devoted to ME70 (or other acoustic bathymetric mapping) operations. Provide the necessary acoustic training to this potential pool of expertise. Sam Greenaway (OCS) mentioned that he holds a three-week training for his team, and has offered to open this to fishery survey technicians and the NMFS science community.

8. OMAO should work on conducting pre-season ME70 system readiness through calibration days.
    a. Cruise instructions used should include acoustic calibrations by scientists as needed.

b. Standard cooperative efforts should be better developed, and scientists and/or whichever personnel of interest need to be trained and engaged in the acoustic operations including calibrations.

Mid-term:

1. Support research (white paper) to utilize ME70 capabilities (Dave Demer SWFSC, Tom Weber UNH information incorporated) to provide recommendations on ME70 beam configuration, and to resolve frequency and beam limitations and multispectral aspects.
    a. Collaborate with IFEMER, ICES Fisheries Acoustic Science and Technology (FAST) Working Group, and GEOHAB backscatter working group expertise.

2. Provide recommendations for standard ME70 configurations for automated data acquisition and post-processing, and promote collaborative research.
    a. Have Caris build automation models for data processing rather than having a full SOP (Caris and QPS have offered to do this).

Long-term:

1. Each region should discuss what their data requirements are to determine what may be the best tool for gathering the type of information that is needed. This also requires the identification and allocation of staff for training in acoustic operations to support seafloor mapping and habitat characterization. Perhaps this could be resolved in follow-up workshop(s).

2. Talk with OMAO and NMFS Leadership to potentially add in complementary systems such as the EM2040 and other systems currently used by OCS. There should also be consideration of the future of the ME70 system, with the pros and cons of the system in mind, but also that additional training of the user community is needed to allow for the application of the ME70 system toward more effective habitat mapping.

As emphasized earlier, for NMFS to build a successful ME70 mapping program would require building a suite of expertise- from systems integration, to planning, processing, troubleshooting, metadata and archival. OCS has developed much of the expertise that NMFS would need, and is willing to take steps toward supporting this application toward supporting this application. However, to be fully successful both OCS and NMFS should identify a robust and reliable strategy for resourcing and coordinating this support.

Next Steps:

Following the two-day workshop, efforts to communicate the outcomes and recommendations for more effective application of the ME70 toward habitat mapping will continue through engagement of the NMFS Science Board, OCS and OMAO leadership, and coordination with the Integrated Ocean and Coastal Mapping working group. Additional efforts to implement the development of a ship-specific information repository containing operating procedures and following the proposed SOP framework will occur, as will coordinated invitation and formulation of training opportunities for the ME70 user community. It is expected that conversations, coordinated dialogue, and the development of the information repository will occur throughout 2019.

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Appendix A: Two-Day Agenda for the Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping Workshop

Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping
Meeting Dates: November 15-16, 2017

Meeting Location:
NOAA Headquarters
SSMC2 – Room 2358
1325 East West Highway
Silver Spring, MD

Day 1: November 15	**9:00am-5:30pm**
9:00 AM	**Welcome to the ME70 workshop** Introductions: - Ned Cyr, Director of NMFS Office of Science & Technology - Tony Marshak, NMFS Office of Science & Technology
9:15 AM	Presentations from experts (15-20 minutes each) - Speakers: 1) Tom Weber - Expectations 2) Sam Greenaway - FSVs ME70 system overview/configuration
10:05 AM	Break
10:30 AM	Introductory presentations from a representative from each region/project. (5-10 minutes each to outline past projects or future uses) - Alaska: Sarah Stienessen - Southwest: Diana Watters - Northwest: Dezhang Chu - Pacific: Michael Parke - Southeast: Brandi Noble - Northeast: Vince Guida - Additional regions: o Chris Caldow – Mapping in sanctuaries o Dezhang Chu - Presenting on Egil Ona's study in Norway o Xavier Lurton – Bay of Biscay and Irish Sea

12:00 AM	Lunch
	Successes and Challenges Discussion
1:15 PM	Roundtable discussion on examples/successes each region has had when using the ME70, including how information collected has been used to inform management. - Methods of operations/processing per region on ship and in situ/post-processing - Continued successes - Application of collected information
1:45 PM	Discussion on challenges when using the ME70 - Issues experienced when trying to use the ME70 for seafloor / habitat mapping. - Questions to pose: What kind of data information are you looking for? What are some of the biggest bottlenecks when working with the ME70 for getting the data you want? What are the limitations of the ME70? What improvements do you most see needed? Do you need more personnel, support from your Science Center, support from leadership, support from ship?
2:45 PM	Break
3:00 PM	Introduction of example SOP and workflow options – Laura Kracker
3:45 PM	Discussion on strategies for developing SOPs and workshop products (audience; project vs OCS vs ship roles; recommendations)
5:15 PM	Begin to wrap-up discussion and go over logistics for the next day
5:30 PM	Adjourn
6:00 PM	Social – Denizens (1115 East West Highway)

Day 2: November 16	**9:00am-5:00pm**
9:00 AM	Welcome: Recap of day 1 and overview of day 2
9:10 AM	Data Acquisition, Processing, Products • Bathymetry and Backscatter - Josh Mode (Teledyne Caris) - Will Sautter - Matt Wilson (QPS) • Post-processing method in data classification and segmentation usable for large-scale mapping - Xavier Lurton
11:30 AM	Break
11:45 AM	Takeaways from the data processing morning conversation & applying them into the SOP (part to be drafted)
12:30 PM	Lunch
1:30 PM	Discussion on drafting SOPs and new technologies available - Work will begin on draft SOP
3:00 PM	Break
3:30 PM	Discussion: ● Next steps with ME70 ● Recommendations to NOAA leadership, NMFS, OMAO
5:00 PM	Adjourn

Appendix B: List of the Using Acoustic Multibeam Echosounder (ME70) Technologies for Habitat Mapping Workshop Participants

*Asterisk indicates those who also served on the workshop steering committee.

Additionally, both Waldo Wakefield (NOAA Northwest Fisheries Science Center) Mary Yoklavich (NOAA Southwest Fisheries Science Center) were workshop steering committee members.

Name	Organization/Office/NOAA Fisheries Science Center
Amend, Mark	Kongsberg Underwater Technology, Inc.
*Bacheler, Nate	NOAA Southeast Fisheries Science Center
*Brady, Peg	NOAA Fisheries Office of Science and Technology
Brown, Steve	NOAA Fisheries Office of Science and Technology
Caldow, Chris	NOAA Office of National Marine Sanctuaries, Channel Islands
Chu, Dezhang	NOAA Northwest Fisheries Science Center
Condiotty, Jeff	Kongsberg Maritime
Demer, David	NOAA Southwest Fisheries Science Center
Greenaway, Sam	NOAA Office of Coast Survey
*Guida, Vincent	NOAA Northeast Fisheries Science Center
Hourigan, Tom	NOAA Fisheries Office of Habitat Conservation
Intelmann, Steve	NOAA Alaska Fisheries Science Center
Jech, Mike	NOAA Northeast Fisheries Science Center
Jones, Donald	NOAA Office of Marine and Aviation Operations
Juergens, Gregg	Simrad
*Kracker, Laura	NOAA National Centers for Coastal Ocean Science
Lurton, Xavier	IFREMER - Institut Français de recherche pour l'exploitation de la mer
Malik, Mashkoor	NOAA Office of Ocean Exploration and Research

Name	Organization/Office/NOAA Fisheries Science Center
*Marshak, Tony	NOAA Fisheries Office of Science and Technology
*McConnaughey, Bob	NOAA Alaska Fisheries Science Center
Michaels, Bill	NOAA Fisheries Office of Science and Technology
Mode, Josh	Teledyne Caris
Noble, Brandi	NOAA Southeast Fisheries Science Center
Osgood, Kenric	NOAA Fisheries Office of Science and Technology
*Parke, Michael	NOAA Pacific Islands Fisheries Science Center
*Peters, Rebecca	NOAA Fisheries Office of Science and Technology
Pirtle, Jodi	NOAA Fisheries Alaska Regional Office
Poti, Matt	NOAA National Centers for Coastal Ocean Science
Rice, Glen	NOAA Office of Coast Survey
Sautter, Will	NOAA National Centers for Coastal Ocean Science
Stienessen, Sarah	NOAA Alaska Fisheries Science Center
*Thompson, Charles	NOAA Southeast Fisheries Science Center
Turner, Paul	NOAA Office of Coast Survey
Wall-Bell, Carrie	NOAA National Centers for Environmental Information
Watters, Diana	NOAA Southwest Fisheries Science Center
Weber, Tom	University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center
Wilson, Matt	Quality Positioning Services BV - QPS