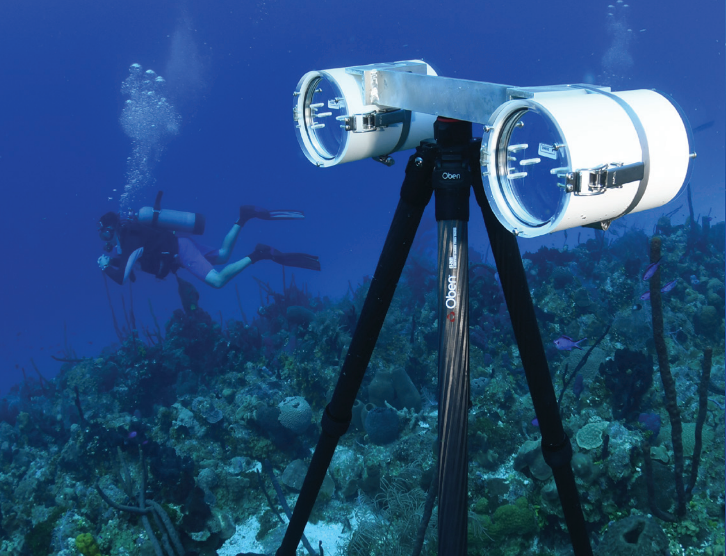
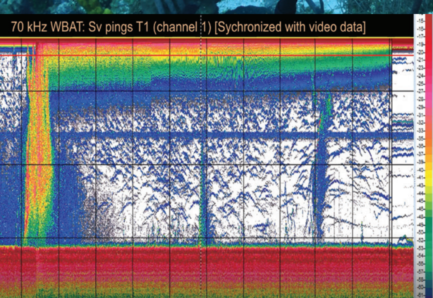
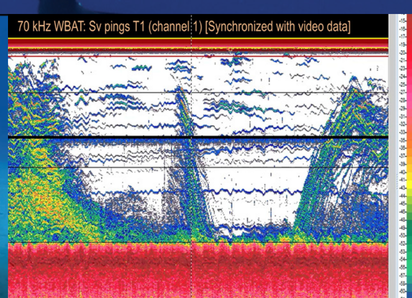
Integrated Optic-Acoustic Studies of Reef Fish

Report of the 2018 GCFI Field Study and Workshop

NOAA Technical Memorandum NMFS-F/SPO-209
November 2020







Cover Photo Credit: Cover photographs of optic-acoustic study operations were taken and permission was granted by the photographer, William Michaels.

Integrated Optic-Acoustic Studies of Reef Fish: Report of the 2018 GCFI Field Study and Workshop

David A. Demer[1], William L. Michaels[2], Tonny Algrøy[3], Lars Nonboe Andersen[3], Omar Abril-Howard[4], Benjamin Binder[5], Derek Bolser[6], Ryan Caillouet[7], Matthew D. Campbell[7], Sergio Cambronero-Solano[8], Erick Castro-Gonzalez[4], Jeff Condiotty[9], Jack Egerton[6], Violeta E. González-Maynez[10], Toby Jarvis[11], Melissa Mayorga- Martínez[12], Jorge Paramo-Granados[13], Camilo Roa[5], Anthony Rojas-Archbold[14], Juliana Sintura-Arango[15], J. Christopher Taylor[16], Charles H. Thompson[7], and Héctor Villalobos[17]

[1]NOAA Fisheries, Southwest Fisheries Science Center, San Diego, CA, USA; [2]NOAA Fisheries, Office of Science and Technology, Silver Spring, MD, USA; [3]Simrad-Kongsberg Maritime, Horten, Norway;

[4]La Gobernación del Departmento de San Andrés, Colombia; [5]Florida International University, North Miami, FL, USA.; [6]University of Texas at Austin Marine Science Institute, Port Aransas, TX, USA; [7]NOAA Fisheries, Southeast Fisheries Science Center, Pascagoula, MS, USA; [8]Laboratorio de Oceanografía y Manejo Costero, Universidad Nacional, Costa Rica; [9]Kongsberg Underwater Technologies, Inc., Lynnwood, WA, USA; [10]Centro de Investigaciones Biológicas del Noroeste, Guaymas, Sonora, México; [11]Echoview Software Pty Ltd, Hobart, Tasmania, Australia;

[12]Universidad Veracruzana, Instituto de Ciencias Marines y Pesqueríca, Veracruz, México; [13]University of Magdalena, Santa Marta, Colombia; [14]Secretaría de Agricultura y Pesca, Gobernación Departamental, Isla de San Andrés, Colombia; [15]Oceanographic and Hydrographic Caribbean Research Center, DIMAR, Cartagena, Colombia;

[16]NOAA National Ocean Service, Beaufort, NC, USA; [17]Instítuto Politécnico Nacional CICIMAR, La Paz, B.C.S., México.

November 2020

NOAA Technical Memorandum NMFS-F/SPO-209

U.S. Department of Commerce
Wilbur L. Ross, Jr.
Secretary of Commerce

National Oceanic and Atmospheric Administration
Neil A. Jacobs, PhD
Acting Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
Christopher W. Oliver
Assistant Administrator for Fisheries

Recommended citation:

Demer, D.A., W.L. Michaels, T. Algrøy, L.N. Andersen, O. Abril-Howard, B. Binder, D. Bolser, R. Caillouet, M.D. Campbell, S. Cambronero-Solano, E. Castro-Gonzalez, J. Condiotty, J. Egerton, V.E. González-Maynez, T. Jarvis, M. Mayorga-Martínez, J. Paramo-Granados, C. Roa, A. Rojas-Archbold, J. Sintura-Arango, J.C. Taylor, C.H. Thompson, and H. Villalobos. 2020. Integrated Optic-Acoustic Studies of Reef Fish: Report of the 2018 GCFI Field Study and Workshop. NMFS-F/SPO-208, 61 p.

Available online at https://spo.nmfs.noaa.gov/tech-memos

CONTENTS

ACKNOWLEDGEMENTS

This symposium, workshop and resulting report were made possible through the Gulf and Caribbean Fisheries Institute (GCFI) Ocean Innovation Strategic Initiative grant supported by the National Oceanic and Atmospheric Administration (NOAA). Robert Glazer (GCFI Executor Director) is acknowledged for the grant submission with the goal of improving scientific information using innovative technologies for the sustainability of living marine resources in the Gulf of Mexico and Caribbean regions. Financial support of this grant was provided by the NOAA Fisheries' Office of Science and Technology, in addition to the GCFI-NOAA partnership. Robert Glazer, Alejandro Acosta (GCFI Deputy Director), and Erick Castro-Gonzalez (La Gobernación del Departmento de San Andrés) were key organizers for the 71st annual Gulf and Caribbean Fisheries Institute (GCFI) Conference in San Andrés, Colombia, November 5-9, 2018.

William Michaels and David Demer were the lead organizers of the 2018 GCFI Optic-Acoustic Study and Workshop reported herein, and established the framework of the study and workshop with the guidance of the steering committee led by internationally recognized experts Tonny Algrøy, Lars Nonboe Andersen, Ryan Caillouet, Matthew Campbell, Jeff Condiotty, Toby Jarvis, Jorge Paramo, Chris Taylor, and Charles Thompson.

William Michaels coordinated the logistics for the field study with Erick Castro and Omar Abril from La Gobernación del Departmento de San Andrés in Colombia, and Juliana Sintura of the Oceanographic and Hydrographic Caribbean Research Center DIMAR de Colombia. Commander Herman Aicardo León Rincón of the Oceanographic and Hydrographic Caribbean Research Center DIMAR de Colombia provided the *A.R.C. Isla Tesoro* as the primary research vessel for the study. Erick Castro from La Gobernación del Departmento de San Andrés provided the second boat and diver support. Omar Abril-Howard from La Gobernación del Departmento de San Andrés provided the ROV operations. Tonny Algrøy, Lars Nonboe Andersen and Jeff Condiotty (Simrad-Kongsberg Maritime, Norway) provided the acoustic systems. Toby Jarvis (Echoview Software Pty Ltd, Australia) provided the Echoview acoustic data-processing software. James Seager (SeaGIS Pty Ltd, Australia) provided the SeaGIS stereo imagery processing software. Ryan Caillouet (NOAA Fisheries) provided the stereo camera systems. Adriana Santos Martinez from the Universidad Nacional de Colombia and Anthony Rojas-Archbold, Secretaria de Agricultura y Pesca, Gobernacion Deparamental de Colombia, assisted in the administrative logistics of the study. William Michaels served as the Chief Scientist of the scientific operations aboard the vessel *A.R.C Isla Tesoro*, and David Demer served as the Chief Scientist aboard the Corolina boat *Queen Conch* during the study. The scientific team that contributed to the success of the field study are listed in Appendix B.

The workshop conveners were William Michaels and David Demer. The workshop instructors were David Demer, Lars Nonboe, Toby Jarvis, Charles Thompson, Jorge Paramo, and Chris Taylor for acoustic analysis, and Ryan Caillouet and Matt Campbell for stereo imagery analysis. The workshop participants provided a diverse and broad range of expertise and balanced perspectives that directly contributed to the success of the workshop. Most importantly, the combined efforts of the sponsors, instructors, support staff, and participants contributed to the overall success of the workshop that we hope will result in long-lasting collaborative expertise to improve the sustainability and health of reef-fish ecosystems in the region.

Executive Summary

The Gulf and Caribbean Fisheries Institute (GCFI) was founded in 1947 to promote the exchange of information on the use and management of marine resources in the Gulf of Mexico and Caribbean region. Fisheries management in this region is challenged by data-limited assessments and the need to improve survey monitoring programs. This is in part because most of the stocks are transboundary and any assessments are the result of mostly fishery-dependent information with a range of quality from a variety of sources. This challenge is compounded by the nature of reef fishes, which are patchily distributed, often aggregate in multi-species assemblages on or near high-relief seabed, and migrate daily and seasonally. To address these challenges, GCFI fosters collaboration among stakeholders to better study and manage fishery stocks and marine resources in the region. GCFI accomplishes this mission through annual conferences, initiatives, and workshops that bring together international expertise and perspectives from scientists, managers, and stakeholders.

The GCFI Ocean Innovation Initiative grant, funded by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office of Science and Technology, endeavors to improve scientific information using innovative technologies for the sustainability of living marine resources in the region. In 2018, the GCFI-NOAA partnership sponsored a field study that integrates optic and acoustic technologies to improve research and survey operations in reef fish habitats, a 3-day training workshop, and a special session at the 71st Annual GCFI Conference in San Andrés, Colombia. Recent availability of innovative and cost-effective technologies (e.g., portable echosounders, stereo cameras, analytical methods and software) have emerged to potentially improve survey monitoring programs and assessments of reef fish populations. The primary objective of the field study was to collect optic and acoustic data to train participants of the GCFI workshop, and to present preliminary results of the field study and workshop during the GCFI special session.

The field study was conducted 1-2 November 2018 on the west coast of Isla de San Andrés, Colombia. Each day, two vessels transited to the study site and cooperatively deployed a 3-point optic-acoustic mooring in ~20 m depth, near the shelf break. There, using a novel setup, echosounder and stereo-camera data were collected simultaneously from the same sampling volume. Meanwhile an echosounder survey was conducted to image the fish and seabed around the mooring site.

Data from the field study was used to train students on procedures for acoustic detection, tracking, and target-strength (*TS*) measurements of fish; optical identification of fish species and estimations of their lengths, orientations, and counts; and optical-acoustic measurements of fish *TS* versus species, lengths and incidence angles. The training also included estimation of the acoustic deadzone height, acoustic and optic observation of animal behaviors, and comparison of optic and acoustic estimates of fish density.

This report includes an overview of the survey considerations, the field study events, workshop activities and preliminary results, and special session presentations. Each of these activities benefited from the expertise provided by the international steering committee, the unique perspectives of students from around the world, and keen interest by conference attendees in the application of novel technologies to address their particular science and management needs. In a practical, tangible manner, these activities provided the GCFI community with training on cutting-edge technologies, experience combining methods, knowledge of practical approaches to surveys and analyses, and access to an international network of experts and collaborators. Collectively, these should serve to improve research and survey operations in reef fish habitats and thereby provide additional scientific information needed to bolster the sustainability of living marine resources in the Gulf and Caribbean region.

1 INTRODUCTION

The Gulf and Caribbean Fisheries Institute (GCFI) was founded in 1947 to promote the exchange of information on the use and management of marine resources in the Gulf of Mexico and Caribbean region. GCFI accomplishes this mission through annual conferences, workshops, and initiatives that bring together international expertise and perspectives from scientists, managers, and stakeholders. The GCFI's Ocean Innovation Initiative grant, supported by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office of Science and Technology, aims to improve scientific information using innovative technologies for the sustainability of living marine resources in the Gulf and Caribbean region. This initiative completed workshops and technical reports on: data-limited stock assessment methods (Cummings et al., 2014); optimization of fisheries-independent and -dependent data collections (Cummings et al., 2015, Cummings et al., 2017); and acoustic technology to improve reef fish ecosystem surveys (Michaels et al., 2013, Michaels et al., 2019). Through these accomplishments, a pool of experts were assembled to enhance scientific capacity and help resolve data-limited assessments in the region.

In 2018, the GCFI-NOAA Ocean Innovation Initiative sponsored a field study that integrated optic and acoustic technologies to improve research and survey operations in reef fish habitats, a training workshop, and a special session at the 71st Annual GCFI Conference in San Andrés, Colombia. The objective of the two-day field study was to collect concomitant optical and acoustic data on a reef near Isla de San Andrés to train students and demonstrate the utility of optic-acoustic technology to improve reef fish assessments. The goals of the 3-day workshop were to train the next generation of collaborative experts in optic-acoustic analysis, establish the best practices for utilizing cost-effective technologies to improve reef fish surveys, and improve scientific capacity to resolve data-limited assessments in the Gulf and Caribbean region. The aim of the 1-day special session was to present the preliminary results of the field study and workshop, as well as other studies using optic-acoustic sampling, so that all of the GCFI registrants would have an opportunity to learn more about integrated optic-acoustic instruments and methods. This report describes the considerations for surveys of reef fishes, the field study, workshop, and preliminary results, and guides the GCFI community to optic-acoustic technologies, expertise, and potential collaborators, to study reef fishes.

2 REEF FISH SURVEY CONSIDERATIONS

Some of the species fished in the Gulf and most from the Caribbean region remain unmanaged or are managed using data-limited assessment approaches. For the Caribbean in particular, this is an artifact of the transboundary spatial distribution of the stocks, and assessments primarily utilize fishery-dependent information with a range of quality from a variety of sources. In this regard, GCFI is challenged to foster collaborations among stakeholders to better study and manage entire stocks. This challenge is compounded by the nature of reef fishes, which are patchily distributed over large areas, often aggregate in multiple-species assemblages on or near high-relief seabed, and migrate vertically daily and regionally over seasons. Additionally, reef seabed cannot be sampled with trawls and longlines because both the gear and habitat would be damaged and would not collect data. Consequently, most of the available fishery-independent data is obtained from visual (e.g. SCUBA) or camera surveys (e.g., using Baited Remote Underwater Video Stations). While these may be of high quality, in the Caribbean these approaches have not been conducted using standardized methods with randomized statistical research designs and therefore have generally not provided the necessary information for population assessment on interannual scales.

Echosounders have long been used to study fishes on large spatial and temporal scales (e.g., Zwolinski et al., 2016), but acoustic sampling generally cannot identify fish species nor detect them near the seabed (<~1 m range). Stereo cameras have emerged as practical tools for quantitatively studying fish species, sizes, and behaviors on fine scales, but stationary camera systems are limited to short ranges with good illumination and water clarity. Consequently, researchers from around the world have endeavored to exploit the advantages of each sampling method by synergistically integrating the technologies (Fig. 2.1). Echosounders are used to map fishes and their seabed habitat on large spatial and temporal scales, and this information can be used to guide the locations and times of optical sampling to better interpret the acoustic data (e.g., Demer et al., 2009; Cutter et al., 2016). With the recent increase in availability of portable echosounders and action cameras, coupled with developments in analysis methods and software, the innovative combination of acoustic and optical technologies has emerged as a means to potentially meet the challenges associated with reef fish surveys and improve the data and management of reef fish populations (Michaels et al., 2019). Practitioners, however, need to be aware of some of the technical considerations for conducting optical-acoustic surveys of reef fishes.

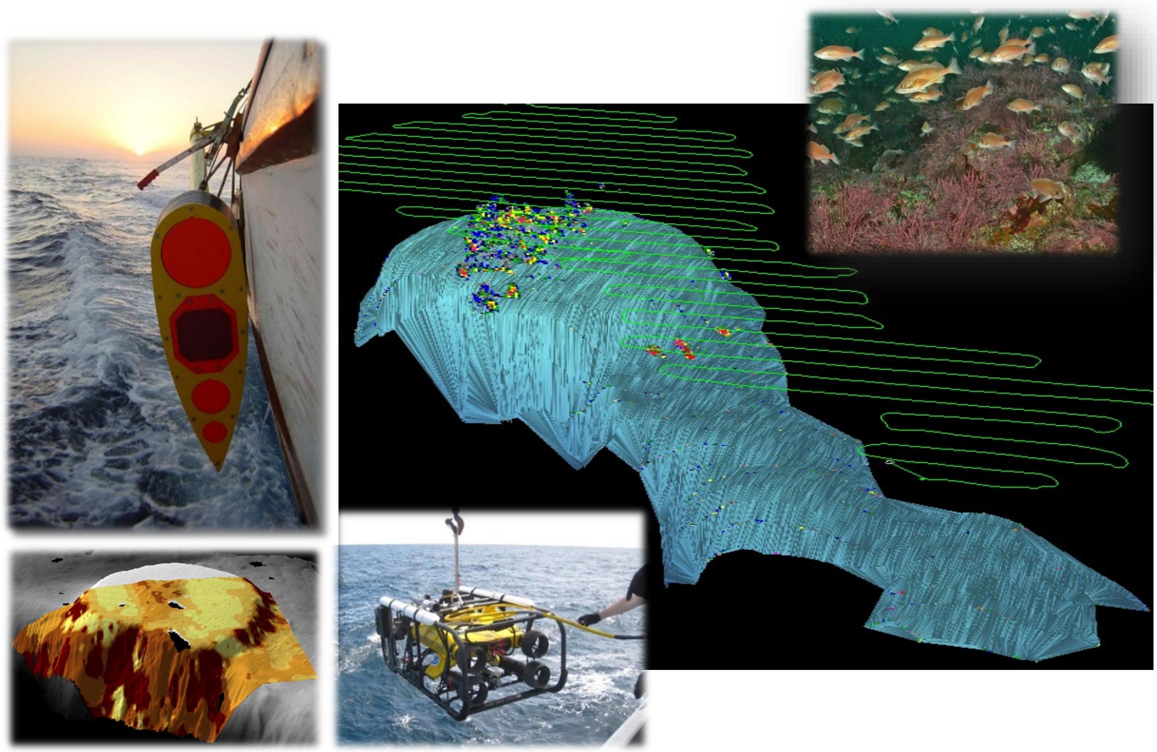


Figure 2.1. An example acoustic-optic survey of reef fishes (Demer et al., 2012) used multi-frequency echosounder transducers (top left) to map fish aggregations over their seabed habitat (center right) and cameras deployed on a remotely operated vehicle (bottom center) to identify the fish species, their lengths and seabed habitat (top right), to aid the conversions of echosounder data to estimates of fish biomasses and seabed classes (Demer et al., 2009).

2.1 Instrument Calibration

Echosounder calibration

For quantitative use of echosounder data, it is necessary to first calibrate the measurements relative to those from known standards. Using post-processing software such as Echoview, the echosounder measurements of received voltage or power are used to calculate the backscattered sound intensity in units of target strength (*TS*; dB re 1 m^2) and volume backscattering strength (S_v; dB re 1 m^2 m^{-3}) (MacLennan et al., 2002), and the accuracy of these calculations is typically calibrated using a standard metal sphere that is suspended within the acoustic beam (Demer et al., 2015). The theoretical backscattered sound intensity of the sphere (Fig. 2.1.1) is then compared to the calculated values, and one or more parameters in the echosounder equations adjusted as necessary to minimize the differences.

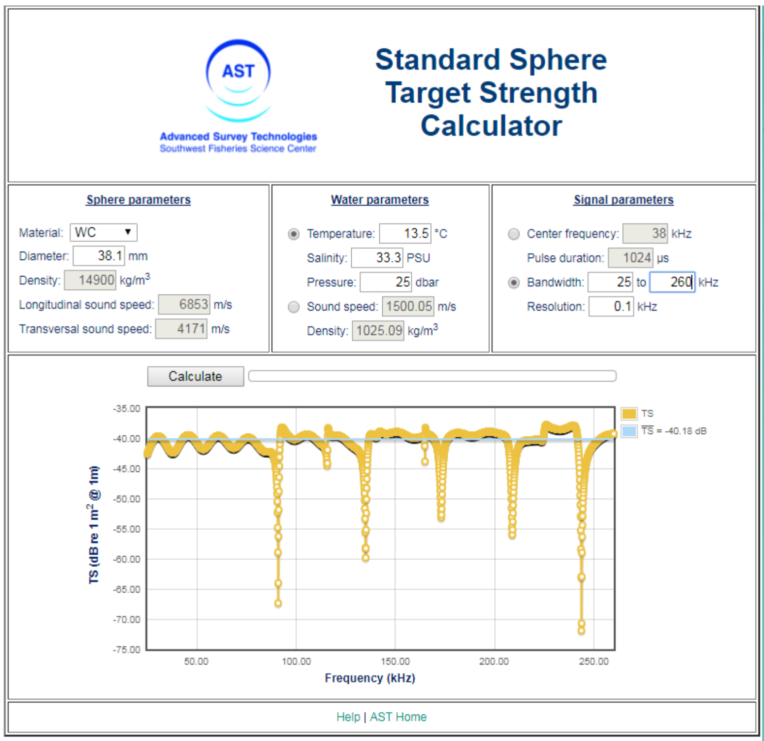


Figure 2.1.1. The theoretical target strength (*TS*; dB re 1 m^2) of a standard metal sphere is a function of the sphere, water and acoustic-signal properties. The sphere *TS* may be estimated by an applet (http://swfscdata.nmfs.noaa.gov/AST/SphereTS/).

Stereo-camera calibration

Calibration of a stereo-camera system is essential to accurately and precisely measure the 3-D positions of points within the image pairs. The camera positions must be fixed relative to each other. This is typically accomplished by rigidly mounting the camera housings to a stiff bar, and often with a slight inward angle, to maximize the overlapping field-of-view of the two cameras (Shortis and Harvey, 1998). The camera housings typically include a method of camera attachment which allows for removal, for purposes of downloading data, charging batteries, and precise repositioning of the cameras. If the camera positions are fixed in this way, a calibration may be completed prior to field work and used for processing. Slight changes to camera orientations will result in improper alignment and inability to accurately measure targets. Therefore, if cameras are repositioned, they must be recalibrated. Alternatively, calibrations can be conducted in-situ, immediately prior to sampling, assuming camera movement is eliminated for the duration of the sampling event. However, this this approach is labor-intensive and time-consuming for surveys with hundreds of deployments, if each deployment requires a new calibration.

The calibration process involves recording images of a calibration target with un-movable, identifiable targets, from multiple orientation and aspect angles (Fig. 2.1.2). The typical calibration fixtures used are either a 2-D checkerboard or a 3-D calibration cube, with the 3-D cube providing a more precise calibration (Boutros et al., 2015). The images are then processed to synchronize the frames, identify the coded target points, and derive calibration factors. The derived factors include both intrinsic (e.g., focal length, distortion properties, principal distance) and extrinsic (e.g., camera separation and relative orientation) calculations, which are used to minimize the triangulation errors in the localizations of numerous points on the target relative to its actual dimensions and position (Shortis and Harvey, 2015).

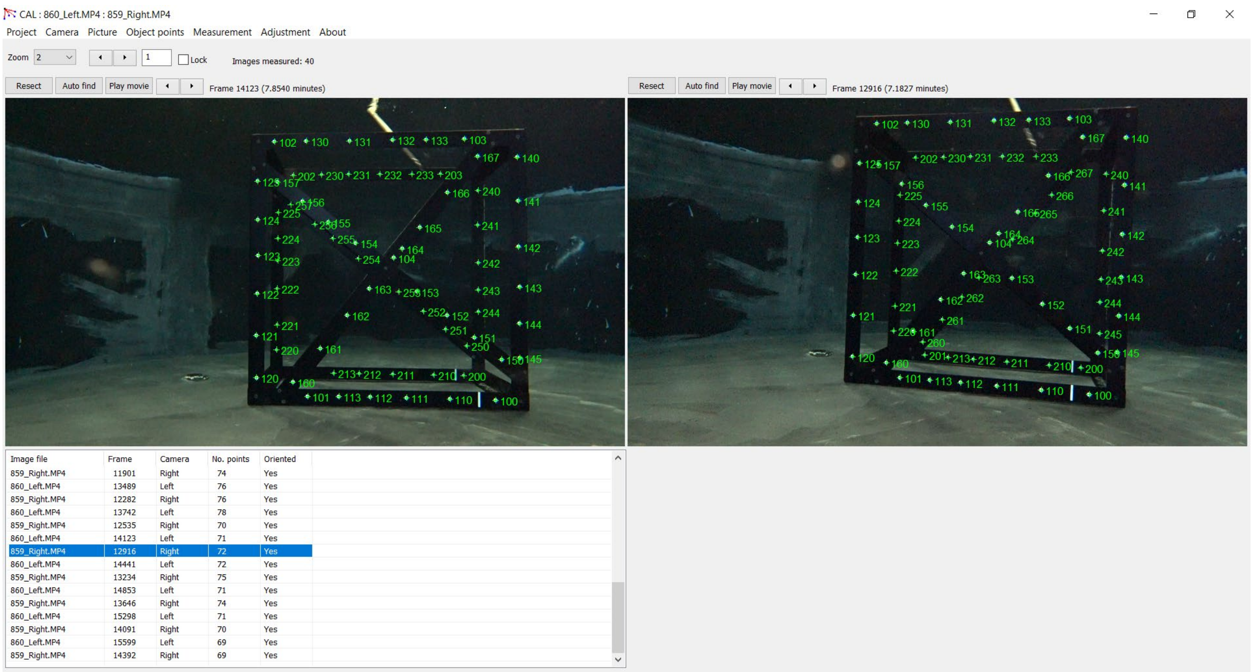


Figure 2.1.2. Calibration of a pair of stereo images using SeaGIS Cal software. Coded targets are identified through multiple orientation and aspect angles to generate camera calibration parameters. Calibration is typically conducted, prior to field sampling, in controlled conditions (e.g., pool) to maximize image quality. Calibration remains valid as long as cameras do not move with respect to one another.

2.2 TARGET LOCALIZATION AND CHARACTERIZATION

Acoustic localization and characterization

Split-beam echosounders (Fig. 2.2.1) may be used to measure bearing angles and ranges to fish as well as other acoustically resolvable targets (e.g., Demer et al., 1999). The bearing angles are derived from phase differences in the signals received on multiple sectors of the transducer. The angle sensitivity, a factor that converts the electrical phases to bearing angles, is a function of the wavelength of the transmitted pulse and the effective separation of the transducer sectors. This parameter is calibrated by the manufacturer and can be refined by the user (Renfree et al., 2018).

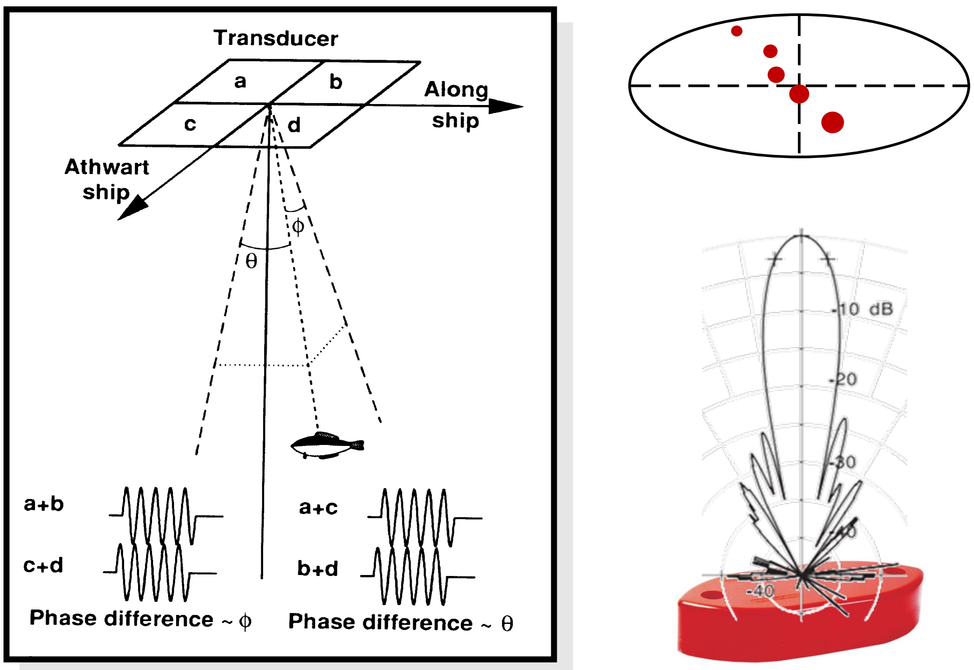


Figure 2.2.1. Split-beam echosounders receive echoes on multiple transducer sectors (left), and comparisons of the signal phases, coupled with measures of range derived from the propagation delay and sound speed, provide measures of the 3-D coordinates of the targets relative to the transducer beam. The 3-D positions are used to normalize the echosounder measurements of target strength (*TS*; dB re 1 m^2) to the gain on the axis of the acoustic beam (bottom right). Sequences of 3-D positions indicate the tracks of fish through the beam (top right). (Adapted from images by Simrad-Kongsberg.)

Sequences of split-beam three-dimensional (3-D) positions may be used to track targets such as fish (Fig. 2.2.1) and thereby quantify their trajectories, infer their orientations and behavior, and perhaps even their species, sizes, and scattering directivities, i.e., *TS* versus acoustic incidence angle (e.g., Cutter et al., 2007, Cutter et al., 2009). Three-dimensional positions may also be measured from facets of the seabed surface (Demer et al., 2009) (Fig. 2.2.2).

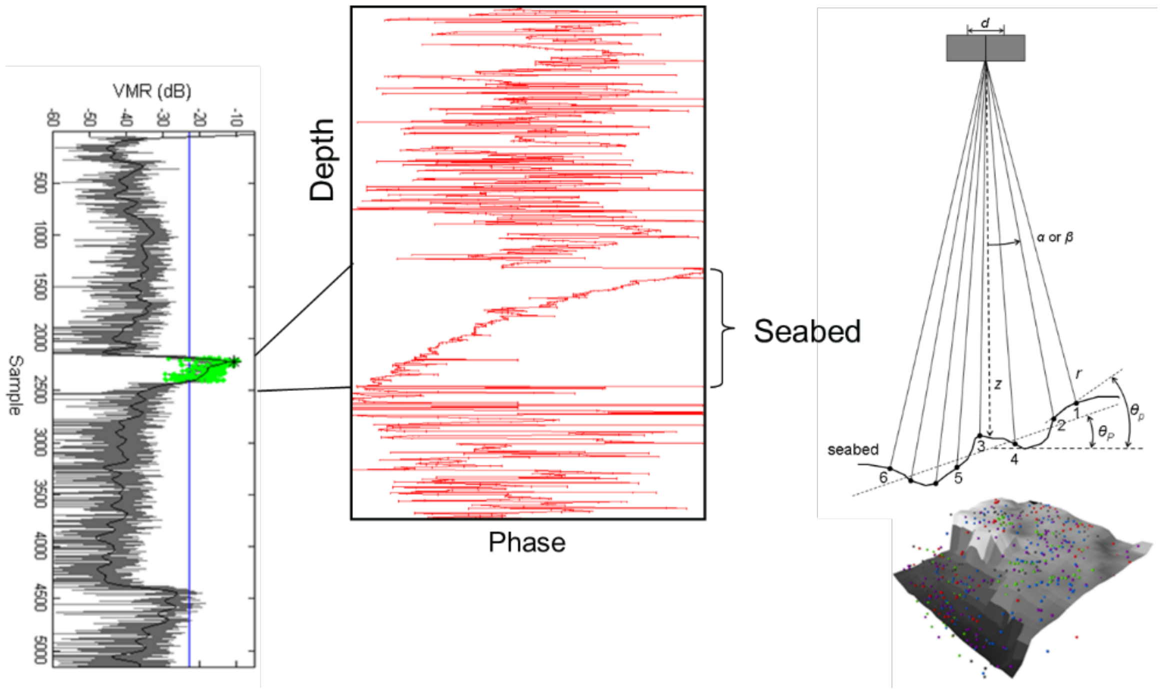


Figure 2.2.2. Samples of the seabed echo, identified by the variance-to-mean ratio (VMR) of the echo amplitude (left), show a progression in the split-beam phase measurements (middle), which correspond the high-resolution bathymetry within the beam footprint (Cutter and Demer, 2010).

Ensembles of these measurements can provide high-resolution bathymetry and characteristics of the seabed (Cutter and Demer, 2010) that can be used to acoustically identify seabed habitat (Cutter et al., 2016) and quantify the height above the seabed that is not acoustically sampled (Demer et al., 2009), known as the acoustic deadzone (Fig. 2.2.3).

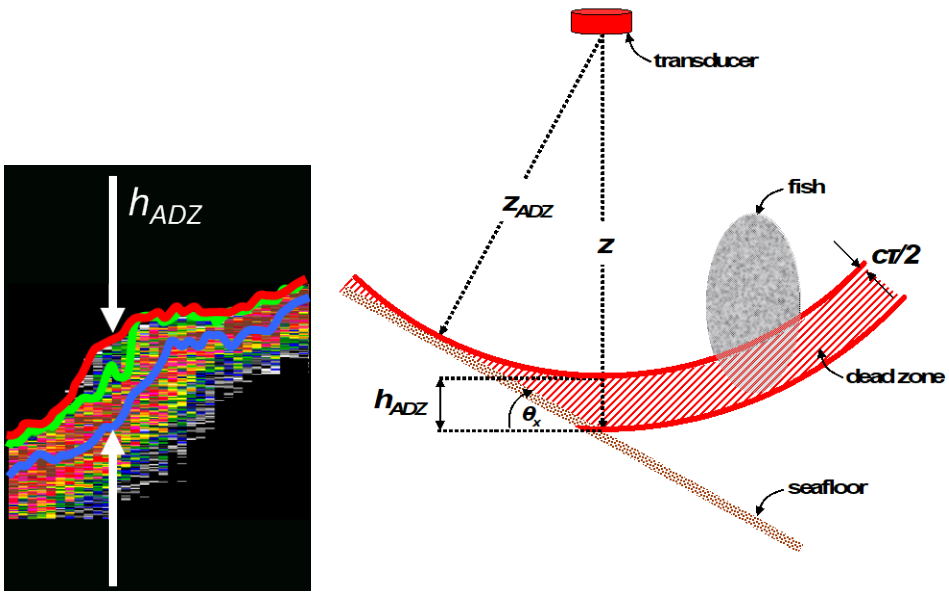


Figure 2.2.3. In the acoustic deadzone (right diagram), echoes from fish are eclipsed by that from the seabed, which has a shorter range to the transducer (z_{ADZ}) than the vertical range (z). The height of the deadzone (h_{ADZ}) depends on the beamwidth, seabed roughness, and the product of the sound speed (c_w; m s^{-1}) and the pulse duration (τ; s). In a typical echogram of a reef (left image), the top of the acoustic deadzone (red line) is above the sounder-detected seabed (green line), which is above the vertical range to the seabed (blue line). (Images from Demer et al., 2009).

Optical Localization and Characterization

Stereo cameras may also be used to measure relative 3-D positions of fish and the seabed. If a sufficient number of seabed positions are measured, they may be used to create an interpolated seabed surface. Fish altitudes may be estimated from the vertical distances between the fish and the seabed surface. If optical and acoustic samples are synchronized and their volumes overlap, the measured 3-D positions may be compared to each other, potentially providing complementary information. For example, the optical measures of fish species, counts, and altitudes may be used to validate acoustic estimates of the deadzone height, measure the quantity and species of fish inside the deadzone, and apportion the acoustic backscatter above the deadzone to species. Calibrated stereo camera systems also provide estimates of fish lengths and tilt angles by measuring 3-D locations of endpoints (head and tail) of fish and calculating the vector between them. Such information can provide distributions of fish size and aspect angle to assist in interpretation of acoustic echosounder data.

3 FIELD STUDY

3.1 STUDY SITE

The field study was conducted on the west side of Isla de San Andrés, Colombia, which is located in the southwest Caribbean, separated from Central America by a north-south fracture in the seabed (Fig. 3.1.1; left). The margin on the west side of the island is small, but to the north and east a barrier reef protects the island from waves (CORALINA-INVEMAR, 2012). The mosaic of seabed depths and types hosts a variety of fish communities.

A two-day field study was conducted in areas <20 m depth, but close to the coast and deep water. On 1 November 2018, studies were conducted at *Piscinita*, N 12º30"29.3 W 081º43"57.5. On 2 November 2018, the sampling was at *Rada El Cove*, 12°32'37.7" N, 81°44'7.1" W.

Each day, vessels *A.R.C. Isla Tesoro* (~17 m length, from the Center of Oceanographic and Hydrographic Investigations) and *Queen Conch* (~10 m length, from Coralina Institute) transited to the study site and cooperatively deployed a 3-point optic-acoustic mooring in ~20 m depth, near the shelf break (Fig. 3.1.1; right). At both sites, the tide and swell were <20 cm, and the weak current had little effect on the mooring.

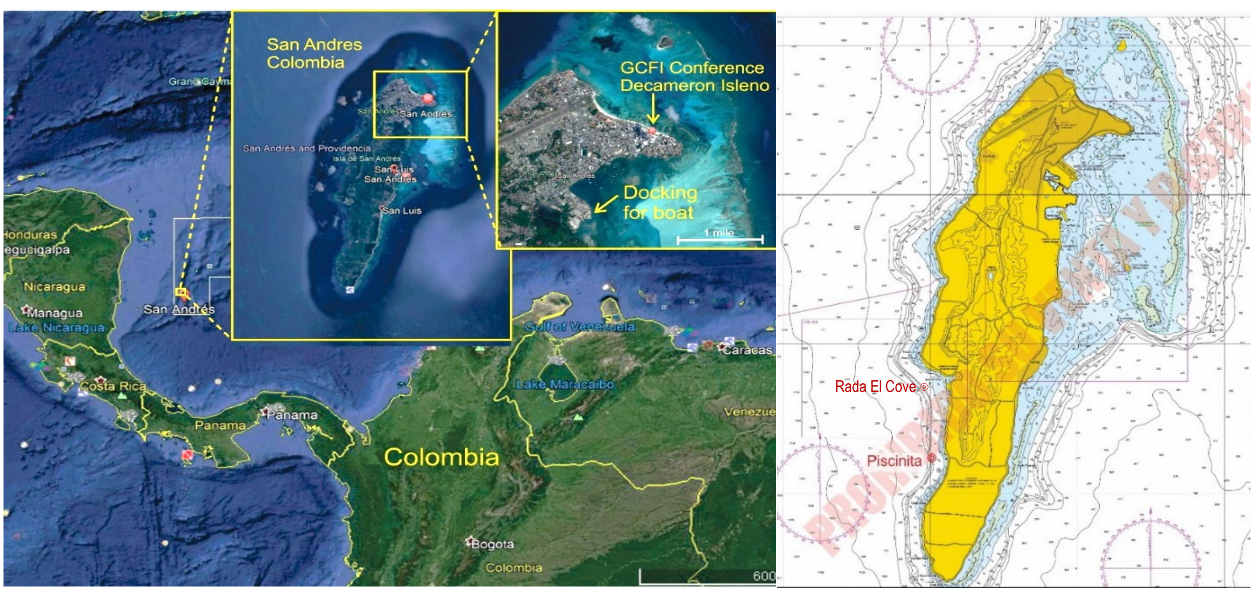


Figure 3.1.1. Isla de San Andrés, Colombia is located in the Caribbean (first inset). The docking facility for the boat is ~1.6 km from Decameron Isléno Hotel (second inset) where the GCFI conference and workshop were held. The mooring was deployed in ~20 m depth (right panel) at *Piscinita* and *Rada El Cove*.

3.2 INSTRUMENTATION AND DEPLOYMENTS

The mooring instrumentation included an autonomous echosounder transceiver (Simrad EK80-WBAT) connected to 70 kHz (Simrad ES70-18CD) and 120 kHz (Simrad ES120-7CD) transducers (nominal center frequencies), and stereo-camera systems (Sony FDR-X3000 stereo and GoPro Hero 4 Black Ed. stereo) (Fig. 3.2.1). Further information on the performance of the Simrad EK80 scientific echosounder for conducting fishery acoustic operation can be found in Demer et al. (2017). The EK80-WBAT was programmed using Mission Planner software (v1.4; Simrad, Horten, Norway). The stereo-camera systems were calibrated using the photogrammetric adjustment program CAL (v3.23; SeaGIS Pty Ltd, Bacchus Marsh, Australia).

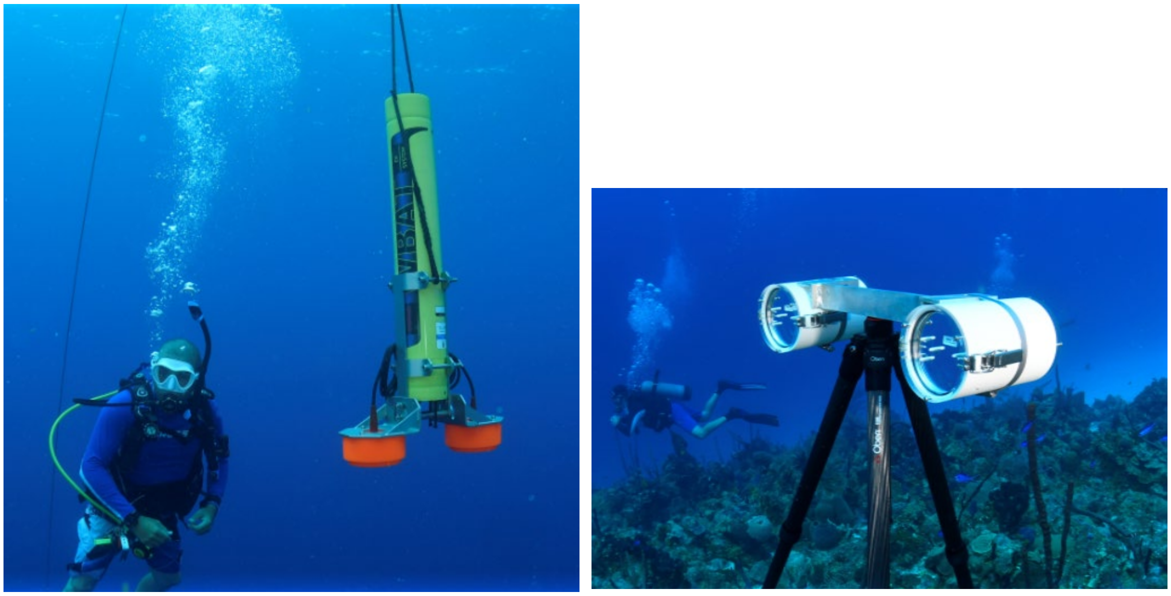


Figure 3.2.1 At the mooring sites, coincident acoustic and optic measurements were made using an autonomous echosounder (Simrad EK80 WBAT) with downward sampling 70 kHz (Simrad ES70-18CD) and 120 kHz (Simrad ES120-7CD) transducers (left), and seabed-mounted stereo-camera systems (Sony FDR-X3000 stereo and GoPro Hero 4 Black Ed. Stereo) (right).

The optical-acoustic mooring (Fig. 3.2.2) was deployed by first lowering a weight on a line to the seabed in the center of the ~20 m deep mooring site. The captain of Coralina boat *Queen Conch* used this reference line to deploy three sets of anchors, vertical lines, and surface floats ~12 m from the reference line, spaced radially every ~120°. The three floats were then pulled together symmetrically above the reference line. SCUBA divers and snorkelers deployed stereo cameras on tripods ~2 m above the seabed and ~5 m from the center of the acoustic beam. Each tripod was held upright using ~15 kg of lead weight. Snorkelers then attached the EK80-WBAT ~4 m below the surface, to reduce wave motion. The transducers were oriented downward, ~15.7 m above the seabed. Finally, a container with fish bait was secured near the weight, and then the weight and the reference line were removed from the optic-acoustic sampling volume. This arrangement facilitated the collection of optic and acoustic data from the same sampling volume.

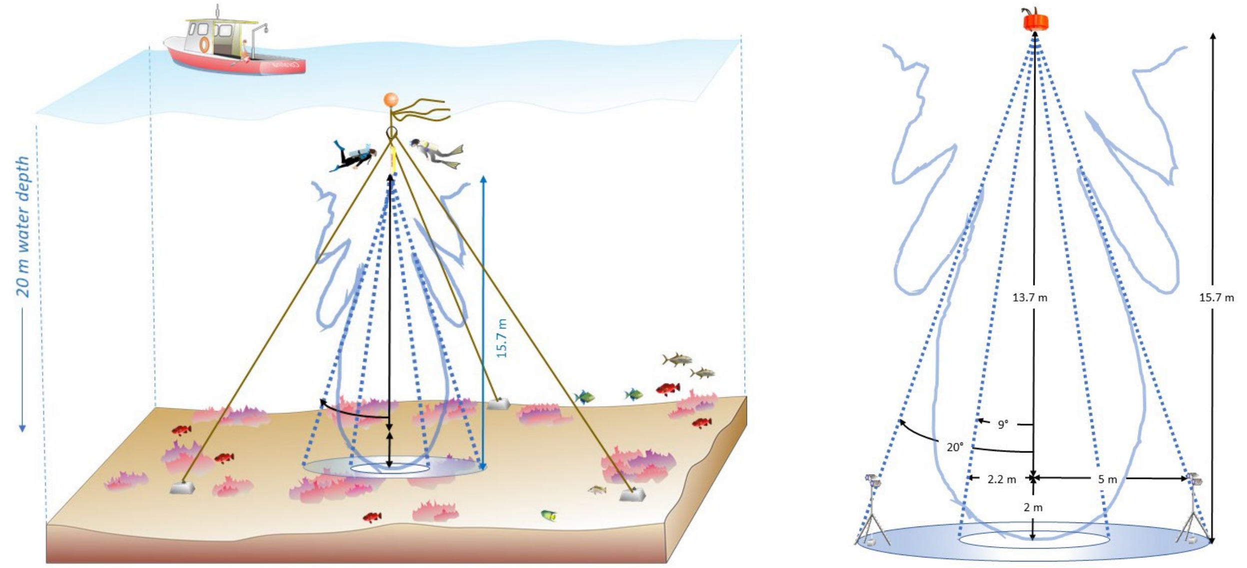


Figure 3.2.2. The three-point moorings, deployed by the captain and crew of *Queen Conch*. Divers and snorkelers, deployed from *A.R.C. Isla Tesoro*, positioned the WBAT ~4 m below the sea surface and ~15.7 m above the seabed (left panel). They also positioned stereo cameras ~2 m above the seabed and ~5 m from the center of the 70 kHz acoustic beam, above the acoustic deadzone and within the first null of the ES70-18CD transducer beam-directivity pattern (right panel). The coincident optic-acoustic sampling volume was ~4 m high with a diameter of ~4.4 m.

Additional photographs and video of the sampling apparatus and reef fish were recorded using diver-held cameras and high resolution (1080 p) video on a remotely operated vehicle (Blue ROV 2). The divers and ROV were deployed from *A.R.C. Isla Tesoro* while at anchor.

In the areas surrounding each of the mooring sites, the distributions of fish and seabed habitat were surveyed using an echosounder (Simrad EK80-Portable) with a combination 38 and 200kHz transducer (Simrad ES38-18/200-18C). The EK80-Portable was calibrated and controlled using EK80 software (v1.12.2; Simrad-Kongsberg, Norway).

3.3 Data collections

At *La Piscinita*, following the mooring deployment, acoustic and stereo-imagery data were collected for ~3.5 hours. Meanwhile, the EK80-Portable echosounder system aboard Coralina boat *Queen Conch* was calibrated using the standard sphere method and a 38.1 mm diameter sphere made from tungsten carbide with 6% cobalt binder. The sphere was suspended beneath the pole-mounted transducer on a single monofilament line and was moved throughout the beam of the 38 kHz transducer using a boat hook and the motion of the boat. The calibrated EK80-Portable system was moved along quasi-parallel transects to map fish and seabed habitat. Snorkelers and divers then retrieved the moored EK80-WBAT and cameras, downloaded the data, and recharged the batteries for both systems.

At *Rada El Cove*, following re-deployment of the mooring, acoustic and stereo-imagery data were again collected for ~3 hours. The EK80-Portable system was again used to survey along quasi-parallel transects to map fish and seabed habitat in the area surrounding the mooring.

4 Workshop

4.1 Introduction

Data from the field study was used by the instructors to train ~20 students (Fig. 4.1.1) on software and methods to integrate coincident optic-acoustic data. Students practiced procedures for acoustic mapping of fish schools and seabed habitat, and detecting, tracking, and enumerating individual fish. They learned methods for optically identifying fish species and estimating their lengths, orientations, counts, and heights above the seabed. The students also gained experience matching optic and acoustic data to observe animal behaviors, compare estimates of counts, estimate the deadzone height, and measure target strength versus species, length, and incidence angle. The students also discussed potential sources of uncertainty in each method and how the combination of optical-acoustic sampling may provide data to quantify and reduce uncertainty in each of the individual approaches. The instructors and students were encouraged to further analyze the data and collaborate on additional publications and applications of these techniques.

Figure 4.1.1. The 2018 GCFI Workshop included 48 participants from 11 countries including (left to right, row 1): Julián Prato, José Avila Cusba, William Michaels, Omar Abril-Howard, Juliana Sintura, Verónica Seda Matos, Aida Rosario, Pablo Urreña, Sergio Cambronero, Jhon Carvajal, Alfredo Abril; (row 2) Diana Castaño, Bob Glazer, Isabella González, Camilo Roa, Melissa Mayorga, Jorge Paramo, Violeta González Maynez, Uriel Rubio Rodríquez, Sarah Margolis, Wilimelie Cruz-Marrero, Edgardo Ojeda; (row 3) Tonny Algrøy, David Demer, Alejandro Acosta, Chris Taylor, Jeff Condiotty, Ryan Caillouet, Matt Kammann, Héctor Villalobos, Derek Bolser, Mancilla Johan; (row 4) Lars Nonboe Andersen, Charles Thompson, Matt Campbell, Ben Binder, Toby Jarvis, Zeb Schobernd, Fabián Kyne, Jose Castro, and Jack Egerton.

4.2 ACOUSTIC IMAGING OF FISH AND SEABED HABITAT

The three-dimensional (3-D) distributions of fish and their seabed habitat were mapped in areas surrounding each of the mooring sites using the 38 kHz channel of the EK80-Portable data and analyzed using Echoview (v9.0.323.34916, Echoview Software, Hobart, Tasmania). First, the geographic position data (GPGGA telegram) was verified and the data collected outside of the planned survey grids were removed from subsequent analyses.

For each transmission (ping) within each survey grid, ranges to the seabed were estimated using Echoview's "Best bottom candidate" line algorithm, with minimum volume backscattering strength S_v = -50 dB re 1 m^2 m^{-3}, and the resulting seabed lines were added to the echograms (Figs. 4.2.1 and 2.2.2). Obvious errors in the detected seabed lines were corrected manually. The refined seabed lines were interpolated in Echoview to create 3-D seabed surfaces. To reject near-surface noise, editable lines were added to the echograms 6.8 m below the water surface. Data between the seabed and 6.8 m deep lines were further analyzed.

For each survey grid, a geographically positioned echogram "curtain" was generated from the S_v data. For both *La Piscinita* and *Rada El Cove*, 3-D scenes were created in Echoview, including the cruise tracks, seabed surfaces, and S_v curtains (Figs. 4.2.2 and 4.2.4).

The EK80-Portable 38 kHz echogram (Fig. 4.2.1) and 3-D scene (Fig. 4.2.2) from *La Piscinita* showed fish schools primarily along the three southernmost transects, near the edge of a steep bathymetric gradient, and few fish in depths < 20 m. The EK80-Portable 38 kHz echogram (Fig. 4.2.3) and 3-D scene (Fig. 4.2.4) from *Rada El Cove* showed fish aggregated close to rough seabed, particularly near the shelf slope, and more of them than at *La Piscinita*.

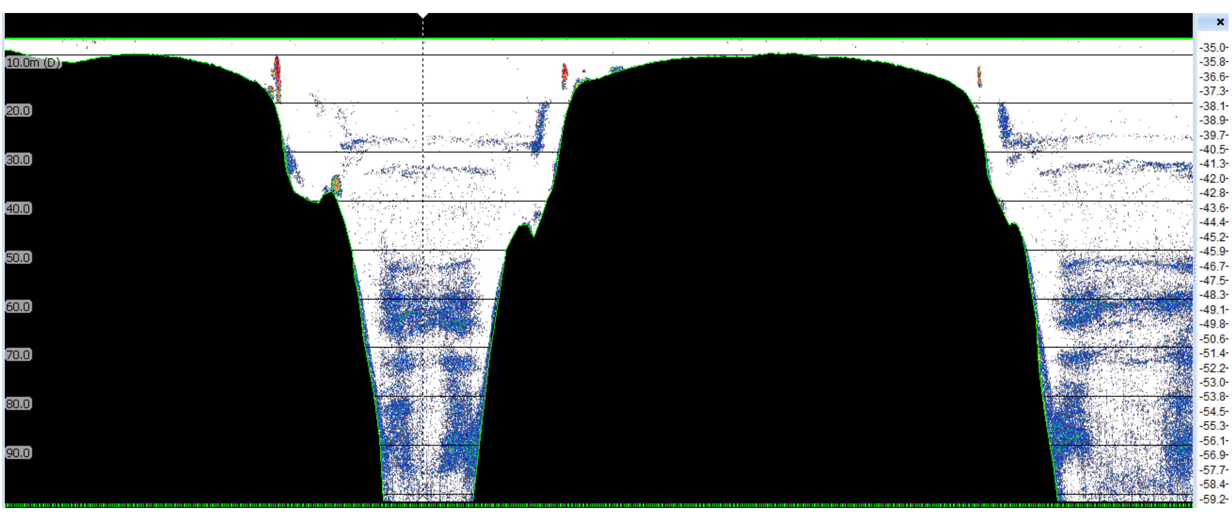


Figure 4.2.1. EK80-Portable 38 kHz echogram of the three southernmost transect in the *La Piscinita* area. Fish schools are apparent (red) near the steep slope

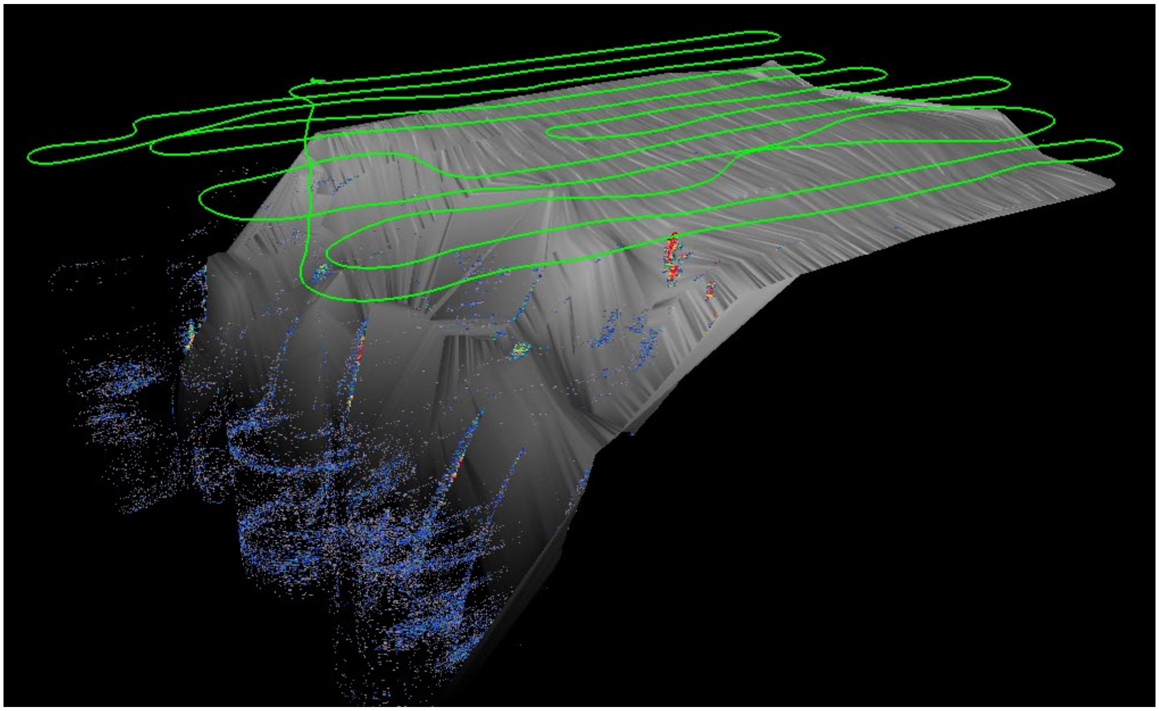


Figure 4.2.2. EK80-Portable 38 kHz 3-D scene of the trackline (green), seabed (grey), fish S_v (red), and zooplankton S_v (blue) at *La Piscinita* on 1 November 2018.

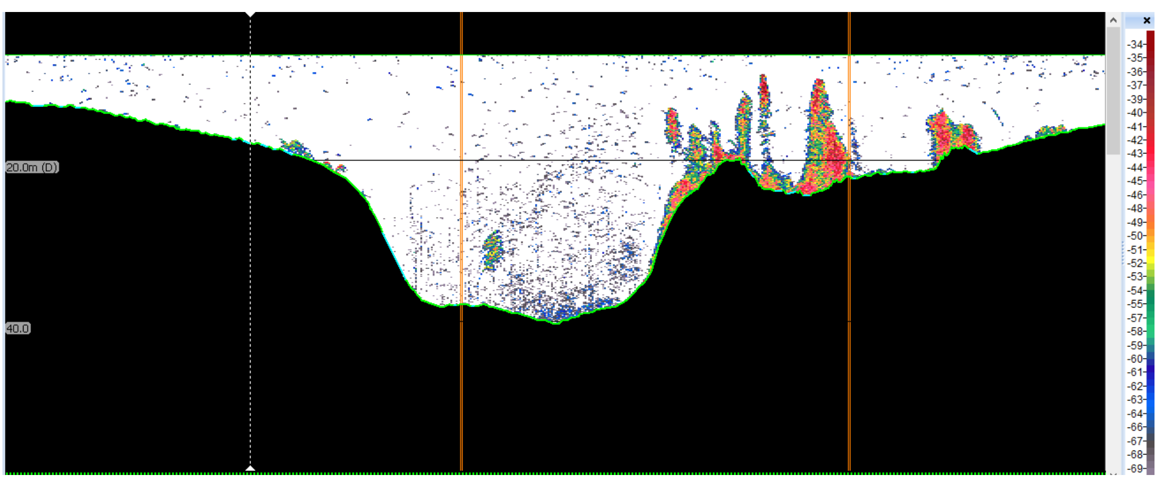


Figure 4.2.3. EK80-Portable 38 kHz S_v echogram of fish schools (red) at *Rada El Cove*. The irregularly shaped schools were associated with the rough seabed.

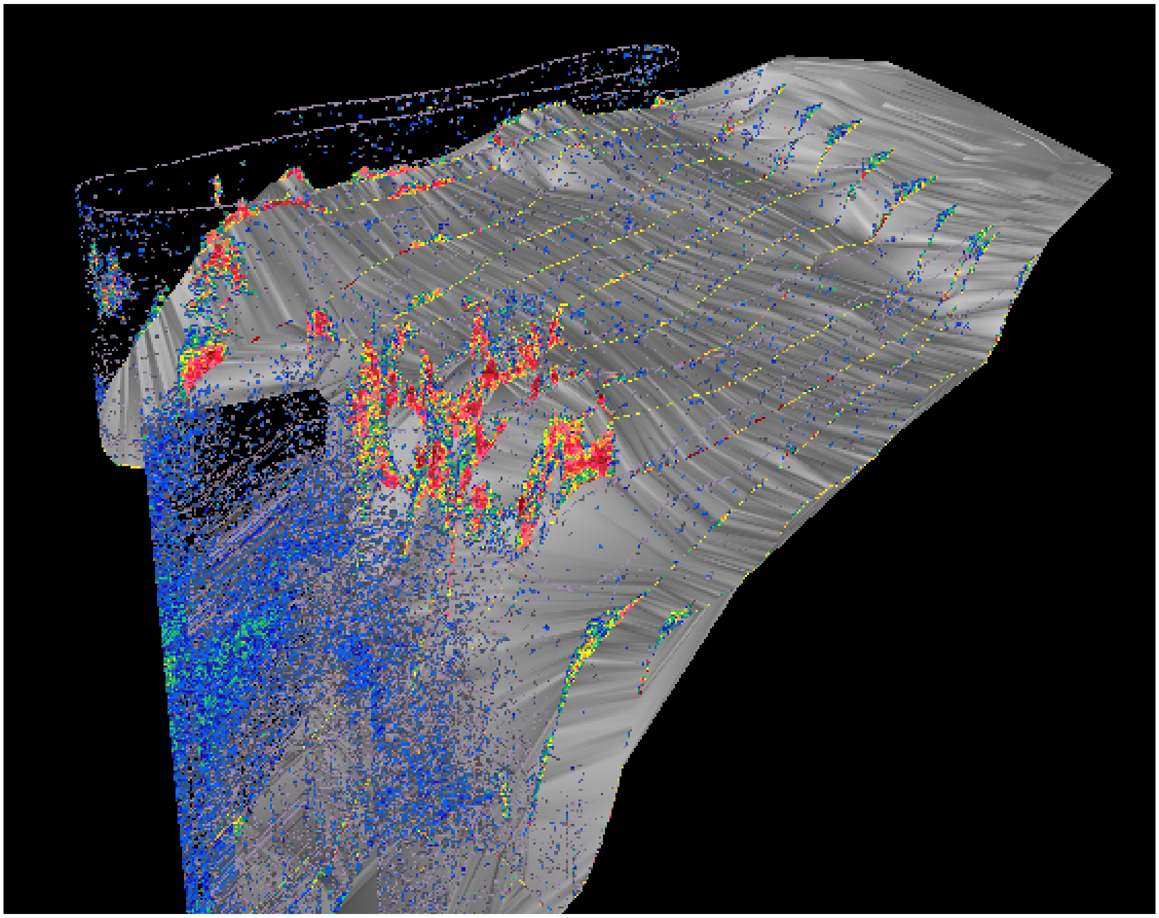


Figure 4.2.4. EK80-Portable 38 kHz three-dimensional scene of the seabed (grey), fish S_v (red), and zooplankton S_v (blue) at *Rada El Cove* on 2 November 2018.

4.3 Acoustic detection, tracking, and directivity

At *La Piscinita*, the moored EK80-WBAT was configured to transmit 0.128-µs duration, 70 kHz continuous wave (CW) pulses every ~0.33 s. A 330-ping subset of these data, collected from 18:51:00 – 18:53:30 GMT, were analyzed. These data included observations of an aggregation of creole wrasse (*Clepticus parrae*) diving into and then rising from the insonified region at ~9.75 m depth.

First, the data were inspected to identify the upper extent of the volume sampled by the stereo-camera system. The echosounder and camera system simultaneously observed the retrieval of the reference-line weight by researchers aboard the survey vessel. An echogram line at 13.4 m depth indicated the shallowest depth where the weight was visible in the video recordings. This indicated the top of the field-of-view (FOV).

The seabed depth was estimated using Echoview's "Best bottom candidate" line algorithm, and a 25.0-cm back-step was applied to exclude seabed echoes from the subsequent analysis. This delineated the top of the acoustic deadzone.

Above the seabed and back-step, echoes from resolvable individual fish were detected using Echoview's "Single target detection – split beam (method 2)" operator, and identified fish echoes were inspected for accuracy. The individual-fish detections were tracked using Echoview's "Detect Fish Tracks" algorithm. The "Fish Track" regions were classified into three behaviors: diving, cruising, and ascending, and the results exported.

The acoustic angle of incidence was estimated from the displacement of sequential detections of tracked fish (Fig. 4.3.1). Changes in the target geo-locations were trigonometrically calculated using "target latitude", "target longitude", and "target true depth". The calculated angles were matched with the estimated target strength (*TS*; dB re 1 m^2), and a generalized linear model was used to characterize the effect of incidence angle on *TS*, i.e., the scattering directivity.

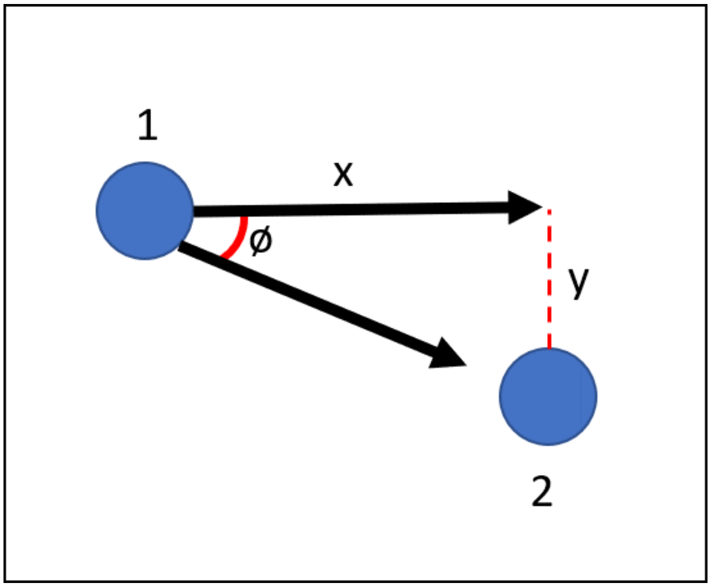


Figure 4.3.1. Acoustic incidence angle (Ø) is estimated from the displacement of targets in a track.

4.4 Optical estimations of fish lengths, tracks, and orientations

The two stereo-video files from *La Piscinita* were split and each of the four halves were analyzed using EventMeasure (v5.22; SeaGIS Pty Ltd, Bacchus Marsh, Australia), to measure three-dimensional (3-D) positions of targets within the stereo images. The videos were scanned for fish that were likely above the acoustic deadzone (e.g., Fig. 4.4.1). The fish were assigned identification numbers and, while they were present in the video, their lengths, 3-D positions, and orientation angles were measured every 30 frames, i.e., in 1-s intervals. These positions were concatenated to estimate the 3-D trajectory of each fish through the optical field.

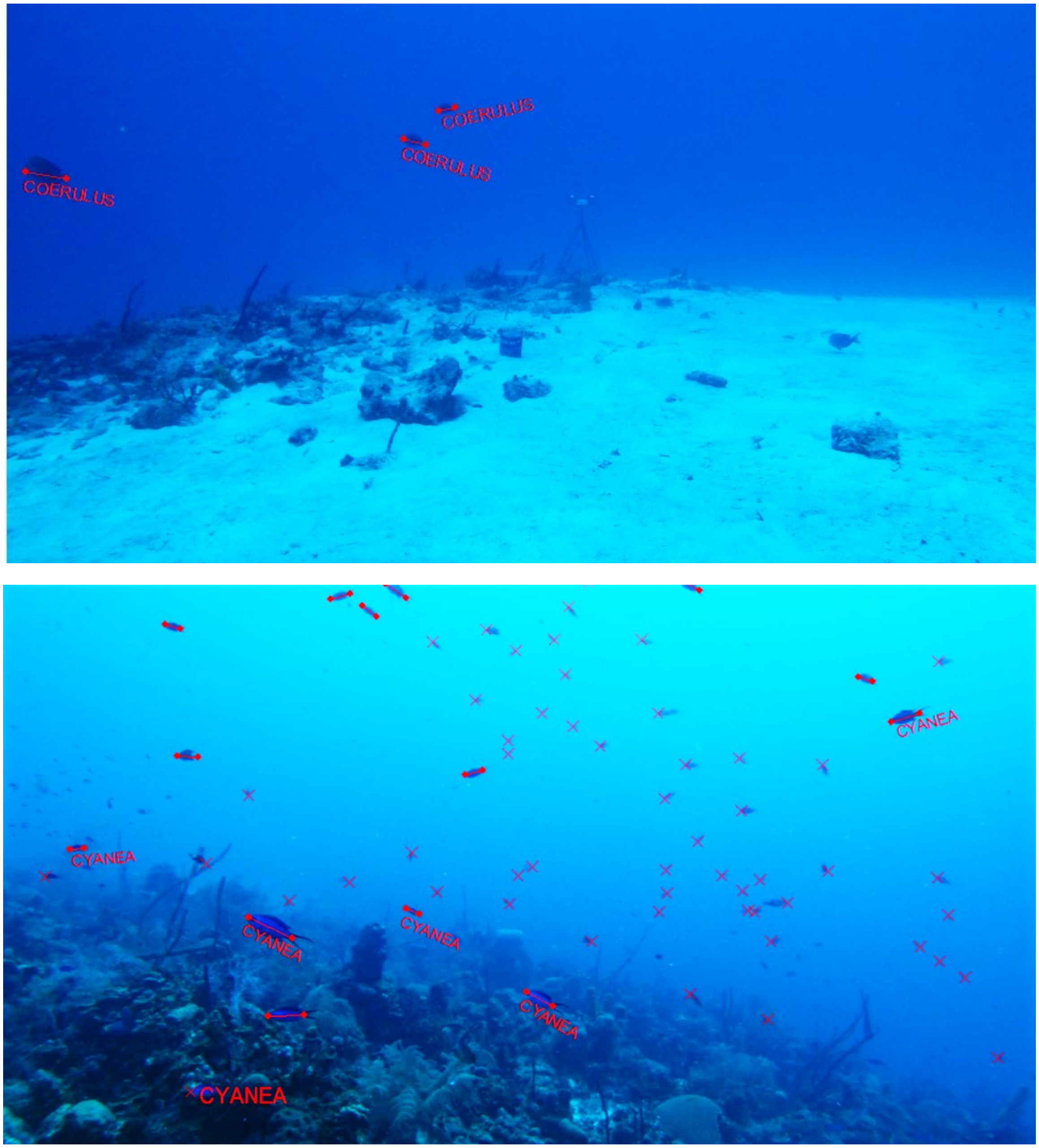


Figure. 4.4.1. Example fish detections, identifications, and length estimations above the acoustic deadzone at *La Piscinita* (top) and both in an out of the deadzone at *Rada El Cove* (bottom).

The stereo-video data collected at *Rada El Cove* was analyzed by selecting 20 frames, each separated by 1 or 2 min, during the 30 min recording period. Spatial coordinates were measured for ~470 fish, and lengths and orientations were estimated for 92 of these targets.

The spatial coordinates were plotted to show the horizontal and vertical distributions of the fish relative to the mooring reference line (Figs. 4.4.1 and 4.4.2). The estimated distributions of fish length and vertical tilt angle were also plotted (Fig. 4.4.3).

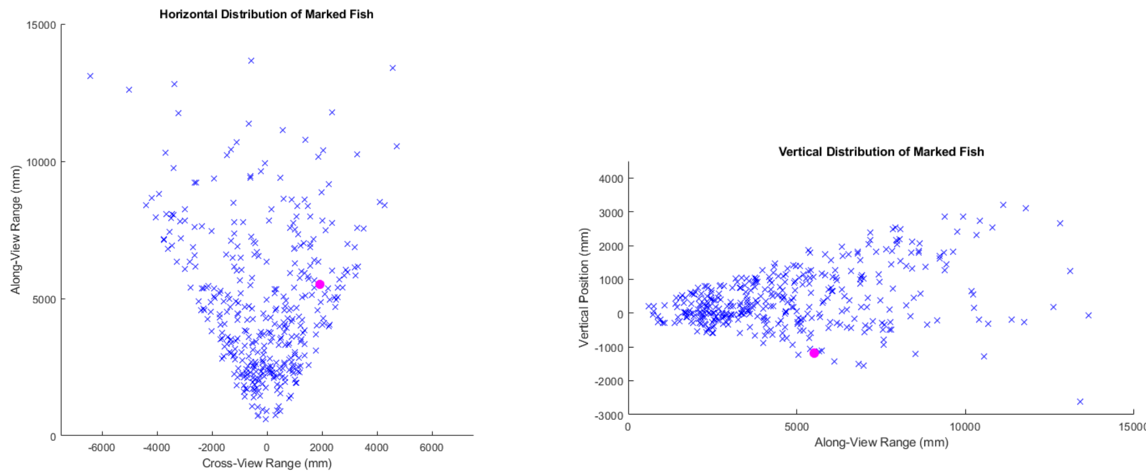


Figure 4.4.2. Horizontal (left) and vertical (right) distribution of fish targets for 20 frames of stereo video. The location of the mooring reference line is indicated (magenta dot).

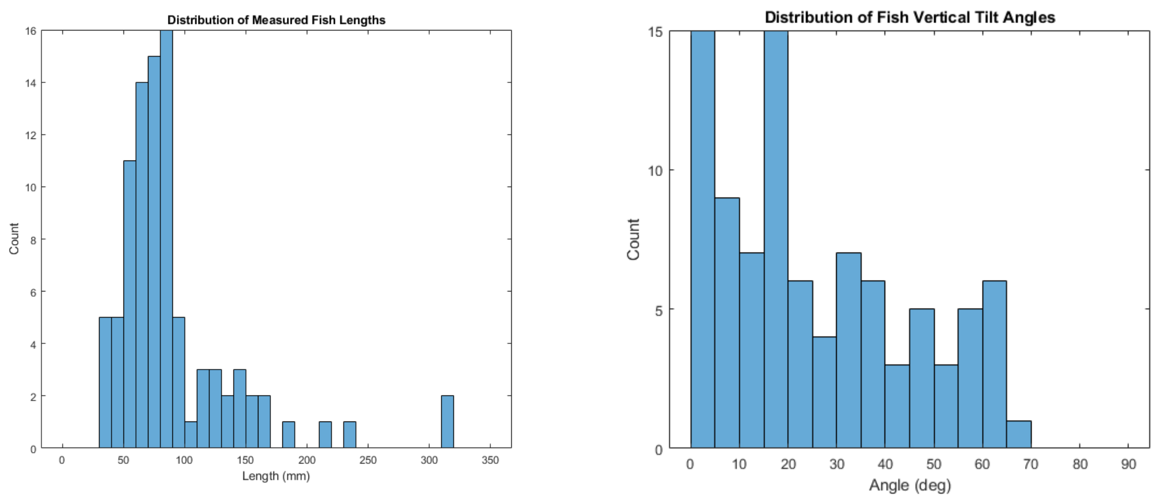


Figure 4.4.3. Observed distributions of fish length (left panel) and vertical orientation (right panel).

Most of the measured fish had lengths between 60 and 90 mm, with some larger than 300 mm. The orientations of the fish, relative to horizontal, were quasi-uniform up to ~70°. Anecdotally, larger angles were observed, some near vertical, in other frames that were not measured.

4.5 Acoustic estimation of number density

Data from the moored EK80-WBAT echosounder at *Rada El Cove* were analyzed in Echoview to estimate volume number density (fish m^{-3}) versus time. The analysis was done on the 70 kHz CW data with pulses every ~0.33 s. First, noise from bubble scatter and transducer ring-down were removed above a line drawn in the echogram 7.4 m below the surface. Seabed backscatter was removed using Echoview's "Best bottom candidate line pick" algorithm using an S_v threshold of -70 dB re 1 m^2 m^{-3} and a discrimination level of -45 dB re 1 m^2 m^{-3}. The algorithm sporadically picked points within dense fish schools, and below the apparent seabed when wind and waves caused transducer motion. These erroneous detections were replaced by the minimum seabed-detection ranges within a 5-ping smoothing window using the "Smoothing filter" virtual-line operator, else by manual editing.

The echogram was then gridded into 1 min intervals and two depth layers. One layer was 4.5 m above the seabed, representing the approximate height from the seabed viewed by the stereo camera. The other layer was bounded by the detected seabed line and the line 7.4 m below the surface. The integrated volume backscattering coefficient (s_A; m^2 nmi^{-2}) was calculated for each 1 min interval within each layer. Number density was then derived by dividing s_A by the mean backscattering cross-sectional area (σ_{bs}), which was estimated in three ways: 1) from the mean *TS* [=10Log(σ_{bs})] of the resolvable targets measured in each cell; 2) from the mean *TS* of all measurements with an "N_v index" for the cell ≥0.1 and "M% of multiple echoes" ≥70% (Sawada et al. 1993); and 3) from a model (*TS* = 19.1*log(*L*)-0.9*log(*f*)-62=-45.8 dB, where the average *L* = 9.0 cm, measured from stereo-video images, and *f* = 70,000 Hz; Love, 1972).

Fish volume number densities varied throughout the sampling period as fish swam through the field of view and the transducer beam (Fig. 4.5.1). Dense schools dominated the acoustic backscatter, though a few individual fish were also observed. The predominant species of schooling midwater fish alternated between Blue Chromis and Creole Wrasse. Occasionally, Bar Jacks chased the Chromis. Also, Gray Snapper roamed the seabed, perhaps slightly above the acoustic deadzone.

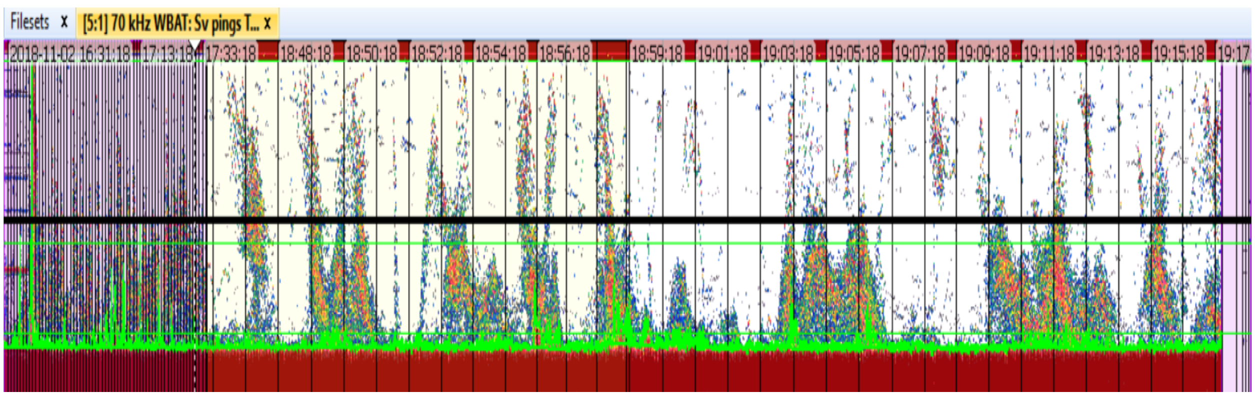


Figure 4.5.1. Example 70 kHz S_v echogram from the EK80-WBAT deployed at *Rada El Cove* showing variations in fish echoes (blue-to-red colors) above the seabed echoes (rust red), and variations in the S_v (dark green line) calculated for the 4.7 m layer above the seabed, i.e., within the optical field-of-view.

4.6 OPTICAL ESTIMATES OF FISH AND SEABED LOCATIONS

Stereo-cameras were deployed for several hours at *La Piscinita* and *Rada El Cove* to concurrently image fish and the seabed. The aim was to measure the 3-D positions of fish and numerous facets of the seabed, and then to measure the vertical distances between the fish and surfaces fit to the measured seabed positions.

First, the camera positions were set relative to each other, calibrated using CAL, and locked to create stereo vision for quantitative measurements of location, size, and orientation. The stereo videos were loaded into EventMeasure and synchronized. Then, a set of ~90 seabed features were identified, and localized in both cameras with an RMS deviation of less than 10 mm. The 3-D positions were also measured for 30 fish and the calibration weight, which was temporarily deployed near the center of the optical sampling volume, directly beneath the WBAT (Figs. 4.6.1 and 4.6.2).

Data from three independent analyses of the two sites were combined into a single, tab-delimited-text table using SeaGIS's 'Generate Database Output' function. This file was imported into R using the 'readr' function and the site information was used to separate the data from each site. Models of the seabed surfaces were created for each site using Generalized Additive Modeling (GAM) in the MGCV package in R (Fig. 4.6.3). The GAM model formulation was Z ~ s(X, Y), where Y = vertical axis, X = axis parallel to the stereo alignment, and Z = axis perpendicular to the stereo alignment. The data were assumed to be normally distributed, and a bivariate smooth function improved the use of the collocated X, Y data.

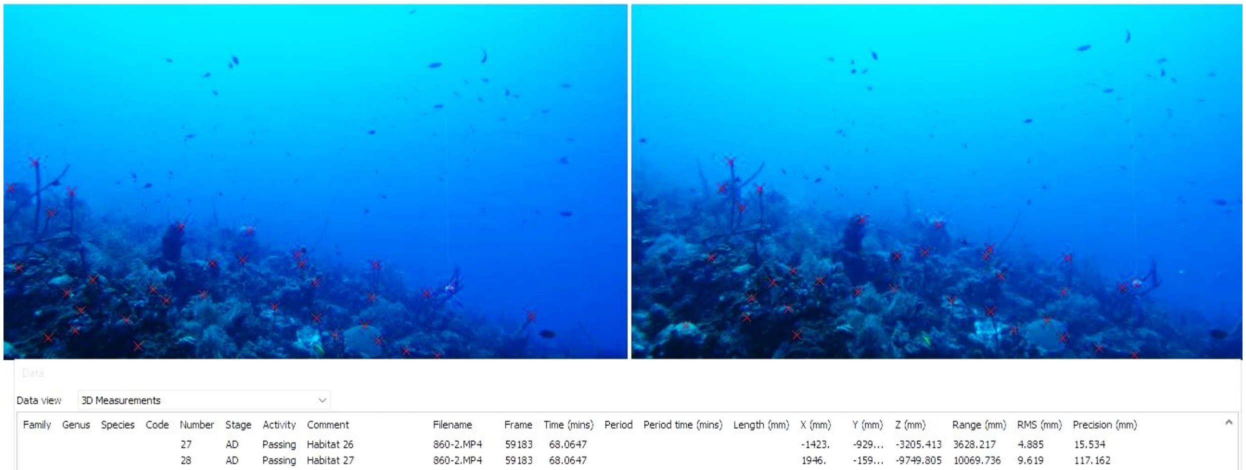
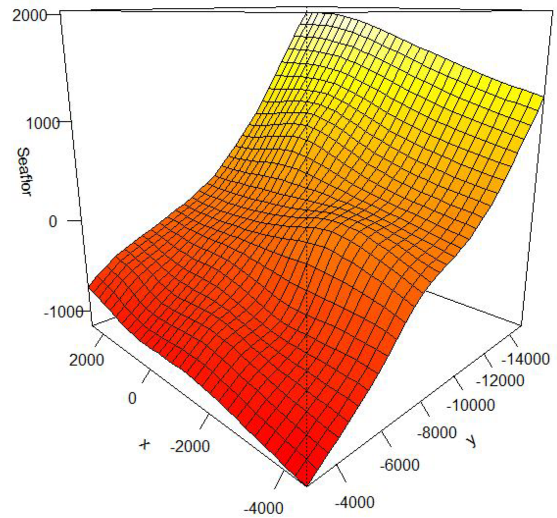


Figure 4.6.1. Left and right images at *La Piscinita* showing point estimates (red x) derived in SeaGIS EventMeasure. This site had sparse coverage of hard seabed and therefore few unique points were identified in the lower right section of the image pair. The bait can, in the center of the image, was located directly beneath the WBAT echosounder.

Figure 4.6.2. Left and right images at *Rada El Cove* with points measured (red x) using SeaGIS EventMeasure. Positions of the encrusting corals distributed over the entire seabed allowed a near complete mapping of the 3-D positions of the seabed surface.



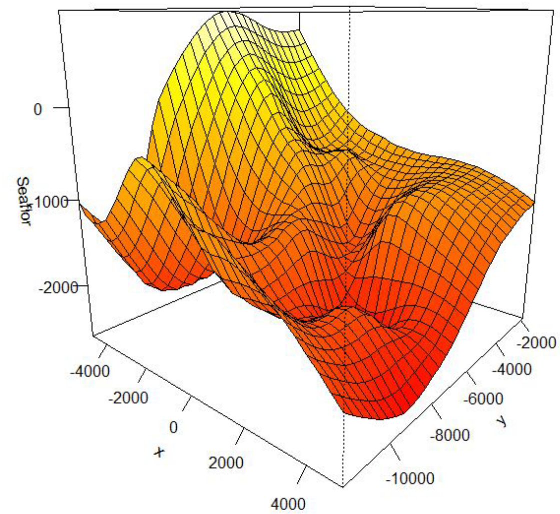


Figure 4.6.3. GAM model biplots of the seabed surfaces at *La Piscinita* (left) and *Rada El Cove* (right), derived from the 3-D positions of numerous seabed facets measured in stereo-camera pairs using SeaGIS EventMeasure.

4.7 OPTIC-ACOUSTIC OBSERVATIONS OF FISH BEHAVIOR

The spatially and temporally coincident sampling provided the workshop participants with a unique opportunity to simultaneously visualize fish sampled both optically and acoustically (Fig. 4.7.1). Using Echoview, this combined sampling allowed the larger-scale echograms to be interpreted more accurately, e.g., for fish species, behaviors, and predator-prey interactions, on the small-scale camera images.

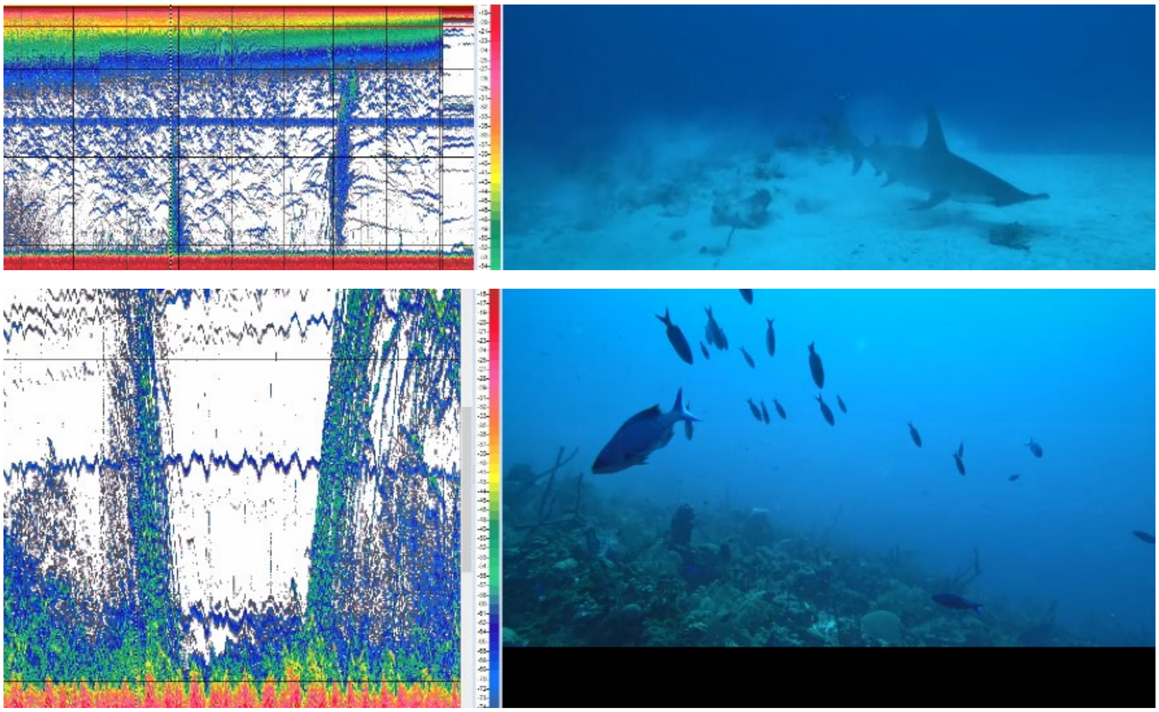


Figure 4.7.1. Synchronized acoustic (left) and optical sampling (right) served to explain many of the dynamic features of the EK80-WBAT echograms from *La Piscinita* (top) and *Rado El Cove* (bottom). Importantly, the combined sampling technique allowed the stereo-camera observations made on the scale of a few meters to be extended to the much larger scale of the acoustic observations. This unique perspective, facilitated by Echoview, helped to explain the sudden plume (top left) resulting from sediment lifted from the seabed by a hammerhead shark while investigating the bait can; and the dynamics of echoes from separated and aggregated fish (bottom left) resulting from transits through the site and sudden ascents and descents, respectively.

5 Discussion and Conclusion

This workshop provided students with experience conducting field studies that combine optical and acoustic instruments and methods, and processing of the data to derive information on the species, their sizes, target strengths, volume densities, and behaviors including associations with each other and the seabed. This concomitant collection of optical and acoustic data from reef fish and their seabed habitats has not, to our knowledge, been previously achieved at this resolution. In any case, the data set collected during this workshop is available for collaborative analyses, to more fully demonstrate the synergistic potentials of optical-acoustic sampling, improve the tools available to the GCFI community, and expand the community's knowledge of reef fish resources. The training and collaborative research efforts should have long-lasting benefits for the advancement of reef fish ecosystem research and surveys in the region.

During the Workshop, discussions were focused on the optic-acoustic operational practices executed during the field study and the analysis of the optic-acoustic data. During the study, water volumes were simultaneously sampled using echosounders and stereo cameras, and reef fish and their seabed habitats were quantitatively characterized. For example, the acoustic backscatter from fish and their seabed habitat were collected throughout a large area, and the optic measures in a portion of the area provided information needed to apportion the acoustic backscatter to fish species and lengths, and estimate biomasses. This approach provided data from two remote sensing techniques to improve our understanding of acoustic measures of reef fish assessments and to address spatial uncertainty associated with video surveys of reef fish populations.

The students compared the acoustic and optical measures collected from the study, and learned the software tools and analytical procedures, and how the tools may be used synergistically to learn more than can be gleaned from either data set alone.

Students learned how to detect and track individual fish using split-beam echosounders and infer their orientations and behaviors from the track trajectories. They learned about echo integration and the importance of target strength for scaling the echo integral to obtain estimates of fish volume number density. They learned how to use data from stereo-cameras to identify the species, lengths, and orientations of fish, and how to match these observations in space and time to the acoustic measures.

Echoview software was used to analyze the acoustic data collected at fixed locations and from a survey vessel. The students learned that uncertainty in acoustic estimates of fish density may result from misinterpretations of unresolvable echoes from multiple fish as individual fish, and the use of *TS*-L models that do not account for other variables, notably acoustic incidence angle. Also, because fish echoes disappeared from the echogram when they were observed diving towards the reef, students learned that some fish were in the acoustic deadzone.

SeaGIS software was used to analyze the stereo images and the resulting 3-D locations were used to geoposition fish relative to the seabed surface. The resolution of the seabed surface was dependent on the accuracies of the calibrations, the qualities of the images, and the number and distribution of objects that could be identified in both the left and right images, e.g., sponges and hard corals. The measurement error was inversely proportional to the range from the cameras, and also diminished towards the centers of the images. Students learned that the species and their proportions in and out of the acoustic deadzone may be estimated by identifying and detecting the positions of all fish near or on the seabed.

The students evaluated the experimental setup and discussed what was successful and what could be improved. For example, the spatial distribution of targets (Fig. 4.4.1) indicates that the camera-view axis was not aligned with the location of the mooring reference line, which was the nominal axis of the 70 kHz transducer beam. Depending on the fish distribution, this misalignment could affect comparisions of concurrent optical and acoustic measures.

The acoustic and optical sampling volumes and their overlapping volumes could be better characterized using multiple sound-scattering targets (e.g., tethered metal and buoyant spheres) and visual targets (e.g., reference flags) both above and on the seabed.

The matching of acoustic and optical estimates of 3-D fish positions could be improved by either fixing the position of the transducer relative to the cameras, or by adding motion sensors and a compass to monitor its dynamic position. Also, the optical field-of-view could be spatially adjusted or increased to maximize its alignment and overlap with the acoustic beam. Moreover, additional cameras could be added that sample in the same direction as the transducer beam. Conversely, a wider acoustic beam or multiple beams could be used to increase the overlapping acoustic and optical sampling volumes.

The estimations of target strength versus fish species and length, and acoustic incidence angle, could be accomplished by identifying the species of all of the measured fish, and more frames could be analyzed to accurately characterize the entire distribution of orientation angles. Also, the concomitant optical and acoustic observations of fish tracks, trajectories, orientations, and altitudes may indicate characteristic behaviors leading to improved classification to species.

To precisely estimate the number of fish in the sampling volume versus time, the analysis interval should match the rate of change. To mitigate the potential of re-counting targets that remain in, or re-enter the optical sampling volume, individual targets should be tracked over time.

This report complements the previous 2017 GCFI report on the best practices for conducting acoustic surveys of reef fish (Michaels et. al., 2019), and demonstrates the benefits of integrating optical and acoustic technologies to improve abundance estimates for stock assessments. During acoustic operations, the use of multiple frequencies provides classification capabilities for identifying fish (Jech and Michaels, 2006). Camera systems are often used during reef fish surveys and tend to have a limited sampling field; therefore, the integration of acoustic survey operations is recommended to address the spatial and temporal uncertainty associated with assessment derived from only optical data. This study and workshop also demonstrated how stereo camera systems can provide more accurate fish length and positional measures which can be used to develop species-specific acoustic target strength to length equations to help improve abundance estimates derived from acoustic operations. Overall, these optical and acoustical technologies have become more readily available and the integration of optical-acoustic can be a cost-effective approach for improving reef fish surveys.

6 REFERENCES

Boutros, N., M. Shortis, and E. Harvey. 2015. A comparison of calibration methods and system configurations of underwater stereo-video systems for applications in marine ecology. Limnol. Oceanogr.: Methods 13: 224-236.

Campbell, M., J. Salisbury, B. Noble, P. Felts, J. Moser, K. Rademacher, and R. Caillouet. 2018. Evaluation of Two Habitat Complexity Metrics and Their Relationship with Fish Abundance and Diversity. Proceedings of the 71st Gulf and Caribbean Fisheries Institute November 5 – 9, 2018 San Andrés, Colombia, p. 204-208.

CORALINA-INVEMAR. 2012. Gómez-López, D.I., C. Segura-Quintero, P.C. Sierra-Correa, y J. Garay-Tinoco. (Eds). Atlas de la Reserva de Biósfera Seaflower. Archipiélago de San Andrés, Providencia y Santa Catalina. Instituto de Investigaciones Marinas y Costeras "José Benito Vives De Andréis" -INVEMAR- y Corporación para el Desarrollo Sostenible del Archipiélago de San Andrés, Providencia y Santa Catalina -CORALINA-. Serie de Publicaciones Especiales de INVEMAR # 28. Santa Marta, Colombia. 180 p.

Cummings, N.J., M.L. Karnauskas, W.L. Michaels, and A. Acosta. 2014. Report of a GCFI Workshop: Evaluation of Current Status and Application of Data-limited Stock Assessment Methods in the Larger Caribbean Region. Gulf and Caribbean Fisheries Institute, Corpus Christi, TX, November 4-8, 2013. NOAA Tech. Memo. NMFS-SEFSC-661, 25 p. https://doi.org/10.7289/V5DN4304

Cummings, N.J., M. Karnauskas, W. Harford, W.L. Michaels, and A. Acosta. 2015. Report of a GCFI workshop: Strategies for improving fishery-dependent data for use in data-limited stock assessments in the wider Caribbean region. Gulf and Caribbean Fisheries Institute, Christ Church, Barbados, November 2-7, 2014. NOAA Tech. Memo. NMFS-SEFSC-681, 25 p. https://doi.org/10.7289/V5BK19BN

Cummings, N.J., M. Karnauskas, A. Rios, W.J. Harford, R. Trumble, R. Glazer, A. Acosta, and W.L. Michaels. 2017. Report of a GCFI workshop: Best practices and trade-offs for selecting between fishery dependent and fishery-independent sampling in data-limited regions. Gulf and Caribbean Fisheries Institute Conference, Panama City, Panama. November 9-13, 2015. NMFS-SEFSC-711, 26 p. https://doi.org/10.7289/V5/TM-SEFSC-711.

Cutter, G.R., Jr., and D.A. Demer. 2007. Accounting for scattering directivity and fish behavior in multibeam-echosounder surveys, ICES Journal of Marine Science, 64(9):1664-1674.

Cutter, G.R., Jr., and D.A. Demer. 2010. Multifrequency-acoustic, bi-planar, interferometric imaging, IEEE Geoscience and Remote Sensing Letters, 7(1):171-175.

Cutter, G.R., Jr., and D.A. Demer. 2014. Seabed classification using surface backscattering strength versus acoustic frequency and incidence angle measured with vertical, split-beam echosounders, ICES Journal of Marine Science, 71(4):882-894.

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

Cutter, G.R., Jr., K.L. Stierhoff, and D.A. Demer. 2016. Remote sensing of habitat characteristics using echo metrics and image-based seabed classes. ICES Journal of Marine Science, 73(8): 1965-1974.

Demer, D.A. 2012. 2004 Survey of rockfishes in the Southern California Bight using the collaborative optical-acoustic survey technique. NOAA-TM-NMFS-SWFSC-497, 101 p.

Demer, D.A., M.A. Soule, and R.P. Hewitt. 1999. A Multi-frequency method for improved accuracy and precision of in situ target strength measurements, Journal of the Acoustical Society of America, 105(4):2359-2376.

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

Demer, D.A., L. Berger, M. Bernasconi, E. Bethke, K. Boswell, D. Chu, R. Domokos, et al. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326, 133 p.

Demer, D.A., L.N. Andersen, C. Bassett, L. Berger, D. Chu, J. Condiotty, G.R. Cutter, B. Hutton, K. Rolf, N. Le Bouffant, G. Macaulay, W.L. Michaels, D. Murfin, A. Pobitzer, J.S. Renfree, T.S. Sessions, L. Stierhoff, and C.H. Thompson. 2017. 2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science. ICES Cooperative Research Report No. 336, 70 p.

Heyman, W.D., and S. Kobara. 2012. Geomorphology of Reef Fish Spawning Aggregations in Belize and the Cayman Islands (Caribbean). *In* Seabed Geomorphology as Benthic Habitat GeoHAB Atlas of Seabed Geomorphic Features and Benthic Habitats (Peter Harris and Elaine Baker, eds.), p. 387-396. Elsevier. https://doi.org/10.1016/B978-0-12-385140-6.00026-8

Jech, J.M., and W.L. Michaels. 2006. A Multifrequency Method to Classify and Evaluate Fisheries Acoustics Data. Can J. Fish Aquat. Sci. 63(10): 2225-2235.

MacLennan, D.N., P.G. Fernandes, and J. Dalen. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science, 59: 365–369.

Michaels, W.L., B. Binder, K. Boswell, L.M. Chérubin, D.A. Demer, T. Jarvis, F.R. Knudsen, C. Lang, J.E. Paramo, P.J. Sullivan, S. Lillo, J.C. Taylor, and C.H. Thompson. 2019. Best Practices for Implementing Acoustic Technologies to Improve Reef Fish Ecosystem Surveys: Report from the 2017 GCFI Acoustics Workshop. Merida, México, November 2-5, 2017. NOAA Tech. Memo. NMFS-F/SPO-192, 161 p.

Renfree, J.S., T.S. Sessions, D. Murfin, D.G. Palance, and D.A. Demer. 2019. Calibrations of Wide-Bandwidth Transceivers (WBT Mini) with Dual-Frequency Transducers (ES38-18/200-18C) for Saildrone Surveys of the California Current Ecosystem during Summer 2018. NOAA-TM-NMFS-SWFSC-608, 27 p.

Shortis, M., and E. Harvey. 1998. Design and calibration of an underwater stereo-video system for the monitoring of marine fauna populations. Int. Arch. Photogramm. Remote Sensing 32: 792-799.

Zwolinski, J.P., D.A. Demer, G.R. Cutter, K.L. Stierhoff, and B.L. Macewicz. 2014. Building on fisheries acoustics for marine ecosystem surveys. Oceanography 27(4):68–79.

7 APPENDICES

7.1 APPENDIX A. STEERING COMMITTEE

Omar Abril-Howard (Sepia ROV SAS and Coralina Instituto, San Andrés, Colombia) provided ROV and field expertise to assist with field study logistic support. Email: OmarAbrilHoward@gmail.com

Alejandro Acosta (Florida Fish and Wildlife Conservation Commission, Fish Wildlife Research Institute, Marathon, FL, USA), the GCFI deputy director, led the organization of the GCFI conference and workshop logistics. Email: Alejandro.Acosta@myfwc.com

Lars Nonboe Andersen (Simrad, Horten, Norway) provided acoustic expertise and support for the EK80 acoustic system. Email: Lars.Nonboe.Andersen@simrad.com

Tonny Algrøy (Simrad, Horten, Norway) provided acoustic expertise and support for the EK80 acoustic system. Email: Tonny.Algroy@simrad.com

Ryan Caillouet (NOAA, Pascagoula, MS, USA) provided stereo camera expertise. Email: ryan.caillouet@noaa.gov

Matt Campbell (NOAA, Pascagoula, MS, USA), Workshop Organizer, led the planning and execution of stereo camera operations during the study, and coordinated the training and analysis of stereo optical data during the workshop. Email: Matthew.D.Campbell@noaa.gov

Erick Castro (La Gobernación del Departmento de San Andrés, Coralina Instituto, San Andrés, Colombia) led the organization of the GCFI conference and coordinated among the institutes in Colombia for workshop communications. Email: mares@coralina.gov.co

Jeff Condiotty (Simrad, Lynnwood, WA, USA) provided acoustic expertise. Email: Jeff.Condiotty@km.kongsberg.com

David Demer (NOAA, San Diego, CA, USA), Workshop Organizer, led the planning and execution of acoustic operations of the pre-workshop study, and coordinated the training and analysis of acoustic data during the workshop. Email: David.Demer@noaa.gov

Bob Glazer (Florida Fish and Wildlife Conservation Commission, Fish Wildlife Research Institute, Marathon, FL, USA), GCFI Director, led the organization of the GCFI conference. Email: Bob.Glazer@myfwc.com

Euan Harvey (Curtin University, Western Australia) provided expertise in optical technology and stereo camera systems. Email: Euan.Harvey@curtin.edu.au

Toby Jarvis (Echoview Software Ltd, Tasmania, Australia) provided acoustic expertise for the Echoview acoustic processing and analysis software. Email: Toby.Jarvis@echoview.com

William Michaels (NOAA, Silver Spring, MD, USA), Lead organizer of the GCFI study and workshop, facilitated communications among the steering committee, and coordinated interorganizational collaborations between GCFI, NOAA, and Colombian institutions. Email: William.Michaels@noaa.gov Email: WMichaels001@gmail.com

Jorge Paramo (University of Magdalena, Santa Marta, Colombia) provided acoustic expertise and EK80 support. Email: JParamo@unimagdalena.edu.co

James Seager (SeaGIS Pty Ltd, Bacchus Marsh, Australia) provided expertise with the SeaGIS software to train participants on the analysis of stereo optical data. Email: JSeager@seagis.com.au

Julian Sintura (Oceanographic and Hydrographic Caribbean Research Center from DIMAR, Cartagena, Colombia) coordinated the Colombian Navy boat used during the field study. Email: JSintura@dimar.mil.co

Chris Taylor (NOAA/NOS, Beaufort, NC, USA) provided acoustic expertise and convened the GCFI session on optical and acoustic technologies. Email: chris.taylor@noaa.gov

Charles Thompson (NOAA, Pascagoula, MS, USA) provided acoustic and optic technology expertise. Email: Charles.H.Thompson@noaa.gov

7.2 APPENDIX B. PROJECT INSTRUCTIONS FOR THE FIELD STUDY

Instructions for the GCFI Optic-Acoustic Field Study:
Integrated Optic-Acoustic Data Collection for Training Workshop

Study Objectives

The Gulf and Caribbean Fisheries Institute (GCFI) was founded in 1947 to promote the exchange of information on the use and management of marine resources in the Gulf of Mexico and Caribbean region. GCFI accomplishes this mission through annual conferences, workshops, and initiatives that bring together international expertise and perspectives from scientists, managers, and stakeholders. The GCFI's Ocean Innovation Initiative grant is supported by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office of Science and Technology to improve scientific information using innovative technologies for the sustainability of living marine resources in the Gulf and Caribbean region. This initiative has completed workshops and technical reports on: data-limited stock assessment methods; optimization of fisheries independent and dependent data collections; and acoustic technology to improve reef fish ecosystem surveys. Through these accomplishments, a pool of experts has been assembled to enhance scientific capacity and help resolve data-limited assessments in the region. Concurrent with the 71st Annual GCFI Conference in San Andrés, this year's Ocean Innovation Initiative will sponsor a GCFI Special Session, 3-day GCFI training workshop, and pre-workshop field study that integrates optic and acoustic technologies to improve research and survey operations in reef fish habitats.

The primary objective of the GCFI Optic-Acoustic Field Study is to collect integrated data for training participants in the GCFI Optic-Acoustic Workshop. A mooring array with a wide-bandwidth autonomous echosounder (Simrad EK80 WBAT) and a stereo camera system will be deployed at a reef fish site in 20 m depth. Simultaneously, optical and acoustical data will be collected from the same sampling field. Concurrently, an acoustic transect survey will be conducted to provide spatial information on the habitat and fish distributions relative to this study site. Depending on the data collected, subtopics for the training and analyses can range from: identifying fish species, apportioning backscatter to species for abundance estimation, measuring fish lengths from stereo imagery, estimating target strength distributions versus species and their lengths, measuring acoustic frequency responses, validating acoustic signatures, tracking fish, estimating detection probability, and quantifying measurement biases due to animal behavior and sampling volume. The concomitant collection of optic and acoustic data from a reef fish habitat has not previously been achieved at this resolution, so the secondary objective is to publish the study results in a peer-reviewed manuscript. The training and collaborative research efforts should have long-lasting benefits for the advancement of reef fish ecosystem research and surveys in the region.

Study Period and Location

On 31 October 2018, equipment will be loaded and installed aboard two boats (see Boats, below). The echosounder systems will be tested, and then calibrated using the standard sphere method.

During 1-2 November 2018, the GCFI Field Study will be conducted in the area called "Piscinita" (N 12º30"29.3 W 081º43"57.5) along the west coast of Isla de San Andrés, Colombia (Fig. 7.2.1), where the seabed depth ranges from 10-40 m (Fig. 7.2.2). The area is a coral garden with abundant tropical fish such as angelfish, parrotfishes, barracudas, jacks, and Caribbean reef sharks.

During each day of the survey, the vessel will transit 1-2 hours from a marina, near Decameron Isléno Hotel, to the study site. There, the mooring array will be deployed in a depth of ~ 20 m, along the top of a pronounced cliff. Normally weak currents and swell in the area should have little effect on the mooring.

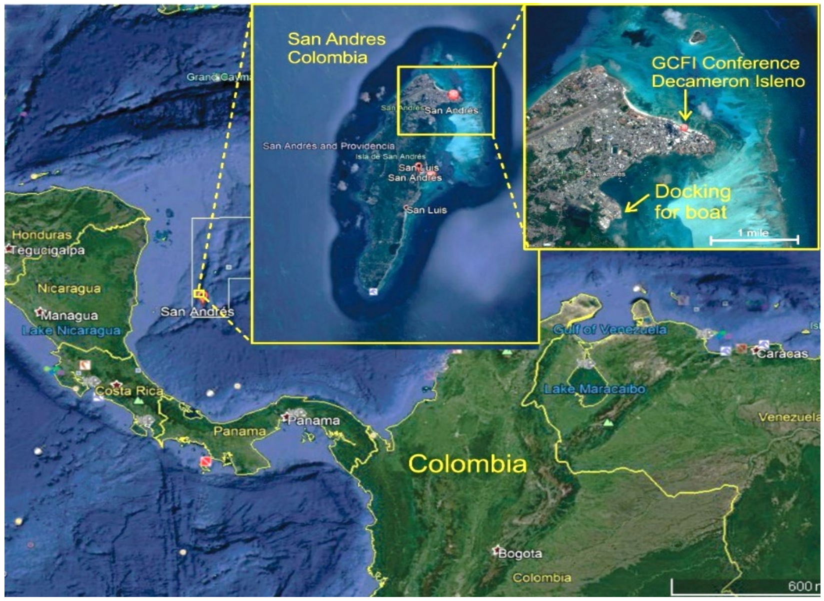


Figure 7.2.1. The Isla de San Andrés, Colombia is located in the Caribbean (first inset). The docking facility for the boat is close (about 1.6 km) to the Decameron Isléno Hotel (second inset) where the GCFI conference and workshop will be held.

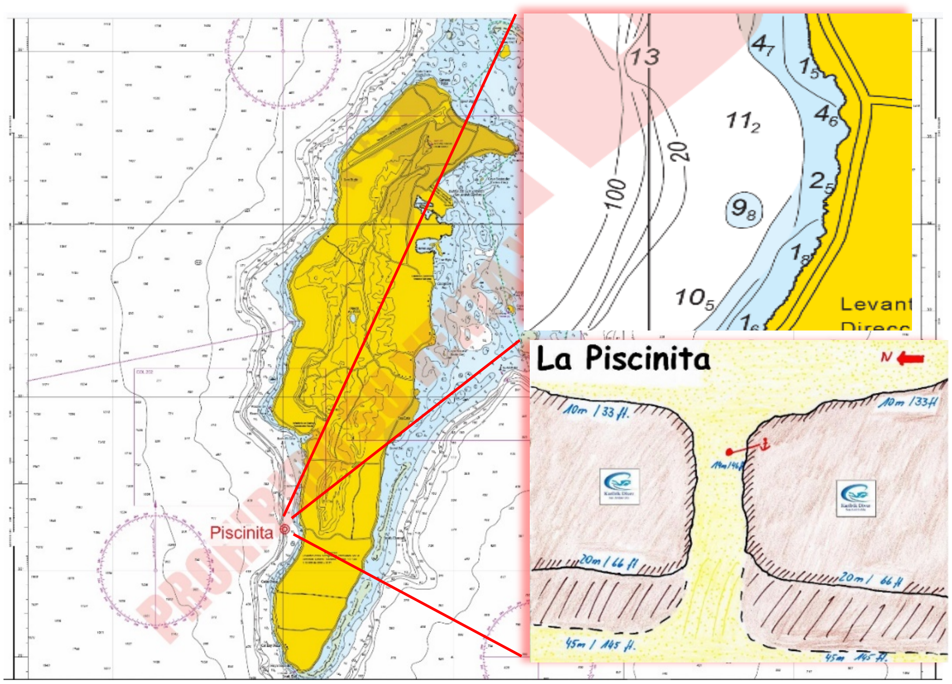


Figure 7.2.2. The study area, “Piscinita” (N 12º30”29.3 W 081º43”57.5), is located along the west side of Isla de San Andrés. The mooring array will be deployed at this site at ~ 20 m depth.

Boats

Two boats will be used for the field study: *A.R.C. Isla Tesoro* (length 17 m, draft 1 m), from the Center of Oceanographic and Hydrographic Investigations (Fig. 7.2.3), will be used to deploy the mooring array, support scuba divers to deploy the mooring sensors (autonomous EK80 WBAT acoustic and stereo camera systems), and conduct a remotely operated vehicle (ROV) survey; and *Queen Conch* (10 m length, draft 0.5 m), from the Coralina Institute (Fig. 7.2.4), will have a pole-mounted transducer to conduct the acoustic transect survey using the Simrad EK80 Reefsounder.

Figure 7.2.3. *A.R.C. Isla Tesoro* (length 17 m, draft 1 m) will deploy the mooring array and conduct the acoustic transect survey in the area around the mooring array.

Figure 7.2.4. *Queen Conch*, (length 10 m, draft 0.5 m, twin 115 hp onboard motors), from Coralina Institute, will provide scuba diver support to deploy the stereo camera systems around the mooring array, and then conduct an ROV (remotely operated vehicle) survey in the area around the mooring array.

Study Schedule

Preparations – Install the transducer pole-mount on *A.R.C. Isla Tesoro* prior to Day 1.

Day 1 – Wednesday, 31 October:
0900: Meet at the boats to review equipment.
1000: Attend a pre-cruise meeting to review cruise operations and safety.

11:00: Load and install equipment aboard the boats.
1300: *A.R.C. Isla Tesoro* transits to area with >7 m depth to calibrate the EK80 Reefsounder.
1600: *A.R.C. Isla Tesoro* returns to dock.

Day 2 – Thursday, 1 November:
0800: *A.R.C. Isla Tesoro* and *Queen Conch* transit to study site (see participant lists, Tables 7.2.1 and 7.2.2).
0930: Crew and scientists deploy a 3-point mooring, ~20 m depth, at the study site (Fig. 7.2.4).
1300: Collect acoustic and stereo imagery data for ~3 hours. Concurrently, *A.R.C. Isla Tesoro* conducts a systematic transect survey and *Queen Conch* conducts an ROV survey.
1600: Snorkelers and divers retrieve the WBAT and cameras, download data and recharge batteries.
1730: Meet at the dock to review plans for Day 3.

Day 3 – Friday, 2 November:
0800: *A.R.C. Isla Tesoro* and *Queen Conch* transit to study site (see participant lists, Tables 7.2.1 and 7.2.2).
0930: Snorkelers reattach the WBAT to the mooring and divers redeploy the cameras.
10:30: Collect acoustic and stereo imagery data for ~3 hours. Concurrently, *A.R.C. Isla Tesoro* conducts a systematic transect survey and Coralina boat *Queen Conch* conducts an ROV survey.
1330: Snorkelers and divers retrieve the WBAT and cameras.
1430: The crew of A.R.C. Isla Tesoro retrieve the mooring.
1600: Arrive to the dock and offload equipment.
1900: Scientists meet at the Decameron Isléno Hotel conference center, review data, and prepare for the GCFI Optic-Acoustic Workshop.

Cruise Operations

Cruise operations will be conducted in five phases:

- Reefsounder calibration – calibrate using the standard sphere method;
- Mooring deployment – deploy weights, lines, and floats at the study site;
- Scuba dive operations – deploy the WBAT and stereo cameras;
- Acoustic transect survey – survey around the mooring using Reefsounder; and
- Optical transect survey – survey around the mooring using ROV video.

Acoustic calibration: On 31 October, the EK80 Reefsounder (Fig. 7.2.5) with ES38-18/200-18C combi-transducer (Fig. 7.2.6) pole-mounted on *A.R.C. Isla Tesoro*, will be calibrated using the standard sphere method. Three fishing poles with monofilament line will be used to move the calibration sphere through the acoustic beam. The acoustic calibration will be conducted while the vessel is either drifting or anchored in a protected harbor with 7 m depth. The calibration may take more than 3 hours to complete.

Figure 7.2.5. The ES38-18/200-18C combi-transducer (30 kHz split-beam and 200 kHz single-beam) will be pole-mounted during the acoustic transect survey.

Figure 7.2.6. The portable EK80 Reefsounder will be used during the acoustic calibration and acoustic transect survey.

Mooring deployment: The field study will involve the deployment of a mooring with optical and acoustic systems in 20 m depth.

First, a line will be dropped in the center of the mooring site. This line will serve as a reference for arranging three equidistant anchor weights. This can be accomplished with snorkelers using a small weight (3 kg), hand reel, and small float. Reference lines for the three mooring weights will also be placed about 20 m around the center reference line.

Then the three mooring weights (about 45 kg each) will be lowered vertically in positions around the center of the site, with a separation radius of about 20 m from the center (Fig. 7.2.7).

Next, the three mooring lines will need to be pulled together to a single point that is centered above the sampling field (Fig. 7.2.8). Care must be taken to avoid habitat damage by not accidentally dragging the mooring weights during deployment operations. The intent of this deployment strategy is to center the mooring lines from a single float positioned in the middle of the sampling field, thereby removing the other floats to minimize drifting effect from currents.

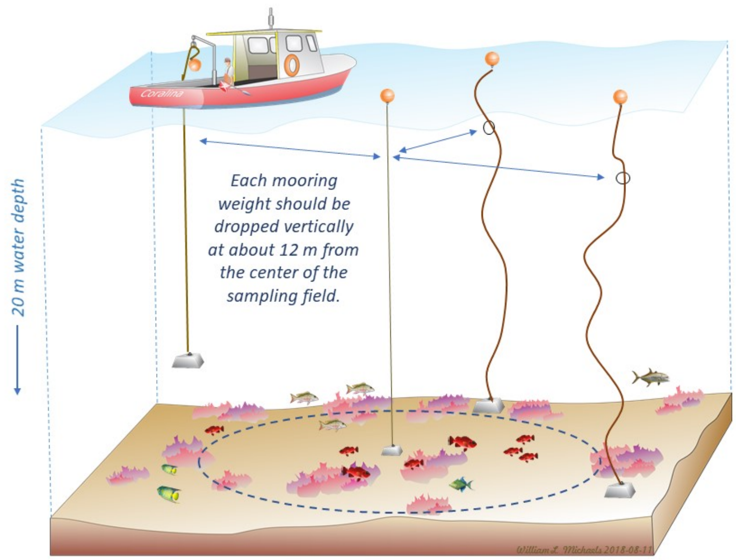


Figure 7.2.7. Three mooring weights (each about 45 kg) should be lowered vertically around a 12-15 m radius from the center of the sampling field marked by the reference line. Vertical deployment and retrieval of the mooring weights is critical to avoid damage to the reef habitat.

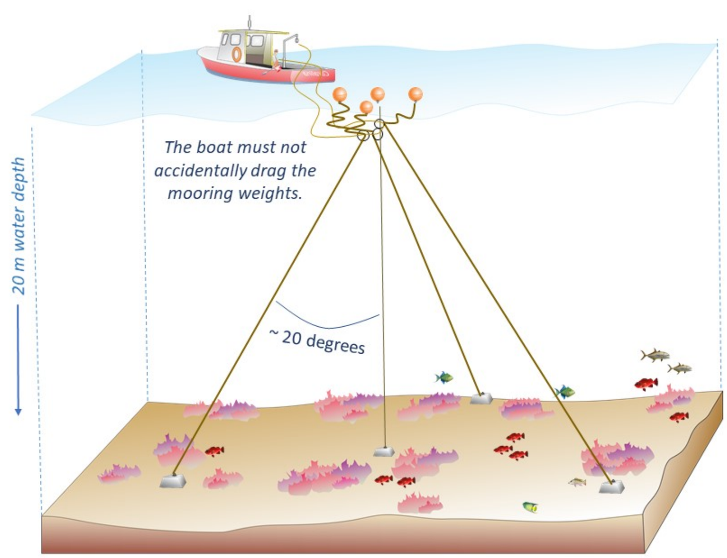


Figure 7.2.8. The crew of the boat will pull together the three mooring lines to be attached together in the center of the sampling field. Care must be taken to not drag the mooring weights during this operation to avoid accidental damage to reef habitat. Then a single float will be attached, thereby eliminate the other floats to minimize the effect of current on the mooring array. Vertical deployment and retrieval of the mooring weights is critical to avoid damage to the reef habitat.

Once the mooring array is symmetrically positioned, snorkelers can attach the autonomous EK80 WBAT system with 70 kHz split-beam transducer (model ES70-18CD) approximately 4 m below the surface (Fig. 7.2.9). This minimizes effects from wave action on the surface. The transducer will be mounted below the EK80 WBAT in a downward looking position, with sufficient weight to eliminate movement from currents (Fig. 7.2.10). The transducer should be positioned in the center of the sampling field approximately 16 m above the bottom. A plume line with small weight will be temporarily attached to the WBAT as a reference for the beam center to the bottom.

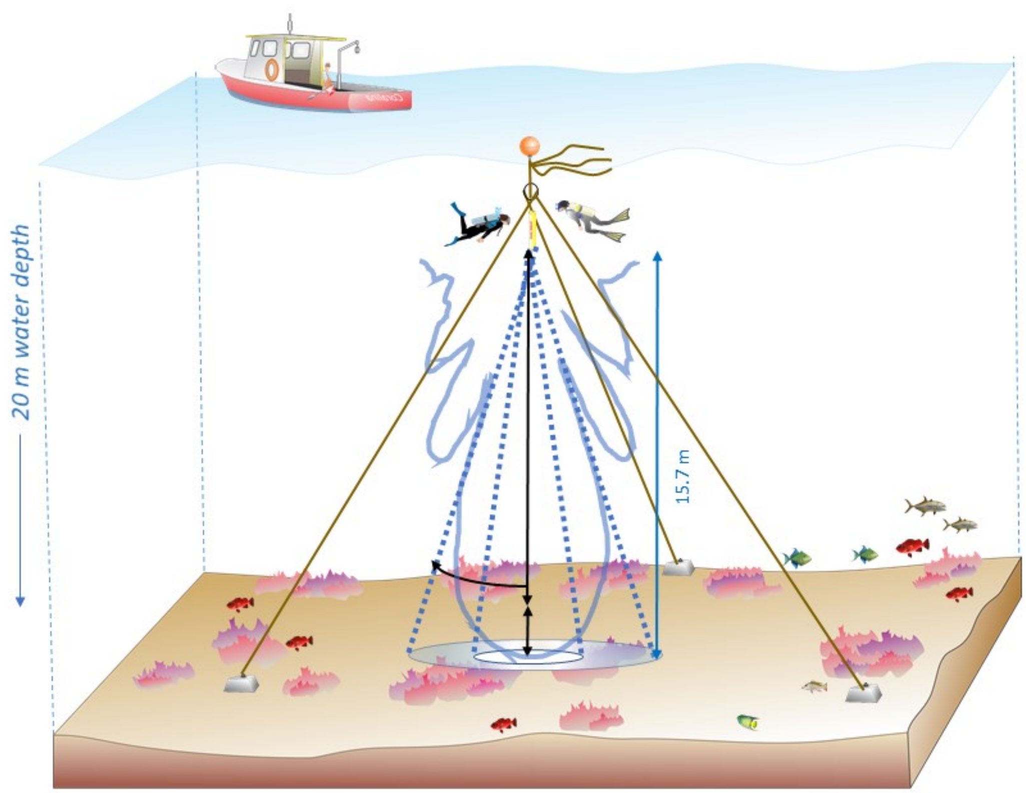


Figure 7.2.9. The three-point mooring array will be positioned with a single float in the center of the sampling field. Snorkelers can attach the autonomous EK80 WBAT systems with quick-links so the downward looking transducer is positioned 4 m below the surface and centered in the sampling field.

Figure 7.2.10. The EK80 WBAT transducer (70 kHz split-beam) will be mounted so it can be suspended in a downward looking position, and sufficient weight can be added to eliminate movement from currents.

The beam geometry of the 70 kHz transducer (model ES70-18CD) with a beamwidth of 18 degrees indicates the optimal incident sampling field for the stereo cameras is 2 m from the bottom and 5 m radius from the center of the beam (Fig. 7.2.11). The stereo cameras will be positioned on tripods about 2 m from the bottom to avoid the acoustic deadzone region.

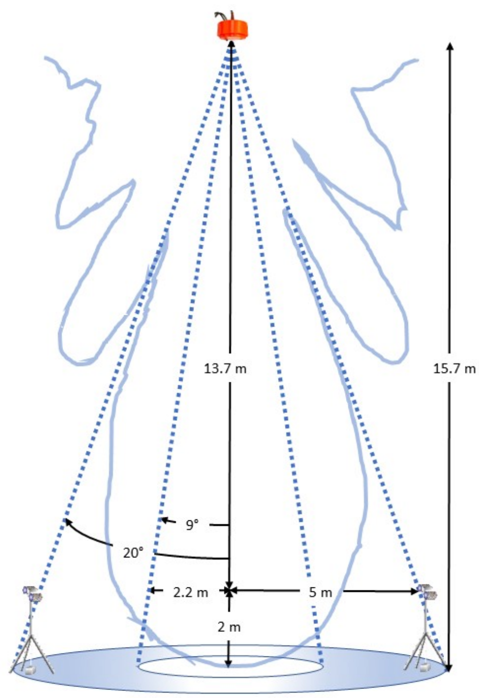


Figure 7.2.11. The mooring array will allow the EK80 WBAT transducer (ES70-18CD, 70 kHz split-beam) to be mounted 4 m below the surface in a downward looking position. This results in the transducer positioned in the center of the sampling field about 16 m above the bottom. Each stereo camera will be mounted on tripods above the acoustic deadzone (2 m above the bottom). Given the beam geometry, cameras will be positioned at a 5 m radius from the center of the sampling field.

Three pairs of SCUBA divers (6 divers) will be deployed to set three stereo cameras (Sony FDR-X3000 stereo and GoPro Hero 4 Black Ed stereo) on tripods at the seafloor (Fig. 7.2.12). Divers must be advanced certified and experienced, and certified for Nitrox enriched air diving (32% enriched air will be used). Lift bags will be used by divers to make the cameras, tripods, and weight neutrally buoyant when deploying equipment to the bottom. The camera tripod arrangement will be set on the bottom in a 5 m radius from the center of the acoustic beam. About 15 kg of lead weight will be used to secure each tripod in an upright position. A container with fish bait will be secured to the weight in the center of the sampling field. At a bottom depth of 20 m, divers should have about 60 minutes of bottom time. If time permits, diver-held cameras will be used to photograph the sampling apparatus and reef fish in the survey area.

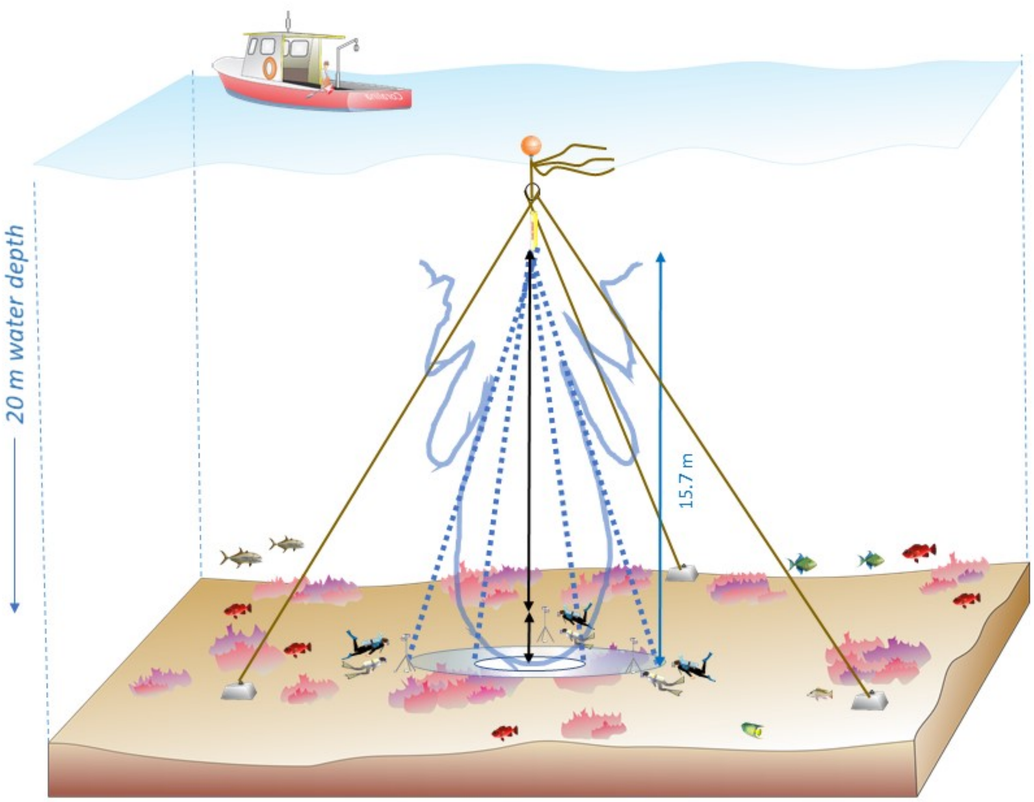


Figure 7.2.12. Three stereo camera systems will be deployed with three pairs of divers, and three camera systems will be positioned along a 5 m radius from the center of the sampling field. At a bottom depth of 20 m, the divers will have about 60 minutes of bottom time to deploy the camera systems.

Arranging three stereo camera systems along a 5 m radius around the center of the acoustic sampling field provides optimal overlap for collecting three-dimensional images within the acoustic beam (Fig. 7.2.13).

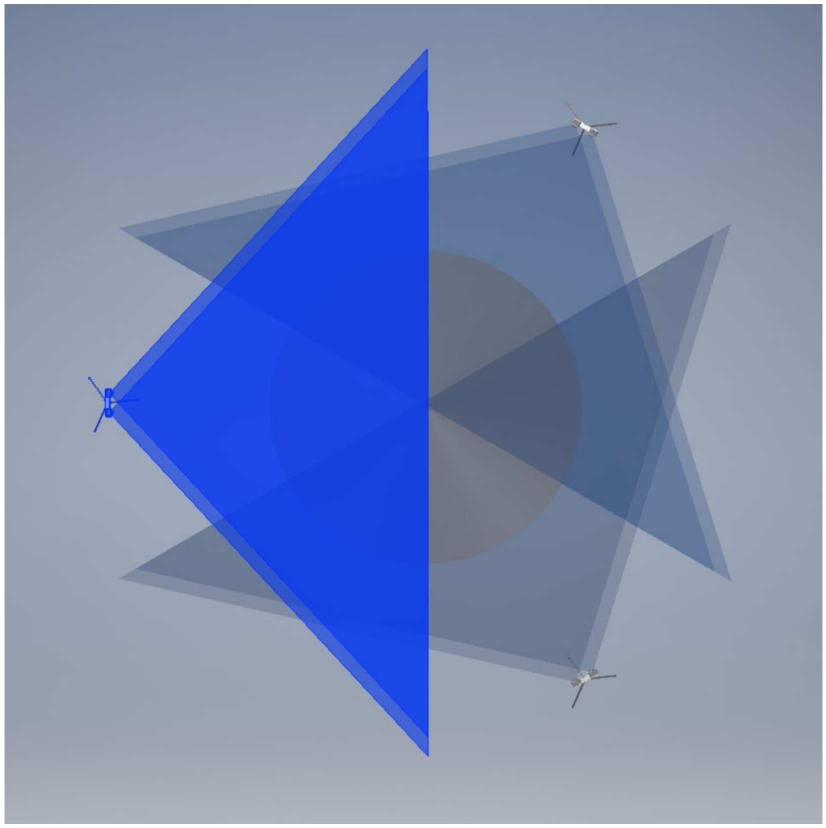


Figure 7.2.13. Three stereo camera systems arranged along a 5 m radius around the center of the acoustic sampling field provides optimal overlap for three-dimensional imaging of fish targets in the acoustic beam.

<u>Scuba diver operations</u>: Scuba divers will deploy the autonomous EK80 WBAT and stereo camera systems in the mooring array (Figs. 7.2.9 and 7.2.12). To increase dive bottom time, Nitrox 32% enriched air is recommended for the Nitrox certified divers. Initially, snorkelers will be used to lower reference lines from the surface to mark the location for mooring. After the mooring array is deployed, six scuba divers will be deployed and arrange the stereo camera systems on the bottom around the mooring site in 20 m water depth. There will be a total of four dive operations: two dives to deploy/retrieve sensors on Day 2, and two dives to deploy/retrieve equipment on Day 3 (refer to Cruise Schedule).

<u>Acoustic transect survey</u>: A parallel transect survey (Fig. 7.2.14) will be conducted using the portable EK80 Reefsounder with pole-mounted ES38-18/200-18C combi-transducer beam to collect 30 kHz split-beam and 200 kHz single-beam data. There will be about three hours to conduct the acoustic transects during Day 2, and the survey will be replicated during Day 3 (refer to Cruise Schedule).

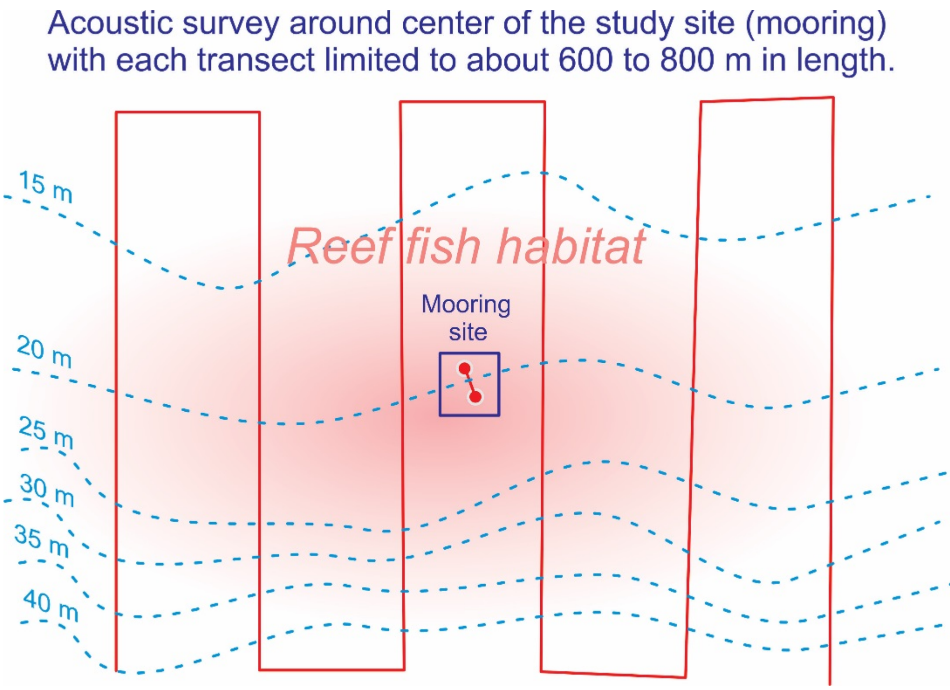


Figure 7.2.14. Acoustic transect survey will be conducted around the mooring site using the EK80 Reefsounder acoustic system.

<u>Optical transect survey</u>: During the acoustic transect survey operations (Fig. 7.2.14) on Day 2 and 3, an optical video survey using a remotely operated vehicle (ROV) will be conducted. The ROV (Blue ROV 2) will provide high resolution (1080 p) video to verify the fish species for analysis of species-specific acoustic abundance estimates (Fig. 7.2.15).

Figure 7.2.15. Blue ROV 2 will provide high definition video during survey operations around the mooring study site.

Cruise List of Scientists

Table 7.2.1. List of scientists for cruise operations onboard the boat *A.R.C. Isla Tesoro* who will deploy the mooring array, scuba divers, and ROV operations.

Last name	First name	Affiliation and Email	Role/Expertise
Abril-Howard	Omar Santiago	Sepia ROV SAS, Carrera 13 # 4a - 16 Barrio Sariey Bay, San Andrés Isla, Colombia; www.sepiarov.com; Email: omarabrilhoward@gmail.com	ROV operations
Acosta	Alejandro	Florida Fish and Wildlife Conservation Commission, Fish Wildlife Research Institute, 2796 Overseas Hwy, Marathon, Florida 33050, USA; Email: Alejandro.Acosta@myfwc.com	Master Diver, Nitrox; Camera deployment
Acosta	Miguel	Blue Life, Isla de San Andrés, Colombia	PADI Instructor, Nitrox
Caillouet	Ryan	NOAA Fisheries, Southeast Fisheries Science Center, 3209 Frederic St., Pascagoula, Mississippi 39567, USA Email: Ryan.Caillouet@noaa.gov	Stereo camera operations
Campbell	Matthew	NOAA Fisheries, Southeast Fisheries Science Center, 3209 Frederic St., Pascagoula, Mississippi 39567, USA Email: Matthew.D.Campbell@noaa.gov	Advanced Diver, Nitrox diver; Stereo camera operations
Garcia	Fabian	Blue Life, Isla de San Andrés, Colombia	PADI Instructor, Nitrox.
Margolis	Sarah	NOAA Fisheries, Office of Science and Technology, Advanced Sampling Technology Program, 1315 E West Hwy, Silver Spring, Maryland 20910, USA Email: Sarah.Margolis@noaa.gov	Advanced Diver, Nitrox; Camera deployment
Michaels	William L.	NOAA Fisheries, Office of Science and Technology, Advanced Sampling Technology Program, 1315 E West Hwy, Silver Spring, Maryland 20910, USA Email: William.Michaels@noaa.gov	Chief Scientist, Master Diver, Nitrox diver; Camera deployment
Sintura Arango	Juliana	Oceanographic and Hydrographic Caribbean Research Center from DIMAR, Cartagena, Colombia Email: JSintura@dimar.mil.co	Advanced Diver; Camera deployment
Taylor	J. Christopher	NOAA National Centers for Coastal Ocean Science (NCCOS), 101 Pivers Island Rd., Beaufort, North Carolina 28516, USA; Email: Chris.Taylor@noaa.gov	Master Diver, Nitrox; Camera deployment

Table 7.2.2. List of scientists for cruise operations onboard the Coralina boat (commanded by Capitán Alex Perez) who will provide scuba diver support to deploy stereo camera systems and conduct ROV operations.

Last name	First name	Affiliation and Email	Role/Expertise
Algrøy	Tonny	Simrad, Kongsberg Maritime, Strandpromenaden 50. NO-3183, Horten, Norway; Email: Tonny.Algroy@simrad.com	Acoustic installation & operations
Andersen	Lars Nonboe	Simrad, Kongsberg Maritime, Strandpromenaden 50. NO-3183, Horten, Norway; Email: Lars.Nonboe.Andersen@simrad.com	Acoustic installation & operations
Condiotty	Jeff	Simrad, Kongsberg Maritime,19210 33rd Ave., Lynnwood, Washington 98036, USA Email: Jeff.Condiotty@km.kongsberg.com	Acoustic installation & operations

Last name	First name	Affiliation and Email	Role/Expertise
Demer	David	NOAA Fisheries, Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, California 92037, USA Email: David.Demer@noaa.gov	Chief Scientist, Acoustic installation & operations
Paramo Granados	Jorge Enrique	University of Magdalena, Carrera 32 # 22-08, Santa Marta, Magdalena, Colombia Email: JParamo@unimagdalena.edu.co	Acoustic installation & operations
Thompson	Charles H.	NOAA Fisheries, Southeast Fisheries Science Center, Stennis Space Center, Mississippi 39549, USA Email: Charles.H.Thompson@noaa.gov	Stereo camera operations
Villalobos Ortiz	Héctor	Depto. De Pesquerías y Biología Marina, Instítuto Politécnico Nacional - Centro Interdisciplinario de Ciencias Marinas (IPN - CICIMAR), Av. Instítuto Politécnico Nacional s/n Col. Playa Palo de Santa Rita, La Paz, Baja California Sur., México 23096; Email: HVillalo@ipn.mx	Acoustic operations

7.3 APPENDIX C: WORKSHOP AGENDA

GCFI Workshop on Integrated Optic-Acoustic Technologies to Improve Reef Fish Surveys

Background: The Gulf and Caribbean Fisheries Institute (GCFI) was founded in 1947 to promote the exchange of information on the use and management of marine resources in the Gulf of Mexico and Caribbean region. GCFI accomplishes this mission through annual conferences, workshops, and initiatives that bring together international expertise and perspectives from scientists, managers, and stakeholders. The GCFI's Ocean Innovation Initiative grant is supported by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office of Science and Technology to improve scientific information using innovative technologies for the sustainability of living marine resources in the Gulf and Caribbean region. To date, this initiative completed a series of workshops and technical reports on data-limited stock assessment methods, optimization of fisheries independent and dependent data collections, and recently a workshop on using acoustic technology to improve reef fish ecosystem surveys. These accomplishments have provided a foundation to build a collaborative pool of experts to enhance scientific capacity and help resolve data-limited assessments in the region. Concurrent with the 71st Annual GCFI Conference in San Andrés, this year's GCFI-NOAA Ocean Innovative Initiative will sponsor a GCFI Special Session, 3-day GCFI training workshop, and pre-workshop field study on the integration of optic and acoustic technologies to improve research and survey operations in reef fish habitats.

Location and dates: The GCFI Workshop on Integrated Optic-Acoustic Technologies to Improve Reef Fish Surveys will be held concurrently with the 71st Annual GCFI conference in San Andrés, Colombia in early November 2018. The dates of the GCFI conference, special session, workshop and pre-workshop field study are:

- GCFI Conference during November 5 - 9
- GCFI Optic-Acoustic Special Session during the morning (0800-1000) of November 8
- **GCFI Optic-Acoustic Workshop during November 3 - 4 (0830-1730) and 8 (1030-1730)**

Further information for the GCFI conference information is available on the GCFI website www.gcfi.org

Terms of Reference (ToR) and Objectives: The GCFI Workshop entitled "Conducting Integrated Optic-Acoustic Reef Fish Survey Operations" (referred to herein as GCFI Optic-Acoustic Workshop) will provide three days of hands-on training using integrated optic (stereo camera imagery) and acoustic (EK80 echosounder) data collected from a GCFI pre-workshop field study. Details of the GCFI field study are available upon request. During the first two days, participants will learn software and analytical methods to explore the use of coincident optic and acoustic data to improve research and survey operations in reef fish habitats. Subtopics for the training and analyses can range from apportioning for abundance estimation, precision of length measures from stereo imagery, species-specific acoustic target strength distributions, species validation, detection probability and fish tracking, frequency response from split-beam and single-beam acoustic analysis, and behavioral and sampling volume biases. During the 3rd day of the workshop, wider attendance from the GCFI community is encouraged during presentations of preliminary results from the study and relevant case studies. The goal of the workshop is to train the next generation of collaborative experts, and to increase awareness among scientists, managers, and stakeholders in the region on the feasibility and value of implementing cost-effective sampling technologies to build scientific capacity in the region. Upon completion of the workshop, a working group will be established to complete analyses and publish a manuscript of results from the study.

<u>Tentative Workshop Agenda</u>: The GCFI Optic-Acoustic Workshop will be held in a classroom setting at the Decameron Isléno Hotel conference center in San Andrés, Colombia during a 3-day period. Further details will be sent to the workshop participants on September 7th. The provisional workshop agenda follows:

Day 1 - Saturday 11/03: Workshop participants will be introduced to theory and methods for the analyses of coincident acoustic and stereo-camera data collected from a reef fish habitat study in the region. The participants with acoustic experience will be paired with participants that have experience processing optical (digital still and video) data.

0830: Overview of GCFI Ocean Innovation Initiative, workshop objectives, and introductions (Bill).
0850: Objectives of acoustic data collection, study data, and analyses for workshop training (Dave).
0910: Objectives of optic data collection, study data, and analyses for workshop training (Matt).
0930: Install Echoview (acoustic) and SeaGIS (imagery) analysis software, and load data for training.
1000: Break
1030: Introduction to stereo imaging theory, equipment, and calibration for underwater research (Ryan)
1100: Hands-on introduction to SeaGIS software (Charles, Matt)
1200: Lunch
1300: Precision of stereo imagery points for fish length measures (Charles)
1320: Hands-on SeaGIS training to calibrate for three-dimensional positions (Ryan, Euan, Charles, Matt)
1330: Hands-on SeaGIS training to obtain fish length distributions (Charles, Euan, Ryan, Matt)
1440: Open discussion on SeaGIS analysis and trouble-shooting (Ryan, Euan, Charles, Matt)
1500: Break
1530: Introduction to acoustic theory and applications for integration with optics (Lars)
1550: Hands-on introduction to Echoview features relevant to target detection (Toby)
1610: Hands-on Echoview training for target tracking and target strength distributions (Dave, Toby)
1700: Open discussion on Echoview analysis, and review of the Day 2 agenda (Toby, Dave, Chris)
1730: Adjourn

Day 2 - Sunday 11/04: Participants will continue with hands-on analyses of stereo-camera and EK80 acoustic data collected from coincident sampling field at the reef fish habitat study.

0830: Survey baseline and sampling resolution considerations for underwater camera surveys (Matt)
0850: Acoustic deadzone considerations when integrating acoustic and optic data (Chris)
0910: Review analytical approach for coincident acoustic-optic data from the study (Dave, Ryan)
1000: Break
1030: Hands-on analysis of spatial-temporal overlap of optic-acoustic data from study (Dave, Matt)
1130: Open discussion on the analytical approach (Dave, Matt, Chris)
1200: Lunch
1300: Continue analysis of spatial-temporal overlap of optic-acoustic data from study (Toby, Dave, Matt)
1500: Break
1530: Open discussion and tasking on preliminary results for presentation on Day 3 of workshop.
1600: Develop summaries of preliminary results
1500: Review preliminary results and develop outline for Day 3 presentation.
1530: Adjourn

Day 3 - Thursday 11/08: After the GCFI Special Session on integrated optic-acoustic technologies, the wider GCFI community will be invited to participant during the 3rd day of the workshop. Presentations of preliminary results from the field study and relevant case studies will encourage panel discussion and one-on-one consultations on the use of technologies to enhance research and surveys in the region.

1030: GCFI Ocean Innovation Initiative and capacity building with innovative technologies (Bill)
1045: Advances in acoustics and acoustic results from the optic-acoustic study/workshop (Dave)
1100: Advances in optics and optic results from the optic-acoustic study/workshop (Matt)
1115: Application of acoustic technologies in Colombia (Juliana, Jorge, or DIMAR staff)
1130: Open discussion on the applications and recommendations for using optic-acoustic technology to improve fish reef ecosystem surveys (Panel: Bill, Dave, Matt, Chris, Euan, Jorge)
1200: Lunch
1330: Opportunity to consult with experts on equipment and methods for conducting optic-acoustic research and survey operations.
1430: Establish a working group for the analysis of the study results, writing tasks, and publication of manuscript.
1500: Break
1530: Working group will develop framework and tasking for the analysis of the study results, writing tasks, and define milestones for review and publication of manuscript.
1700: Adjourn

Participant List for the GCFI Optic-Acoustic Workshop (***** indicates instructors and expert support):

Last name	**First name**	**Affiliation and Email**	**Role/Expertise**
Abril Howard	Alfredo Joaquin	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44, Isla de San Andrés, Colombia Email: aabrilh@unal.edu.co	Participant
Abril Howard	Omar Santiago	Sepia ROV SAS, Carrera 13 # 4a - 16 Barrio Sariey Bay, Isla de San Andrés, Colombia; www.sepiarov.com Email: omarabrilhoward@gmail.com	Participant; field study support
Acosta	Alejandro	Florida Fish and Wildlife Conservation Commission, Fish Wildlife Research Institute, 2796 Overseas Hwy, Marathon, Florida 33050, USA Email: alejandro.acosta@myfwc.com	Participant; field study support
Algrøy *****	Tonny	Simrad, Kongsberg Maritime, Strandpromenaden 50. NO-3183, Horten, Norway Email: tonny.algroy@simrad.com	Acoustic expert support
Andersen *****	Lars Nonboe	Simrad, Kongsberg Maritime, Strandpromenaden 50. NO-3183, Horten, Norway Email: Lars.Nonboe.Andersen@simrad.com	Instructor, acoustic expert
Avila Cusba	José	University of Magdalena, Carrera 32 # 22-08, Santa Marta, Magdalena, Colombia; Email: josecusba21@gmail.com	Participant
Barrios	David	Comision Colombiana del Oceano, Avenida Coli No. 51-66 off. 306, Bogota, Colombia; Email: estrtegicas.caribe@cco.gov.co	Participant
Binder	Benjamin	Florida International University, North Miami, Florida, USA; Email: bbind002@fiu.edu	Participant
Bolser	Derek	University of Texas at Austin Marine Science Institute, 750 Channel View Drive, Port Aransas, Texas 78373, USA Email: derekbolser@utexas.edu	Participant

Last name	First name	Affiliation and Email	Role/Expertise
Caillouet *	Ryan	NOAA Fisheries, Southeast Fisheries Science Center, 3209 Frederic St., Pascagoula, Mississippi 39567, USA Email: ryan.caillouet@noaa.gov	Instructor; stereo camera expert
Cambronero Solano	Sergio	Laboratorio de Oceanografía y Manejo Costero. Universidad Nacional, Avenida 1, Calle 9; 86-3000, Heredia, Costa Rica Email: sergiocambroscs@gmail.com	Participant
Castro Gonzalez	Erick Richard	La Gobernación del Departmento de San Andrés, Departmento Archpiélogo de San Andrés, Providencia y Santa Catalina, Km 26 Via San Luis, San Andrés, Colombia Email: mares@coralina.gov.co	Participant
Castro	Jose Humberto	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44, Isla de San Andrés, Colombia Email: jocastrom@unal.edu.co	Participant
Campbell *	Matthew	NOAA Fisheries, Southeast Fisheries Science Center, 3209 Frederic St., Pascagoula, Mississippi 39567, USA Email: matthew.d.campbell@noaa.gov	Instructor; stereo camera expert
Carvajal	Jhon Alberto	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: jocarvajalg@unal.edu.co	Participant
Castaño Giraldo	Diana	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: dcastano@unal.edu.co	Participant
Chaparro	Fabián	University of Puerto Rico, Mayagüez, Puerto Rico 00681 Email: fabian.chaparro@upr.edu	Participant
Condiotty *	Jeff	Simrad, Kongsberg Maritime,19210 33rd Ave., Lynnwood, Washington 98036, USA Email: jeff.condiotty@km.kongsberg.com	Acoustic expert support
Cruz-Marrero	Wilmelie	University of Maryland Eastern Shore, Marine Estuarine Environmental Science Program, 11868 College Backbone Rd., Anne, Maryland 21853, USA Email: wcruz-marrero@umes.edu	Participant
Demer *	David	NOAA Fisheries, Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, California 92037, USA Email: david.demer@noaa.gov	Instructor; acoustic expert
Egerton	Jack P.	Marine Science Institute, University of Texas at Austin, 750 Channel View Drive, Port Aransas, Texas 78373, USA Email: j.egerton@utexas.edu	Participant
Erisman	Brad	Marine Science Institute, University of Texas at Austin, 750 Channel View Drive, Port Aransas, Texas 78373, USA Email: berisman@utexas.edu	Participant
Glazer	Robert	Florida Fish and Wildlife Conservation Commission, Fish Wildlife Research Institute, 2796 Overseas Hwy, Marathon, Florida 33050, USA Email: bob.glazer@myfwc.com	Participant
González Gamboa	Isabella	Universidad pedagógica tecnológica de Colombia. Avenida Central del Norte 39-115, 150003 Tunja, Tunja, Boyacá, Colombia Email: isabella.gonzalez@uptc.edu.co	
González Máynez	Violeta Estefanía	Centro de Investigaciones Biológicas del Noroeste, Guaymas, Sonora, México Email: bios.maynez@gmail.com	Participant; Scholarship nominee

Last name	First name	Affiliation and Email	Role/Expertise
Heyman	Will	LGL Ecological Research Associates Inc., 4103 Texas Ave. 211, Bryan, Texas 77802, USA Email: heymanwill@yahoo.com	Participant
Jarvis *	Toby	Echoview Software Ltd., 1c/38 Montpelier Retreat, Battery Point, Tasmania 7004, Australia Email: toby.jarvis@echoview.com	Instructor; acoustic expert
Jimemez	Aida Rosario	Division of Commercial Fisheries Research and Management, Marina Station, Mayagüez, Puerto Rico 00680 Email: arosario@drna.pr.gov	Participant
Kammann	Matthew	Division of Fish and Wildlife, St. Thomas, Virgin Islands 00802 Email: matthew.kammann@dpnr.vi.gov	Participant
Kyne	Fabian	Alligator Head Foundation, Anchovy, Port Antonio, Portland, Jamaica; Email: fabiankyne@gmail.com	Participant
León Rincón	Herman Aicardo	Dirección General Marítima Centro de Investigaciones, Oceanográficas e Hidrográficas del Caribe, CIOH - Escuela Naval Almirante Padilla Isla Manzanillo, Barrio el Bosque, Cartagena de Indias, Bolivar 11021 Colombia jefcioh@dimar.mil.co	Participant
Mancilla	Johan	Coralina Institute, Isla de San Andrés, Colombia; Email: johanmancillo@gmail.com	Participant
Margolis	Sarah P.	NOAA Fisheries, Office of Science and Technology, Advanced Sampling Technology Program, 1315 E West Hwy, Silver Spring, Maryland 20910, USA Email: sarah.margolis@noaa.gov	Participant; rapporteur
Mayorga Martínez	Melissa	Universidad Veracruzana, Instituto de Ciencias Marines y Pesqueríca, Boca del Río, Veracruz, México Email: mmayorga0104gmail.com	Participant; Scholarship nominee
Michaels *	William L.	NOAA Fisheries, Office of Science and Technology, Advanced Sampling Technology Program, 1315 E West Hwy, Silver Spring, Maryland 20910, USA Email: william.michaels@noaa.gov	Technology expert support
Ojeda	Edgardo	University of Puerto Rico, Mayagüez, Puerto Rico 00681 Email: edgardo.ojeda@upr.edu	Participant
Olson	Jack	Department of Marine Sciences, University of Puerto Rico, Mayaguez, Puerto Rico Email: olson.jack@gmail.com	Participant
Ontivero	Maria Katherine	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: mkontiverosos@unal.edu.co	Participant
Prato Valderrama	Julián Alberto	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: jprato@unal.edu.co	Participant
Paramo Granados *	Jorge Enrique	University of Magdalena, Carrera 32 # 22-08, Santa Marta, Magdalena, Colombia Email: jparamo@unimagdalena.edu.co	Acoustic expert support
Rivas Escobar	Natalia	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: nrivase@unal.edu.co	Participant
Roa	Camilo	Florida International University, North Miami, Florida, USA Email: croa@fiu.edu	Participant

Last name	First name	Affiliation and Email	Role/Expertise
Rojas Archbold	Anthony	Secretaría de Agricultura y Pesca, Gobernación Departamental, Isla de San Andrés, Colombia Email: antroojasa@gmail.com	Participant
Rubio Rodríguez	Uriel	Instituto Politécnico Nacional – CICIMAR, Av. Instituto Politécnico Nacional s/n Col. Playa Palo de Sta. Rita. La Paz, B.C.S. México Email: urubio33@gmail.com	Participant
Santos Martínez	Adriana	Univeridad Nacional de Colombia, Providencia y Santa Catalina, Isla de San Andrés, Colombia Email: asantosma@unal.edu.com	Participant
Schobernd	Zebulon Hanks	NOAA Southeast Fisheries Science Center, 101 Pivers Island Rd., Beaufort, North Carolina 28516, USA; Email: zeb.schobernd@noaa.gov	Participant
Seda Matos	Verónica	Division of Commercial Fisheries Research and Management, Marina Station, Mayagüez, Puerto Rico 00680 Email: vseda@drna.pr.gov	Participant
Sintura Arango	Juliana	Oceanographic and Hydrographic Caribbean Research Center from DIMAR, Cartagena, Colombia Email: jsintura@dimar.mil.co	Participant; field study support
Taylor *****	Christopher	NOAA National Centers for Coastal Ocean Science (NCCOS), 101 Pivers Island Rd., Beaufort, North Carolina 28516, USA Email: chris.taylor@noaa.gov	Acoustic expert support
Thompson *****	Charles H.	NOAA Fisheries, Southeast Fisheries Science Center, Stennis Space Center, Mississippi 39549, USA Email: charles.h.thompson@noaa.gov	Technology expert support
Ureña Iannini	Pablo Jose	Universidad Nacional de Colombia Sede Caribe. Carr. Cirulv. San Luis Freetow #52-44. Isla de San Andrés, Colombia Email: pjurenai@unal.edu.co	Participant
Valles	Henri	University of the West Indies, Cave Hill, Barbados; Email: henri.valles@cavehill.uwi.edu	Participant
Villalobos Ortiz	Héctor	Depto. De Pesquerías y Biología Marina, Instítuto Politécnico Nacional - Centro Interdisciplinario de Ciencias Marinas (IPN - CICIMAR), Av. Instítuto Politécnico Nacional s/n Col. Playa Palo de Santa Rita, La Paz, Baja California Sur., México 23096 Email: hvillalo@ipn.mx	Participant
Waterhouse	Lynn	Scripps Institution of Oceanography, Biological Oceanography Dep., Semmens Lab., University of California, San Diego, California 92093, USA Email: lwaterho@ucsd.edu	Participant

7.4 APPENDIX D: SPECIAL SESSION PRESENTATION AND POSTER ABSTRACTS

Order of Presentations for the GCFI Optic-Acoustic Technology Session on Thursday 11/8 morning:

Time	First Name	Last Name	Presentation Title
0800	Hermann Aicardo	León Rincón	Geomorfologia Submarina del Archipiélago de San Andrés, Providencia y Santa Catalina (Caribe Occidental) y la Correlación con la Distribución Potencial de Pesquerías
0815	Matthew	Campbell	Evaluation of two habitat complexity metrics and their relationship with fish abundance and diversity.
0830	David	Demer	The Combined Optical-Acoustic Survey Technique (COAST) for estimating the abundances and distributions of reef fishes, and mapping their seabed habitats
0845	Derek	Bolser	Spatio-temporal variation in fish density and distribution within a Gulf of Mexico shipping channel
0900	Jack	Egerton	Hydroacoustics for the discovery and quantification of Nassau grouper (Epinephelus striatus) spawning aggregations
0915	Melissa	Mayorga Martínez	Caracterización de ecosistemas coralinos mesofóticos mediante el uso de un sonar multihaz y un vehículo de operación remota
0930	Sarah	Margolis	Accessibility of Big Data Imagery for Next Generation Computer Vision Applications
0945	William	Michaels	Building Scientific Capacity with Integrated Technologies for the Next Generation Marine Ecosystem Surveys

The Seaflower Scientific Expeditions as a strategy for the monitoring and appropriate management of fishing resources

Las Expediciones Científicas Seaflower como una estrategia para el monitoreo y apropiado manejo de los recursos pesqueros

Les expéditions Cientifiques Seaflower comme une stratégie de surveillance et appropriée gestion de les resources de pêche

Juliana Sintura[1], Alex Ferrero[1], Rafael Hurtado[1], Juan M. Soltau[2], Hermann León[3], Alexandra Chadid[4], Nacor Bolaños[5], Anthony Rojas[6]

[1]*Comisión Colombiana del Océano, Avenida Ciudad de Cali No. 51-66 Oficina 306, Edificio WBC, Bogotá D.C., Colombia*

[2]*Jefatura de Intereses Marítimos y Asuntos Internacionales, Armada Nacional, Carrera 10 # 26 - 27 Edificio Bachue Piso 4, Bogotá D.C., Colombia*

[3]*Dirección General Marítima Centro de Investigaciones Oceanográficas e Hidrográficas del Caribe CIOH - Escuela Naval Almirante Padilla, Isla Manzanillo, Barrio el Bosque Cartagena de Indias, Bolivar 11021, Colombia*

[4]*Armada Nacional, Ministerio de Defensa Nacional, Carrera 54 Nº 26 – 25 CAN Bogotá D.C., Colombia*

[5]*Corporación para el Desarrollo Sostenible de San Andrés, Providencia y Santa Catalina – CORALINA, Vía San Luis, Bight, Km 26, San Andrés, Colombia*

[6]*Gobernación San Andrés, Providencia y Santa Catalina, Avenida Francisco Newball No. 6-30, Edificio Coral Palace, San Andrés, Colombia*

Abstract

The Seaflower Scientific Expedition is the most ambitious program of the Colombian Government to increase research and improve the concept of ecosystem integrity in the largest marine Biosphere Reserve in the Colombian Caribbean, Seaflower. These expeditions, planned annually until 2023, are a product of multiple stakeholders' collaborative work to generate systematic investigation in the 180000 km^2 of the San Andrés, Providencia and Santa Catalina Department Archipelago. Using the best technology available in the country and involving scientists from different marine science branches, the Seaflower Scientific Expedition has been carried out since 2014, in which more than 20 scientists are working on projects related to fish ecology, diversity and management. Additionally, other fishing resources such as the queen conch (*Lobatus gigas*) and the Caribbean spiny lobster (*Panulirus argus*), characterized for being among the most important resources in the Archipelago, have been monitored in the Island Cays of Roncador, Quitasueño, Serrana, Serranilla, Providencia and San Andrés. All these efforts are focused on contributing to the management and sustainable development that promotes the UNESCO "Man and Biosphere" program, which recognized Seaflower as a Biosphere Reserve in 2000. The Seaflower Expeditions are the best example of science cooperation, because it brings together different kind of institutions and organizations with one purpose: understand the Colombian sea and its insular systems with a holistic view, for its appropriate management to successfully meet the World Sustainable Development Goals.

Spatio-temporal variation in fish density and distribution within a Gulf of Mexico shipping channel

Variación espacio-temporal en la densidad y distribución de peces en un canal de envío en el Golfo de México

Variation spatio-temporelle de la densité et de la répartition des poissons dans un chenal d'expédition du Golfe du Mexique

Derek Bolser[1], Jack Egerton[2], Brad Erisman[3]

[1]*University of Texas Marine Science Institute, 750 Channel View Drive, Port Aransas, TX 78373, United States, derekbolser@utexas.edu*

[2]*University of Texas Marine Science Institute, 750 Channel View Drive, Port Aransas, TX 78373, United States*

[3]*University of Texas Marine Science Institute, 750 Channel View Drive, Port Aransas, TX 78373, United States*

ABSTRACT

Man-made channels are ubiquitous throughout the Gulf coast of the United States. In the northwestern Gulf of Mexico, they can represent the only connection between bays and the coastal ocean for tens of kilometers. As such, many fishes move in and out of these channels depending on life history stage, resource availability, and environmental conditions. Further, these channels have been identified as important multi-species spawning aggregation sites. Here, we report early results from a long-term hydroacoustic monitoring study of fishes in the Aransas Channel in Port Aransas, Texas. Starting in January 2018, we conducted bi-weekly surveys of fishes in the channel with a Simrad EK80 echosounder in order to describe fish density and spatial distribution. We also collected environmental data (e.g., temperature, salinity, dissolved oxygen) in the channel and nearby bays. To assess relationships between environmental data and fish density, we fit linear and quadratic models to our data. Environmental data were not significantly associated with fish density in any linear models, but a quadratic model revealed temperature in the channel as a predictor of fish density. This quadratic relationship was driven by exceptionally high fish density during a 'cold snap', and the presence of a massive, densely packed fish school on a warm survey day. Fish density within the channel was higher at the deeper, Gulf-ward edge of the channel on colder survey days, while fishes were more uniformly distributed on warmer survey days. Upon completion of this study, we hope to better understand the importance of channel habitat, and identify specific times and environmental conditions that support high densities of fishes in the channel.

KEYWORDS: Hydroacoustics, Fish Distribution, Shipping Channels

Evaluation of two habitat complexity metrics and their relationship with fish abundance and diversity.

Evaluación de dos métricas de complejidad del hábitat y su relación con la abundancia y diversidad de peces.

Évaluation de deux paramètres de complexité de l'habitat et de leur relation avec l'abondance et la diversité des poissons.

Matthew Campbell[1], Joseph Salisbury[2], Brandi Noble[1], Paul Feltsfelts[1], John Moser[1], Kevin Rademacher[1], Ryan Caillouet[1]

[1]NMFS–SEFSC, 3209 Frederic Street, Pascagoula, MS 39567, United States, matthew.d.campbell@noaa.gov

[2]Riverside Technology Inc., NMFS–SEFSC, 3209 Frederic Street, Pascagoula, Mississippi 39567, United States

ABSTRACT

Modern fisheries assessments increasingly rely on high-precision abundance data and indices produced by fisheries-independent surveys. Further, advancements in underwater optical technology has allowed for the simultaneous collection of both fish and habitat data. In theory habitat data can be used as covariates to explain fish abundance trends but it is often the case that individual metrics (e.g., areal cover of coral) do not explain trends and often only marginally improve precision. In contrast, aggregative habitat-complexity metrics have shown improved explanatory capacity in this regard. Herein we compare two approaches to constructing habitat-complexity metrics based on their ease of use and relationships to fish abundance and diversity. The visual habitat-complexity metric, derived from a visual scaling procedure, proved to have the best capacity to explain both fish abundance and diversity. Conversely, the habitat diversity metric, estimated using Shannon-Weiner equations, allows for quick creation of a metric from historic data and showed less powerful but similar relationships in comparison to the habitat-complexity metric. We recommend that video-based surveys include some form of habitat complexity data during video annotation as the approach was efficient in explaining fish abundance and diversity trends. Specific use of either method demonstrated here will depend on the state of historic data, staffing, capacity to annotate video, and time constraints.

KEYWORDS: Habitat Complexity, Abundance, Diversity

The Combined Optical-Acoustic Survey Technique (COAST) for estimating the abundances and distributions of reef fishes, and mapping their seabed habitats

La técnica combinada de acústica-óptica (COAST) para estimar las abundancias y distribuciones de peces de arrecife, y mapear sus hábitats de fondos marinos

La technique combinée de relevé optique-acoustique (COAST) pour estimer l'abondance et la distribution des poissons de récif et cartographier leurs habitats dans les fonds marins

David Demer[1], Juan Zwolinski[2], Kevin Stierhoff[1], David Murfin[1], Josiah Renfree[1], Scott Mau[1], Steve Sessions[1]

[1]Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA 92037, United States, david.demer@noaa.gov

[2]University of California Santa Cruz, Earth and Marine Sciences Building, Room A317, Santa Cruz, California 95064, United States, juan.zwolinski@noaa.gov

ABSTRACT

The distributions and abundances of reef fishes are estimated and their seabed habitats are mapped using data from multifrequency echosounders and images from underwater cameras. Acoustic sampling is used to measure and map the acoustic backscatter from fishes; optical sampling is used to estimate the proportions of each species and their length distributions; and the combined acoustic-optical dataset is used to estimate fish abundances by species and their habitat types. Towards estimation of uncertainty, the acoustic sampling provides information about fish reactions to the camera platform and the height above the seabed that is ineffectively sampled by the echosounders. Example applications of the Combined Optical-Acoustic Survey Technique (COAST) are shown for rockfishes in the Southern California Bight.

KEYWORDS: acoustic, optical, reef fishes

Hydroacoustics for the discovery and quantification of Nassau grouper (Epinephelus striatus) spawning aggregations

Hidroacústica para el descubrimiento y cuantificación de Nassau grouper (Epinephelus striatus) agregación de desove

Hydroacoustique pour la découverte et la quantification de Nassau grouper (Epinephelus striatus) agrégation de frai

Jack Egerton

University of Texas at Austin, Marine Science Institute, 750 Channel View Dr, Port Aransas, Texas 78373, United States, j.egerton@utexas.edu

ABSTRACT

Fish spawning aggregations (FSAs) are vital life-history events that need to be monitored to determine the health of aggregating populations; this is especially true of the endangered Nassau grouper

(*Epinephelus striatus*). Hydroacoustics were used to locate Nassau grouper FSAs at sites on the west end of Little Cayman (LCW), and east ends of Grand Cayman (GCE) and Cayman Brac (CBE). Fish abundance and biomass at each FSA were estimated via echo integration and FSA extent. Acoustic mean fish abundance estimates on the FSA at LCW did not differ significantly from concurrent SCUBA estimates. Mean fish densities were significantly higher at LCW than at the other sites. We investigate different acoustic post-processing options to obtain target strength (TS), and we examine the different TS to total length (TL) formulas available. The SCUBA surveys also provided measures of TL through the use of laser calipers allowing development of an in situ TS to TL formula for Nassau grouper at the LCW FSA. Application of this formula revealed mean fish TL was significantly higher at LCW than GCE, but not CBE. Use of the empirical TS to TL formula resulted in underestimation of fish length in comparison with diver measurements, highlighting the benefits of secondary length data and deriving specific TS to TL formulas for each population. FSA location examined with reference to seasonal marine protected areas (Designated Grouper Spawning Areas) showed FSAs were partially outside these areas at GCE and very close to the boundary at CBE. As FSAs often occur at the limits of safe diving operations, hydroacoustic technology provides an alternative method to monitor and inform future management of aggregating fish species.

KEYWORDS: Hydroacoustics, Nassau Grouper, Spawning aggregations

Submarine Geomorphology of the Archipelago of San Andrés, Providencia and Santa Catalina (Western Caribbean) and its Correlation with the Potential Distribution of Fisheries

Geomorfologia Submarina del Archipiélago de San Andrés, Providencia y Santa Catalina (Caribe Occidental) y la Correlación con la Distribución Potencial de Pesquerías

Geomorphologie Sous-Marine de l'Archipel de San Andrés, Providencia et Santa Catalina (Caraïbes Occidentales) et la Correlation avec la Distribution Potentielle des Peches

Commander Hermann Aicardo León Rincón

Dirección General Marítima Centro de Investigaciones, Oceanográficas e Hidrográficas del Caribe, CIOH - Escuela Naval Almirante Padilla Isla Manzanillo, Barrio el Bosque, Cartagena de Indias, Bolivar 11021 Colombia, jefcioh@dimar.mil.co

ABSTRACT

The recent acquisition and interpretation of approximately 82,000 km^2 of high-resolution multibeam bathymetric information in the western region of the Colombian Caribbean allowed illuminating for the first time the submarine geomorphology of the Archipelago of San Andrés, Providencia and Santa Catalina (ASAPSC), and how these geological formations interact with other conditions of marine environment dynamics, that influences the presence and abundance of species of fishing interest, in the archipelago areas.

Qualitative analysis of the multibeam bathymetric data let us differentiate geomorphological units in the islands and correlate geological information with ecosystem potential distribution. The ASAPSC and surrounding areas are characterized, from the geomorphological point of view, by having volcanism-related submarine landforms. These landforms are the geological foundations of the several islands (San Andrés and Providencia) and banks and atolls (Albuquerque, Este-Sudeste, Roncador, Quitasueño, Serrana, Serranilla, and Bajo Nuevo) that comprise the archipelago. Also, it was possible to determine that most of these landforms are aligned in specific directions, parallel to the trends of the main fault systems in the area, which indicates that the genesis and evolution of the archipelago and the species and ecosystems trends and distribution are influenced by large temporal scale processes that mold the islands as they are known today. All this new information has great value for decision making around fisheries policy in the Colombian western Caribbean, as a contribution from the maritime authority for the stakeholders concerned about fisheries in the ASAPSC.

KEYWORDS: Geomorphology, Multibeam bathymetric, fisheries

Accessibility of Big Data Imagery for Next Generation Computer Vision Applications

Accesibilidad de Big Data Imagery para aplicaciones de visión por computadora de última generación

Accessibilité de l'imagerie Big Data pour les applications de vision informatique de prochaine génératio

Sarah P. Margolis[1], Christopher Beavorson, Mashkoor Malik[2], William L. Michaels[1], Benjomin Richards[3]

[1]NOAA/NMFS Office of Science and Technology, Silver Spring, Maryland, USA
[2]NOAA/OAR Office of Ocean Exploration, Silver Spring, Maryland, USA
[3]NOAA/NMFS Pacific Islands Fisheries Science Center, Honolulu, Hawaii, USA

There is an unprecedented growth of digital imagery information collected from research and surveys conducted in marine ecosystems. To increase accessibility of big data imagery to research and discovery by the broader scientific community, data enterprises must develop the necessary metadata and storage to enable the use of analytical tools that use computer vision and machine learning capabilities. NOAA programs have made progress with the collection, storage, and processing of imagery data, yet efforts are underway to improve the accessibility of these data to new analytic tools to streamline processing and provide more precise quantitative measures. Standardized metadata, reliable storage, and timely user access to big data imagery are a priority for NOAA's data enterprise. The current state of NOAA Fisheries' imagery collection, storage, and accessibility is presented to highlight challenges, lessons learned, and recommendations for improving the accessibility of big data imagery for computer vision applications. The benefits of these efforts increase accessibility of big data imagery, significantly reduce processing costs, and provide more precise and timely scientific products for the sustainability of marine resources.

Keywords: Technology, Imagery, Computer Vision

Characterization of mesophotic coral ecosystems through the use of a multibeam echosounder system and a remotely operated vehicle

Caracterización de ecosistemas coralinos mesofóticos mediante el uso de un sonar multihaz y un vehículo de operación remota

Caractérisation des écosystèmes coralliens mésophotiques grâce à l'utilisation d'un système de sondeur multifaisceaux et d'un véhicule télécommandé

Melissa Mayorga Martínez, Javier Bello Pineda, Horacio Perez España, Héctor Perales Valdivia

INSTITUTO DE CIENCIAS MARINAS Y PESQUERÍAS UNIVERSIDAD VERACRUZANA, Mar Mediterráneo 314 Fracc. Costa Verde Colonia Río Jamapa, Boca del río, Veracruz 94294, México, mmayorga0104@gmail.com

INSTITUTO DE CIENCIAS MARINAS Y PESQUERÍAS UNIVERSIDAD VERACRUZANA, Mar Mediterráneo 314 Fracc. Costa Verd, BOCA DEL RIO, Veracruz 94294 México, jabello@uv.mx

INSTITUTO DE CIENCIAS MARINAS Y PESQUERÍAS UNIVERSIDAD VERACRUZANA, Mar Mediterráneo 314 Fracc. Costa Verde, BOCA DEL RIO, Veracruz, 94294 México, hespana@gmail.com

INSTITUTO DE CIENCIAS MARINAS Y PESQUERÍAS UNIVERSIDAD VERACRUZANA, Mar Mediterráneo 314 Fracc. Costa Verde, BOCA DEL RIO, Veracruz 94294, México, h_perales_v@hotmail.com

ABSTRACT

Los ecosistemas coralinos mesofóticos (ECM) son comunidades arrecifales que se distribuyen entre las profundidades intermedias (~30 m) y más bajas de la zona eufótica (~150 m), las cuales varían entre regiones. En zonas costeras donde las condiciones son turbias, el límite superior puede presentarse a <30 m de profundidad. Este trabajo tomó como caso de estudio cinco arrecifes del Parque Nacional Sistema Arrecifal Veracruzano, el cual se encuentra influenciado por la descarga de tres ríos y un importante desarrollo portuario. Con la finalidad de caracterizar a los ECM costeros, en este trabajo se combinó el uso de métodos acústicos y ópticos. Los equipos consistieron en un sistema de sonar multihaz (MBES), un vehículo de operación remota (ROV) con dos cámaras de alta definición 4k, y sensores para medir intensidad de luz y la Radiación Fotosintéticamente Activa (PAR). Para la caracterización geomorfológica se realizaron levantamientos hidrográficos con la MBES durante 2015-2017. Se realizaron análisis de variabilidad de terreno y con base en los resultados de pendiente, rugosidad, curvatura, y aspereza del terreno se identificaron áreas estructuralmente complejas. Para la caracterización de la comunidad bentónica se obtuvieron 30 video-transectos de ~150 m de longitud. Se observó la presencia de colonias coralinas con formas de plato como Stephanocoenia intercepta, Agaricia lamarcki, Agaricia grahamae, que están registradas en la región del caribe como especies exclusivas de la zona mesofótica. Finalmente, en las mediciones de intensidad de luz in situ, se observaron diferencias entre arrecifes.

Mesophotic coral ecosystems (MCE) are reef communities that are distributed between the intermediate depths (~ 30 m) and lower depths of the euphotic zone (~ 150 m), which vary between regions. In coastal areas where conditions are cloudy, the upper limit can occur at a depth of <30 m. This work took as a case study five reefs of the National Park Sistema Arrecifal Veracruzano, which is influenced by the discharge of three rivers and an important port development. In order to characterize coastal MCEs, this work combined the use of acoustic and optical methods. The equipment consisted of a multibeam sonar system (MBES), a remote operating vehicle (ROV) with two 4k high definition cameras, and sensors to measure light intensity and Photosynthetically Active Radiation (PAR). For the geomorphological characterization, hydrographic surveys were carried out with the MBES during 2015-2017. Analysis of terrain variability was carried out and, based on the results of slope, roughness, curvature, and roughness of the terrain, structurally complex areas were identified. For the characterization of the benthic community, 30 video-transects of ~ 150 m in length were obtained. The presence of coralline colonies with plate shapes such as *Stephanocoenia intercepta*, *Agaricia lamarcki*, *Agaricia grahamae*, which are registered in the Caribbean region as species exclusive to the mesophotic zone, was observed. Finally, in the in situ light intensity measurements, differences were observed between reefs.

KEYWORDS: Mesophotic coral ecosystem, ROV, Multibeam echosounder system

Building Scientific Capacity with Integrated Technologies for the Next Generation Marine Ecosystem Surveys

Creación de capacidad científica con tecnologías integradas para las encuestas de ecosistemas marinos de la próxima generación

Création de capacité de sécurité avec technologie intégrée pour des applications écologiques de luxe de génération

William L. Michaels[1], Alejandro Acosta[2], Ryan Caillouet[3], Matthew Campbell[3], David A. Demer[4], Robert Glazer[2], Jorge Paramo[5], J. Christopher Taylor[6], Charles H. Thompson[7], Héctor Villalobos[8]

[1]NOAA Office of Science and Technology, 1315 E West Hwy, Silver Spring, MD, United States William.Michaels@noaa.gov

[2]Florida Fish and Wildlife Commission, Marathon, FL, United States

[3]NOAA Southeast Fisheries Science Center, Pascagoula, MS, United States[4]NOAA Southwest Fisheries Science Center, La Jolla, CA, United States

[4]NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA, United States

[5]University of Magdelena, Magdalena, Santa Marta, Colombia

[6]NOAA National Centers for Coastal Ocean Science, Beaufort, NC, United States

[7]NOAA Southeast Fisheries Science Center, Stennis Space Center, MS, United States

[8]IPN Centro Interdisciplinario de Ciencias Marinas, La Paz, BCS, México

ABSTRACT

Ocean innovations using sensor, platform and analytic technologies are more readily available for monitoring marine ecosystems. Recent collaborative efforts have demonstrated that sampling technologies can cost-effectively enhance research and survey operations to provide more synoptic, precise and timely scientific information for the sustainability of living marine resources. Reef fish habitats that were once difficult to systematically survey with conventional sampling gear, can now be feasibility monitored with integrated acoustical, optical and environmental technologies, thereby resolving data-limited assessments common to the Caribbean and Gulf region. The connectivity of our marine resources across the various geopolitical jurisdictions in the region requires a collborative pool of international experts to deploy the best practices in statistical survey design, calibrations and operations with technologies for the next generation of integrated survey and ocean observations.

KEYWORDS: Technology, Ecosystem, Survey

Accepted as Poster:

Poster	Matthew	Campbell	Development and Application of Full Spherical Camera Technology for Monitoring Fish
Poster	Violeta	González-Máynez	Mediciones *in situ* de la fuerza de blanco (TS) del calamar gigante *Dosidicus gigas* en el Golfo de California, México

Poster	Uriel	Rubio Rodriguez	Gregarious behavior of the small pelagic fish in the Gulf of California using acoustic methods
Poster	Juliana	Sintura	Seaflower

Development and Application of Full Spherical Camera Technology for Monitoring Fish

Desarrollo y aplicación de tecnología de cámara esférica completa para el seguimiento de peces

Dévelopement et application d'une technologie de caméra entièrement sphérique pour la surveillance des poissons

Matthew Campbell, Ryan Caillouet

NMFS – SEFSC, 3209 Frederic Street, Pascagoula, MS 39567 United States
matthew.d.campbell@noaa.gov

NMFS – SEFSC, 3209 Frederic Street, Pascagoula, MS 39567 United States

ABSTRACT

Visual surveys of fish populations have become an integral part of many fisheries-independent monitoring programs. Typically these surveys consist of a single camera, or stereo pair, recording a small portion of the surrounding area. The video is then post processed to generate species and abundance estimates, most commonly MaxN. While this method provides a number that can be scaled to give a relative abundance index, studies have shown that this method is asymptotically related to true abundance. Results from a spatially explicit individual-based model theorized that by increasing the camera's field of view, MaxN estimates become linear to true abundance and thus more accurately estimate increases in population size. To begin to evaluate this property, several camera systems were tested, ranging from off-the-shelf action camera based systems to a fully custom stereo spherical array. We present information about system performance to guide decision making concerning system selection. We also show preliminary information on the relationship between reduced and spherical view abundance estimates that demonstrate that empirical data supports the relationship demonstrated in the theoretical model.

KEYWORDS: Full spherical, Cameras, Fisheries Independent

Mediciones *in situ* de la fuerza de blanco (TS) del calamar gigante *Dosidicus gigas* en el Golfo de California, México

***In situ* measurements of jumbo squid, *Dosidicus gigas* target strength (TS) in the Gulf of California, México**

Mensuration in situ de l'Index de réflexion (TS) de l'encornet géant, *Dosidicus gigas* dans le Gulf de Californie, Mexique

Violeta González-Máynez[1], Héctor Villalobos[2], Manuel Nevárez-Martínez[3], Juana López-Martínez[1], Melissa Mayorga Martínez[4].

[1]Centro de Investigaciones Biológicas del Noroeste, Unidad Sonora, Campus Guaymas. [2]Instituto Politécnico Nacional – CICIMAR, La Paz, Baja California Sur. [3]Instituto Nacional de Pesca y Acuacultura, Centro Regional de Investigación Pesquera, Guaymas, Sonora. [4]Universidad Veracruzana, Xalapa, Veracruz, México, vmaynez@pg.cibnor.mx

ABSTRACT

La pesquería de calamar gigante *Dosidicus gigas* (D'Orbigny, 1835), representa una fuente importante de ingresos para México, sin embargo la inestabilidad de sus poblaciones dificulta su manejo pesquero. Los métodos acústicos ofrecen observaciones de alta resolución en la columna de agua y son una alternativa para estimar la distribución y abundancia de este recurso. Sin embargo, para realizar una evaluación precisa es necesaria la correcta estimación de la fuerza de blanco (TS) de este organismo. En este trabajo se analizaron tres campañas de prospección (2014-2016) en el Golfo de California donde se utilizó una ecosonda SIMRAD EK60 con dos transductores *split beam* de 38 y 120 kHz con los que se registraron mediciones *in situ* del TS (dB) del calamar gigante. Se muestrearon calamares con poteras hasta 50 m de profundidad usando luz como método de atracción. Se eligieron siete estaciones con las mayores capturas en peso y número de individuos representando una amplia distribución de tallas, además de condiciones calmas durante el muestreo. Se utilizó el programa ESP3 para la selección de objetivos individuales, se calculó el índice N_v para disminuir la probabilidad de ocurrencia de ecos múltiples. Los resultados de los modelos de regresión ajustados son: $TS_{38kHz} = 20\log_{10}(\mathrm{LM}) - 62$ (R^2 = 0.69 , LM = 15-57 cm); $TS_{120kHz} = 20\log_{10}(\mathrm{LM}) - 76.59$ (R^2 = 0.70, LM = 15-57 cm). Estos modelos tienen una diferencia de hasta 11 dB menor con respecto a los modelos publicados para esta misma especie en las mismas frecuencias (Benoit-Bird *et al*., 2008). Nuestros modelos tuvieron mayor semejanza a los publicados para otras especies como *Sthenoteuthis oualaniensis* y *Todarodes pacificus*. El constante movimiento del calamar gigante durante el nado activo genera cambios en el ángulo de insonificación que son la razón más probable de esta gran diferencia.

The giant squid fishery *Dosidicus gigas* (D'Orbigny, 1835), represents an important source of income for Mexico, however the instability of its populations makes fishing management difficult. Acoustic methods offer high resolution observations in the water column and are an alternative to estimate the distribution and abundance of this resource. However, to make an accurate evaluation, a correct estimate of the target strength (TS) of this organism is necessary. In this work, three prospecting campaigns (2014-2016) in the Gulf of California were analyzed where a SIMRAD EK60 echo sounder was used with two split beam transducers of 38 and 120 kHz with which in situ measurements of the TS (dB) of the giant squid were recorded. Squid were sampled with jars up to 50 m deep using light as a method of attraction. Seven stations were chosen with the highest catches in weight and number of individuals representing a wide distribution of sizes, in addition to calm conditions during the sampling. The ESP3 program was used for the selection of individual targets, the N_v index was calculated to decrease the probability of multiple echoes occurring. The results of the adjusted regression models are: $TS_{38kHz} = 20\log_{10}(\mathrm{LM}) - 62$ (R^2 = 0.69, LM = 15-57 cm); $TS_{120kHz} = 20\log_{10}(\mathrm{LM}) - 76.59$ (R^2 = 0.70, LM = 15-57 cm). These models have a difference of up to 11 dB lower with respect to the models published for this same species at the same frequencies (Benoit-Bird et al., 2008). Our models were more similar to those published for other species such as *Sthenoteuthis oualaniensis* and *Todarodes pacificus*. The constant movement of the giant squid during active swimming generates changes in the angle of insonification that are the most likely reason for this large difference.

Gregarious behavior of the small pelagic fish in the Gulf of California using acoustic methods

Caracterización del comportamiento gregario de los peces pelágicos menores en el golfo de California mediante métodos acústicos

Comportement grégaire des petits poissons pélagiques dans le Golfe de Californie en utilisant de méthodes acoustiques

Uriel Rubio Rodriguez[1], Héctor Villalobos Ortiz[2], Manuel O. Nevárez Martínez[3]

[1]Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional Politecnico Nacional El Conchalito La paz baja california sur 23096 México, urubio33@gmail.com

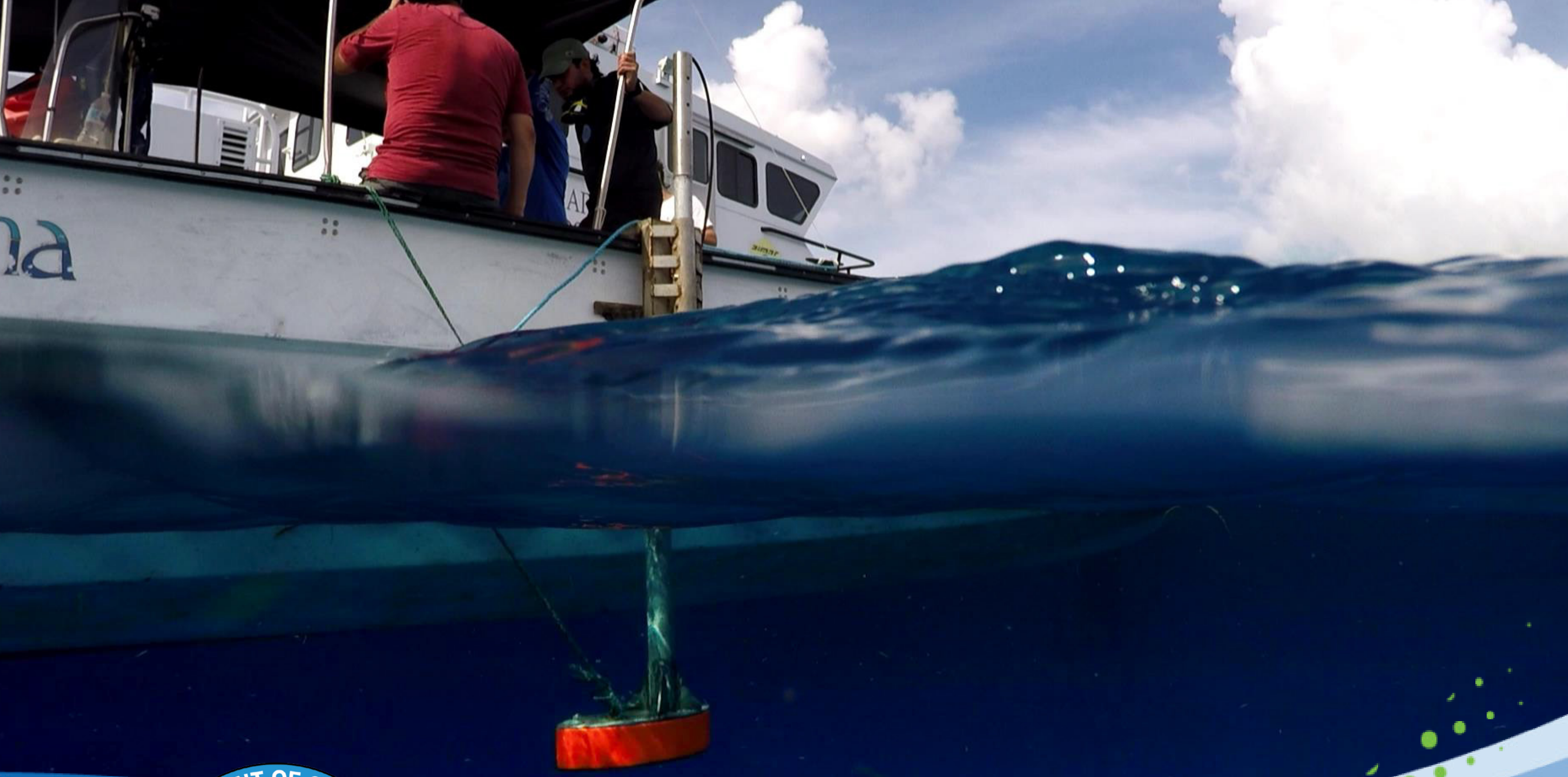
[2]Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional Politecnico Nacional El Conchalito La paz baja california sur 23096 México, hvillalo@ipn.mx

[3]Instituto Nacional de Pesca, CRIAP Unidad Guaymas Col. Cantera Calle Sur No. 20, Guaymas, Sonora 85400 México, manuel.nevarez@inapesca.gob.mx

ABSTRACT

In the Gulf of California (GC), small pelagic fish (sardines, anchovies and mackerels) have a high ecological and economic value. A distinctive feature of these species is their ability to form schools, which can be defined by their size, density, position and location in the water column. The objective of the present work is characterizing its aggregative and dynamic behavior in the water column by analyzing the acoustic information obtained in May and June of 2012 to 2014, and February 2014 and its relationship with the prevailing environmental variables in the GC. A total of 1100 schools were recognized, which were more abundant during 2012 when the net primary productivity values in the area were highest. The importance that the Midriff islands zone (lowest sea surface temperature and highest productivity) represents for the distribution of many species was corroborated, especially for the small pelagic schools, obtaining in this zone the highest number of detections per nautical mile prospected. The significant number of schools detected during the twilights and the night suggest that within the GC the typical dispersal behavior of the small pelagic schools during the night is not fulfilled. This could have favored traditional fishing methods in this area. The moon elevation and the phases appear to have an influence in the schooling behavior of the small pelagic species, reflected in a greater depth at the time of the moon's appearance and a greater proximity to the surface during full moon nights; this behavior could be motivated by a high presence of zooplankton prey in shallow layers during full moon nights.

KEYWORDS: schools, vertical distribution, Midriff islands region



U.S. Secretary of Commerce
Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, PhD, Acting Under Secretary
for Oceans and Atmosphere

National Marine Fisheries Service
Christopher W. Oliver, Assistant Administrator
for Fisheries

www.fisheries.noaa.gov

OFFICIAL BUSINESS

National Marine Fisheries Service
1315 East West Highway, SSMC3, F/ST
Silver Spring, MD 20910