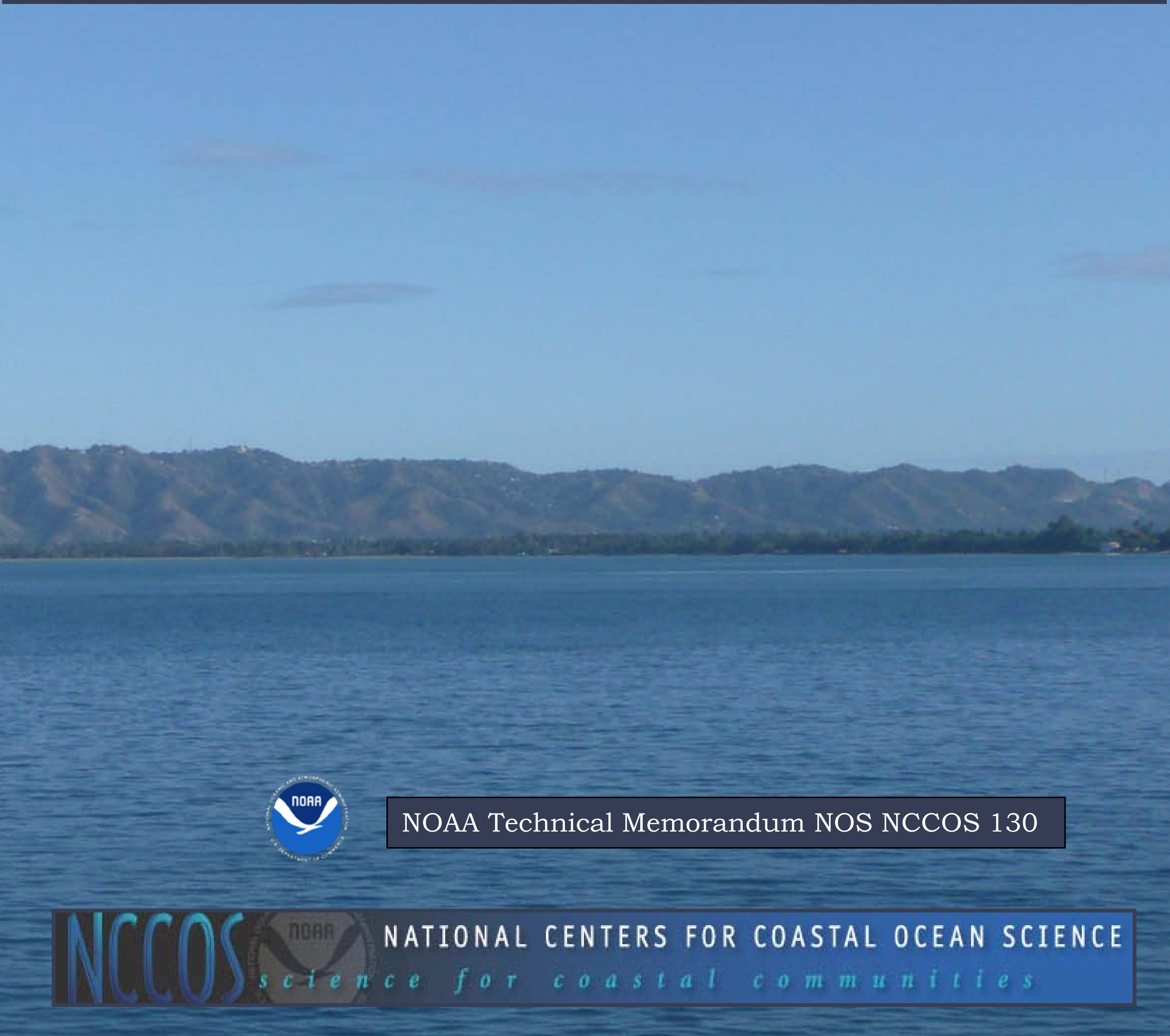
Integration of fisheries acoustics surveys and bathymetric mapping to characterize midwater-seafloor habitats of US Virgin Islands and Puerto Rico (2008–2010)



NOAA Technical Memorandum NOS NCCOS 130

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Acknowledgements

We appreciate the contribution of the officers and crew of the NOAA ship *Nancy Foster*. They provided safe sailing and many hours of diving and engineering support to make these deployments possible. Lance Horn and Glenn Taylor of NOAA's Undersea Research Center at the University of North Carolina Wilmington provided ROV and DIDSON support. Len Balthis provided programming support for processing the acoustics data. Stephen Roth reviewed and documented ROV video data collected in 2010. Special thanks to Len Balthis, Peter Etnoyer and Todd Kellison for their helpful review of this document.

Citation for this Report

Kracker, L.M., J.C. Taylor, E. F. Ebert, T.A. Battista, and C. Menza. 2011. Integration of fisheries acoustics surveys and bathymetric mapping to characterize midwater-seafloor habitats of US Virgin Islands and Puerto Rico (2008–2010). NOAA Technical Memorandum NOS NCCOS 130. 44 pp.

Integration of fisheries acoustics surveys and bathymetric mapping to characterize midwater-seafloor habitats of US Virgin Islands and Puerto Rico (2008–2010)

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NOAA Technical Memorandum NOS NCCOS 130

May 2011

United States Department of Commerce	National Oceanic and Atmospheric Administration	National Ocean Service
Gary Locke Secretary	Jane Lubchenco Administrator	David Kennedy Assistant Administrator

Executive Summary

NOAA's Coral Reef Conservation program (CRCP) develops coral reef management priorities by bringing together various partners to better understand threats to coral reef ecosystems with the goal of conserving, protecting and restoring these resources. Place-based and ecosystem-based management approaches employed by CRCP require that spatially explicit information about benthic habitats and fish utilization are available to characterize coral reef ecosystems and set conservation priorities. To accomplish this, seafloor habitat mapping of coral reefs around the U.S. Virgin Islands (USVI) and Puerto Rico has been ongoing since 2004. In 2008, fishery acoustics surveys were added to NOAA survey missions in the USVI and Puerto Rico to assess fish distribution and abundance in relation to benthic habitats in high priority conservation areas.

NOAA's National Centers for Coastal Ocean Science (NCCOS) have developed fisheries acoustics survey capabilities onboard the NOAA ship *Nancy Foster* to complement the CRCP seafloor habitat mapping effort spearheaded by the Center for Coastal Monitoring and Assessment Biogeography Branch (CCMA-BB). The integration of these activities has evolved on the *Nancy Foster* over the three years summarized in this report. A strategy for improved operations and products has emerged over that time. Not only has the concurrent operation of multibeam and fisheries acoustics surveys been beneficial in terms of optimizing ship time and resources, this joint effort has advanced an integrated approach to characterizing bottom and mid-water habitats and the fishes associated with them.

CCMA conducts multibeam surveys to systematically map and characterize coral reef ecosystems, resulting in products such as high resolution bathymetric maps, backscatter information, and benthic habitat classification maps. These products focus on benthic features and live bottom habitats associated with them. NCCOS Centers (the Center for Coastal Fisheries and Habitat Research and the Center for Coastal Environmental Health and Biomolecular Research) characterize coral reef ecosystems by using fisheries acoustics methods to capture biological information through the entire water column. Spatially-explicit information on marine resources derived from fisheries acoustics surveys, such as maps of fish density, supports marine spatial planning strategies and decision making by providing a biological metric for evaluating coral reef ecosystems and assessing impacts from pollution, fishing pressure, and climate change.

Data from fisheries acoustics surveys address management needs by providing a measure of biomass in management areas, detecting spatial and temporal responses in distribution relative to natural and anthropogenic impacts, and identifying hotspots that support high fish abundance or fish aggregations. Fisheries acoustics surveys conducted alongside multibeam mapping efforts inherently couple water column data with information on benthic habitats and provide information on the heterogeneity of both benthic habitats and biota in the water column. Building on this information serves to inform resource managers regarding how fishes are organized around habitat structure and the scale at which these relationships are important. Where resource managers require place-based assessments regarding the location of critical habitats along with high abundances of fish, concurrent multibeam and fisheries acoustics surveys serve as an important tool for characterizing and prioritizing coral reef ecosystems.

This report summarizes the evolution of fisheries acoustics surveys onboard the NOAA ship *Nancy Foster* from 2008 to 2010, in conjunction with multibeam data collection, aimed at characterizing benthic and mid-water habitats in high priority conservation areas around the USVI and Puerto Rico. It also serves as a resource for the continued development of consistent data products derived from acoustic surveys. By focusing on the activities of 2010, this report highlights the progress made to date and illustrates the potential application of fisheries data derived from acoustic surveys to the management of coral reef ecosystems.

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1. Introduction

Through NOAA's Coral Reef Conservation Program, the Center for Coastal Monitoring and Assessment (CCMA) Biogeography Branch has conducted surveys on board the NOAA ship *Nancy Foster* since 2004 as part of an ongoing effort to produce comprehensive digital coral reef ecosystem maps for all U.S. States, Territories and Commonwealths. The primary objective of CCMA's benthic habitat mapping effort is to collect high resolution multibeam bathymetric and acoustic backscatter data to produce accurate information on marine resources in high priority conservation areas in support of coral reef research, monitoring, and management needs. This effort focuses on bathymetry and the classification of benthic habitats, as well as the utilization of these habitats by important marine species.

Methods for quantifying and classifying benthic habitats have been successfully developed and implemented in Puerto Rico and U.S. Caribbean (Kendall et al.2001, Costa et al.2009). In addition, long term monitoring of reef fishes conducted throughout the USVI documented the changing trophic structure of reef fish assemblages. An increase in herbivorous fish and macroalgae, a decline in large predators such as groupers and snappers, and the decimation of some spawning aggregations has resulted from overfishing in spite of existing management strategies (Friedlander and Beets 2008). Recently, priority areas have been established through the Coral Reef Conservation Program and CCMA in collaboration with the Caribbean Fishery Management Council and other partners to conduct additional mapping to better understand benthic resources and species utilization of these habitats.

Data from fisheries acoustic surveys using spilt-beam echo-sounding systems support these resource management needs and offer several advantages over diver based surveys and other methods of assessing fisheries resources. For instance, while monitoring programs that rely on diving to census fish are valuable in providing a high level of detail on fish and invertebrate communities, as well as monitoring trends in fish communities at specific locations, there are limitations in terms of level of effort required and the area that can be covered. Ship-board fisheries acoustics surveys provide information on abundance and location of individual fish and fish aggregations throughout the water column, from small planktivores to large predators, allowing for estimation of fish density at nearly any spatial resolution. This results in spatially-explicit data on fish distribution at resolutions and extents comparable to habitat maps, allowing for examination of benthic features as a driver of reef fish habitat use (Ross and Quattrini 2007). Furthermore, this sampling strategy is non-destructive compared to other methods such as trawling.

One limitation of acoustic surveys is the lack of explicit information on fish species. However, in many cases, size-specific (rather than species-specific) data may be sufficient to address management needs such as increasing biomass in management areas and detecting spatial and temporal responses in distribution relative to natural and anthropogenic impacts. Size-specific data can also be used to identify functional groups such as mature snapper-grouper and rule out smaller species. By mapping the spatial distribution of fish across broad areas, hotspots supporting high abundance or fish aggregations can be identified and assessed for their biological value. Fisheries acoustics surveys conducted alongside multibeam mapping efforts inherently couple water column data with information on benthic habitats and provide information on the heterogeneity of both benthic habitats and biota in the water column. Building on this information serves to inform resource managers regarding physical and biological relationships within coral reef ecosystems, how fishes are organized around habitat structure, and the scale at which these relationships are important (Kracker et al.2008). In addition, the changing temporal and spatial patterns indicative of fish behavior can be observed, for instance, as fish move off the reef or up into the water column at night and return during the day. Where resource managers require place-based assessments regarding the location of critical habitats and high abundance of fish, concurrent multibeam and fisheries acoustics surveys serve as an important tool for characterizing and prioritizing coral reef ecosystems.

This report details the evolution of surveys using spilt-beam echo-sounding systems onboard the NOAA ship *Nancy Foster* in conjunction with multibeam data collection aimed at characterizing benthic and mid-water habitats in high-priority conservation areas of the USVI and Puerto Rico (Table 1). Specifically, this document describes fisheries acoustics surveys conducted from 2008 to 2010, presents data products related to fisheries resources that support the characterization of marine habitats, and outlines procedures for data collection and processing of fisheries information derived from acoustic surveys (See also Rudstam et al.2009 and Simmonds and MacLennan 2005).

Table 1.
Cruise numbers, dates and locations of joint fisheries acoustics and multibeam mapping missions on the NOAA ship *Nancy Foster*
--
NF-08-04-USVI
February 25-March 8, 2008
Tourmaline Bank, Mona Is., PR
--
NF-08-06-SEAS
March 26-April 4, 2008
Vieques, PR

NF-09-01-USVI
March 21-April 3, 2009
El Seco, PR

NF-10-03-USVI
March 18-April 6, 2010
St. Thomas Virgin Passage
St. John shelf

1.1 NOAA's Coral Reef Conservation Program benthic habitat mapping

NOAA works in partnership with the Caribbean Fisheries Management Council, the University of the Virgin Islands, the USVI Department of Fish and Wildlife, and the National Park Service to identify and protect coral reef ecosystems throughout the U.S. Caribbean, including important fish aggregation sites subject to intense fishing pressure. Much of this effort has focused on utilizing multibeam data to map and classify benthic habitats. In 2008, CCMA's coral reef benthic habitat mapping activities were expanded to include fisheries acoustics surveys as a technique for quantifying biotic resources associated with coral reef habitats and associated waters within coral reef ecosystems.

Priority coral reef ecosystems, including historic and candidate fish aggregation sites, identified for multibeam and fisheries acoustics mapping (Figure 1) consist of waters west of Puerto Rico around Tourmaline Bank and Mona Island (2008), nearshore habitats around Vieques Island (2008) and El Seco (2009) off the east coast of Puerto Rico, and Virgin Passage south of St. Thomas and St. John shelf (2010). From 2008-2010, fisheries acoustics surveys were conducted simultaneously with multibeam operations to map the abundance and distribution of biomass in the entire water column in these priority areas. The Center for Coastal Fisheries and Habitat Research (CCFHR) and the Center for Coastal Environmental Health and Biomolecular Research

(CCEHBR) have been instrumental in developing the fisheries acoustics component of these surveys.

Multibeam data acquisition capabilities for benthic mapping have become an integral component of the NOAA ship *Nancy Foster*. A Kongsberg/Simrad EM1002 multibeam sonar is permanently hull-mounted. The EM1002 is a 95kHz system with a 150^o swath comprised of 111 individual 2^o beams. In 2009 and 2010, a Reson 7125 multibeam 200 and 400 kHz sonar with 512 individual beams and 128^o swath was deployed to conduct shallow water mapping. On all such missions, an ROV equipped with video and high resolution still cameras was deployed using a modified stratified random sampling approach to validate the benthic habitat types derived from the multibeam data. These survey data are processed to produce high resolution bathymetry, backscatter and habitat classification maps (Costa et al.2009). Data and documentation are available at: http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/overview.html

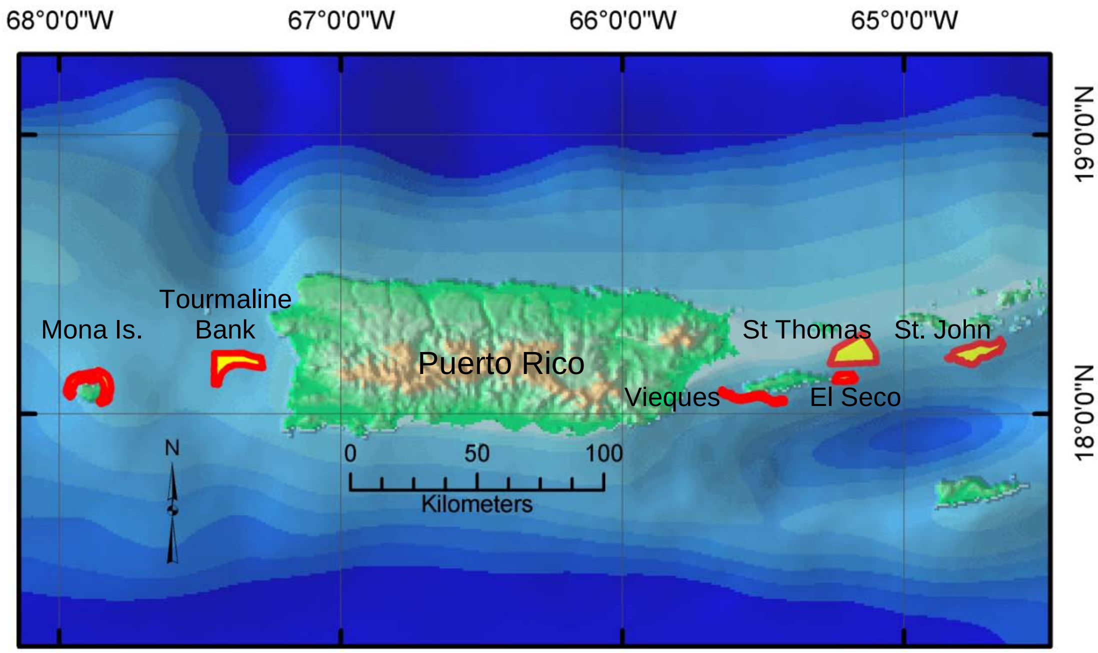


Figure 1. Priority benthic habitats mapped in 2008 (Mona Island, Tourmaline Bank, Vieques), 2009 (El Seco) and 2010 (St. Thomas, St. John).

1.2 Fisheries acoustics surveys of water column and seafloor habitats

Fisheries acoustics surveys were conducted in waters around Puerto Rico and the USVI from the NOAA ship *Nancy Foster* using hull mounted split-beam echosounders. A Biosonics 120 kHz split-beam system was deployed at Tourmaline Bank and Mona Island in 2008. A Simrad EK-60 120 kHz system was used at Vieques in 2008 and El Seco in 2009. A two frequency (38/120 kHz) Simrad EK-60 system was used for St. Thomas and St. John priority mapping areas in 2010. These operations were run concurrently with multibeam bottom mapping and ROV ground truthing activities. Additionally, in 2010, two survey days were dedicated to exploring specific locations identified as historic fish spawning sites. Results from acoustic surveys were viewed as echograms that capture information on fish size and spatial distribution within the water column along multibeam transects (Figure 2). Fish aggregations were also detected and quantified based on the echogram.

Within the survey area, the crepuscular period was of particular interest in waters that are 20-40m deep since there was a high probability of occurrence of spawning aggregations of yellowfin grouper (*Mycteroperca venenosa*), tiger grouper (*Mycterperca tigris*), and red hind (*Epinephelus guttatus*). Yellowfin grouper spawning aggregations may occur at a depth of approximately 25m at the shelf break one half hour after sunset (Michelle Scharer pers comm. Feb 2008). Spawning aggregations of tiger grouper have been recorded at Vieques, east of Puerto Rico since the late 1980's (Sadovy et al.1994). In 1991, aggregations were observed a few days before full moon and remained for up to a week after full moon. Red hind are known to aggregate along the southwest coast of Puerto Rico at depths of 20-30m around full moon, typically in January, February or March (Shapiro et al.1993). Aggregations that are presumed to consist of spawning red hind have been detected using hydroacoustics around the coast of Puerto Rico and Mona Island (Johnston et al.2006). This interpretation was based on the unique shape of the aggregation (vertically stacked, coherent schools), near-shelf distribution, and timing around full moon. Shapiro et al.(1993), on the other hand, describes the spatial structure of red hind spawning aggregations based on diver observations in 1986 and 1987 as primarily horizontal, two-dimensional small clusters of fish.

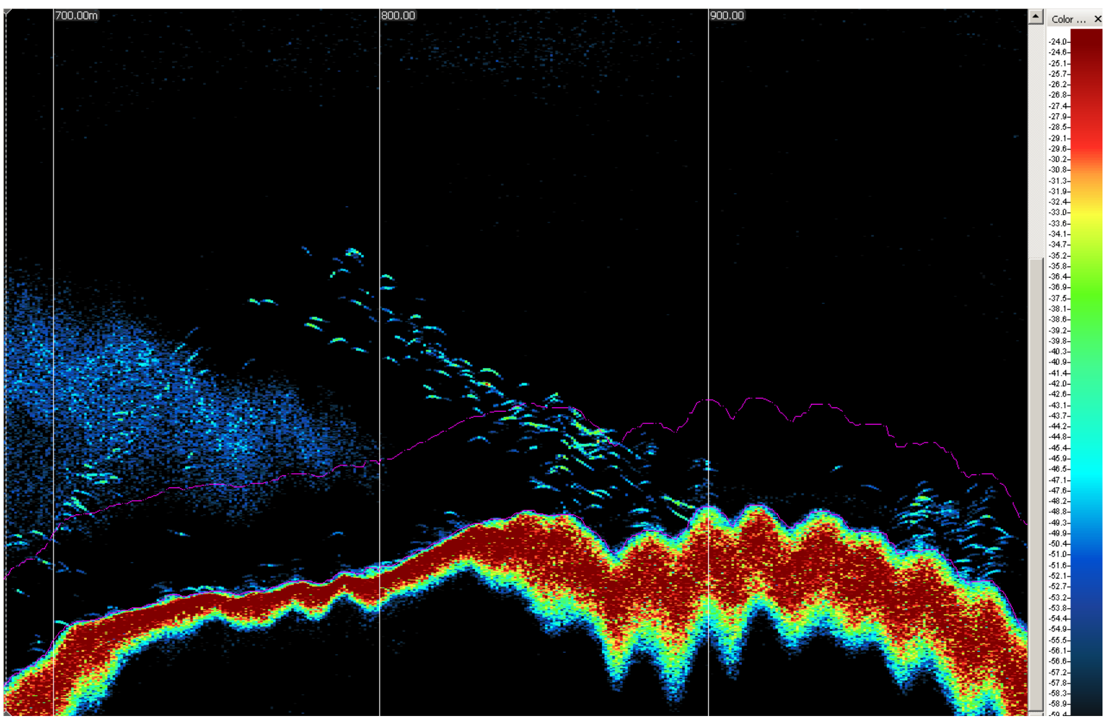


Figure 2. Echogram depicting water column features detected by acoustic surveys, including scattering of zooplankton and aggregations of fish. The thick red line indicates the bottom. The color scale represents the strength of the returned echo in decibels (dB) with red indicating a strong return and blue a weaker return.

In 2008, analysis of acoustic survey data focused on depths down to 100m to detect possible spawning aggregations at Tourmaline Bank and off the west coast of Mona Island. Data were collected using a Biosonics split-beam 120 kHz system. Analysis included estimates of biomass and fish density for each 100m segment along survey transects. Fish density estimates were binned along 100m segments as a common sampling unit for all three years for comparison and to ensure that a sufficient number of fish targets were included to constitute a valid sample size. In addition, echograms were reviewed for features that may be indicative of spawning or schooling aggregations.

Similar surveys were conducted along the south shore of Vieques in 2008. Surveys in 2009 covered waters around El Seco. Acoustic data were collected aboard the NOAA Ship *Nancy Foster* using a Simrad 120 kHz splitbeam transducer. Data were collected simultaneously with multibeam data collection. Analysis of the fisheries acoustics data from 2008 and 2009 included mapping of fish densities by size class along 100m segments of survey transects.

In 2010, acoustic surveys were conducted using a hull mounted sled with two EK-60 spilt-beam transducers (38 and 120 kHz). A Reson 7125 multibeam 200 and 400 kHz sonar was also attached to the sled. Split-beam transects were analyzed for fish density, the spatial distribution of fish sizes across the survey area, and differences in spatial patterns from day to night. In addition, ship time was dedicated to exploring potential fish spawning sites at Grammanik Bank and Tampo, both potential yellowfin grouper spawning sites. Maps of fish densities and temporal changes at these locations were mapped.

Fisheries acoustics survey data were analyzed using Myriax Echoview software. Echograms were produced based on the raw variables: backscatter of pings (Sv), angular position of pings, and target strength (TS) of pings (Table 2). Split beam echosounding systems are capable of determining the location of single targets within the beam. The amount of time is takes for a sonar ping to reach a target in the water column and return an echo to the transducer is indicative of the depth of the target. The strength of the returned echo is related to the size of the target. Since the echo returns from off axis targets are diminished compared to targets located directly on the center axis of the beam, an off-axis beam angle compensation algorithm uses the angular position echogram to provide more accurate estimates of target strength, measured in decibels (dB). Therefore, each fish detected by the splitbeam sonar has three spatial dimensions (x, y, depth) calculated relative to the acoustic beam and in real-world coordinates when coupled with the ship's navigation system, as well as an associated target strength relative to fish size.

Table 2. Description of echograms based on raw variables collected
Myriax Echoview 4.6. Hobart, Tasmania.

Sv echogram - Each data point on an Sv echogram represents a volume backscattering coefficient measured in decibels referenced to 1 m^2/m^3. It is possible to integrate Sv data. Indeed Sv data are considered by many to have meaning only when they are integrated.

Angular position echogram - Each data point on an angular position echogram represents a position within the transducer beam, measured by a pair of angles, one in the direction of the minor axis, and the other in the direction of the major axis of the transducer.

TS echogram - Each data point on a TS echogram represents a Target Strength measured in decibels referenced to $1m^2$.

Single target echograms are distinct from ordinary echograms in that they do not consist of a grid of data points. Pings are displayed left to right as usual, but each single target in the data file (or detected by Echoview) is displayed at its depth.

Post processing of data involved applying a bottom detection algorithm to the echo return to create a line representing the sea floor. Edits were made to the bottom detection line where it was necessary to better define the separation between bottom and fish returns to ensure that the bottom signature was not included in the water column analysis and fish targets were not associated with the bottom signal inadvertently. Bad data regions (for example, when ship speeds were too fast or too slow, or ship turns created bubbles in the water column) were identified and excluded from analysis. 'Virtual' and fixed lines were created at various depth strata to partition the water column horizontally. An analysis grid was applied to partition the water column vertically, every 100m along the transect. Offsets were included to account for the configuration of transducers and GPS relative to the ship. These settings were saved in a template to ensure that all processing parameters were applied consistently. The variables created in Echoview (Figure 3) and the data processing procedures (Figure 4) are outlined here. Fish tracks detected within the single target echogram (Figure 5) form the basis of fish density maps. Target strength is the measure of the reflected acoustic energy from the transmitted pulse or ping, is proportional to the size of the fish, and relates primarily to the size and morphology of the fish's swim bladder. The equation used here to convert target strength to fish length was based on the general equation of Love (1977): *Total Length (cm) = 10^((TS_mean+64.0035)/19.2)*

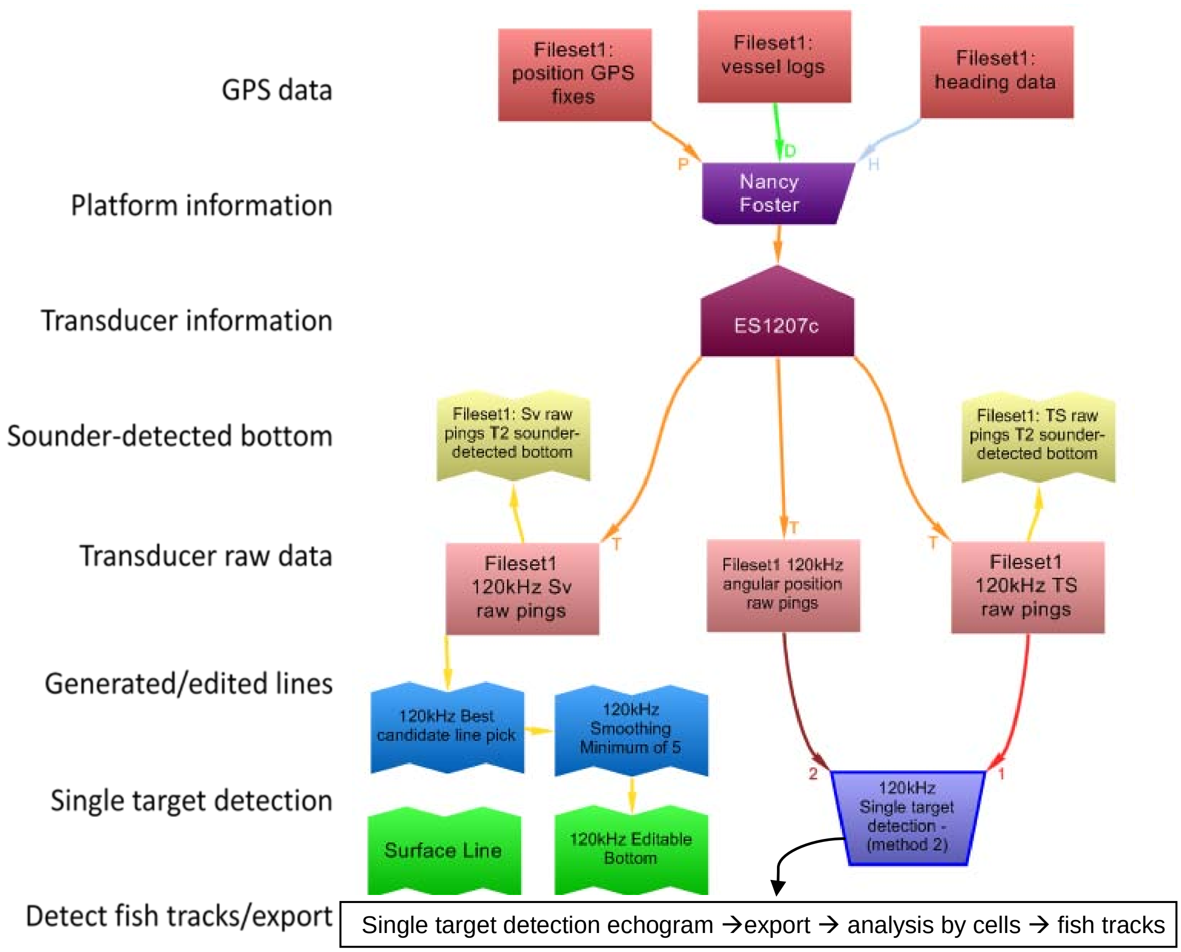


Figure 3. Template that contains properties for platform, sensors, echograms, lines and virtual variables in Echoview.

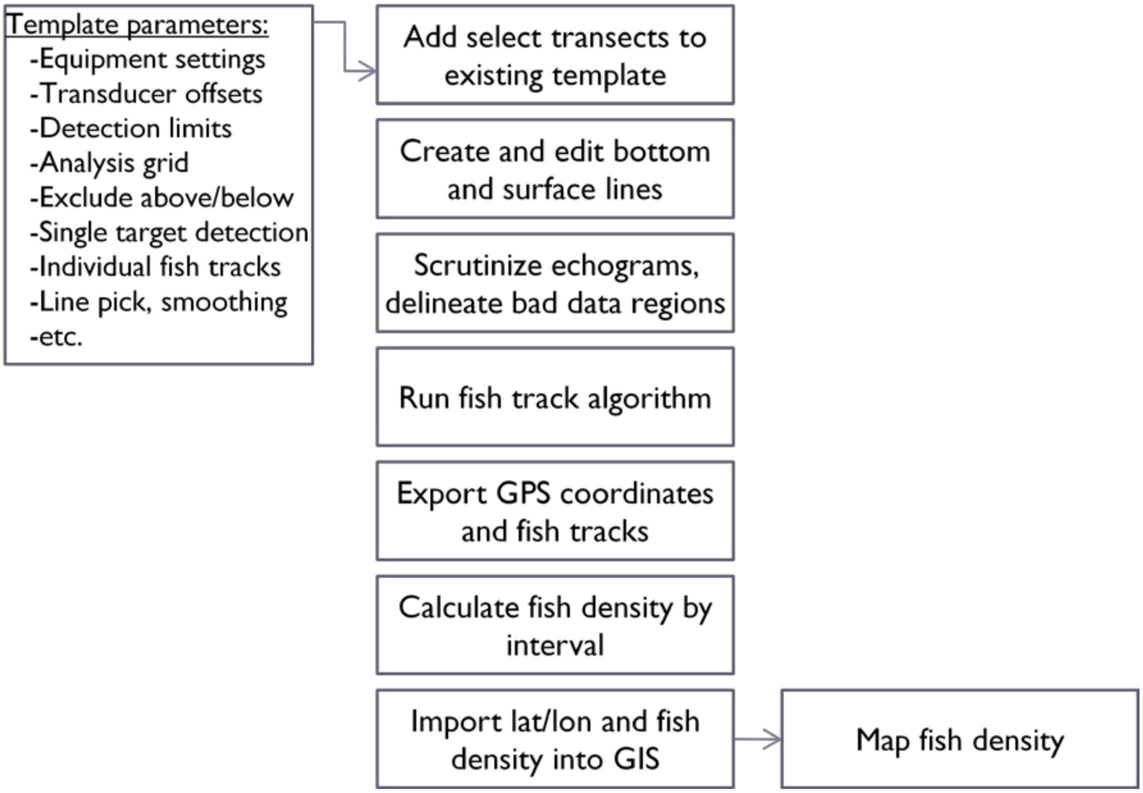


Figure 4. Flow diagram showing data processing steps from Echoview to ArcGIS.

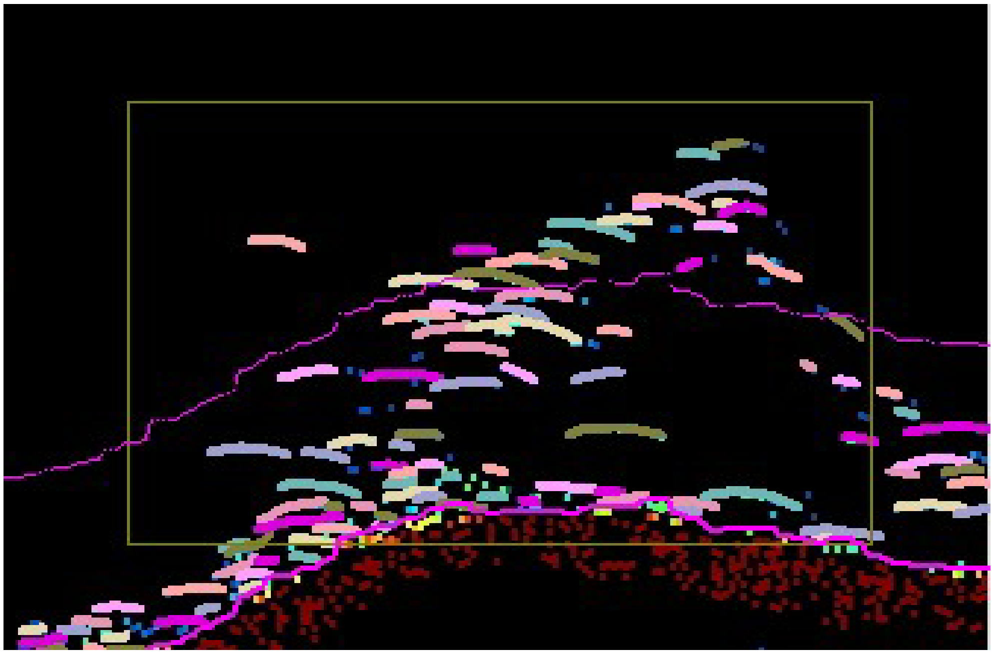


Figure 5. Result of bottom detection, virtual line 5m from bottom, and fish tracking algorithm applied to mid-water targets.

1.3 Integration of multibeam bathymetric mapping and fisheries acoustics

The mission plan for these surveys focused first on multibeam mapping as a priority in terms of ship operations, with fisheries acoustics intended to complement that effort. Therefore, fisheries acoustics survey data were collected along planned night time multibeam lines. The spacing of multibeam tracklines is dependent on water depth and beam width. Generally, tracklines are run parallel to bathymetric contours to provide full coverage for bottom mapping. By comparison, swath coverage of the acoustic beam is only 5% of multibeam coverage. Surveys are typically conducted at ship speeds of 4-10 knots.

Typically, daily ship operations for multibeam surveys utilize daytime hours for ROV transects to ground truth the multibeam data. While fisheries acoustics data can be collected during ROV transects, these surveys are conducted at very slow speeds (less than 1 knot) which are not conducive to acoustic data collection unless a truly stationary deployment is designed. However, observations from ROV operations are useful for determining fish species within the survey area.

The following section describes the methods and results of fisheries acoustics surveys conducted in 2008, 2009 and 2010, concurrent with multibeam mapping efforts.

2. Fisheries acoustics surveys

2.1 Western Puerto Rico (NF-08-04-USVI)

In 2008, the waters around Mona Island and Tourmaline Bank were identified as priority areas for benthic habitat mapping (Figure 6). Acoustic surveys were conducted to characterize potential yellowfin grouper, tiger grouper and red hind spawning sites.

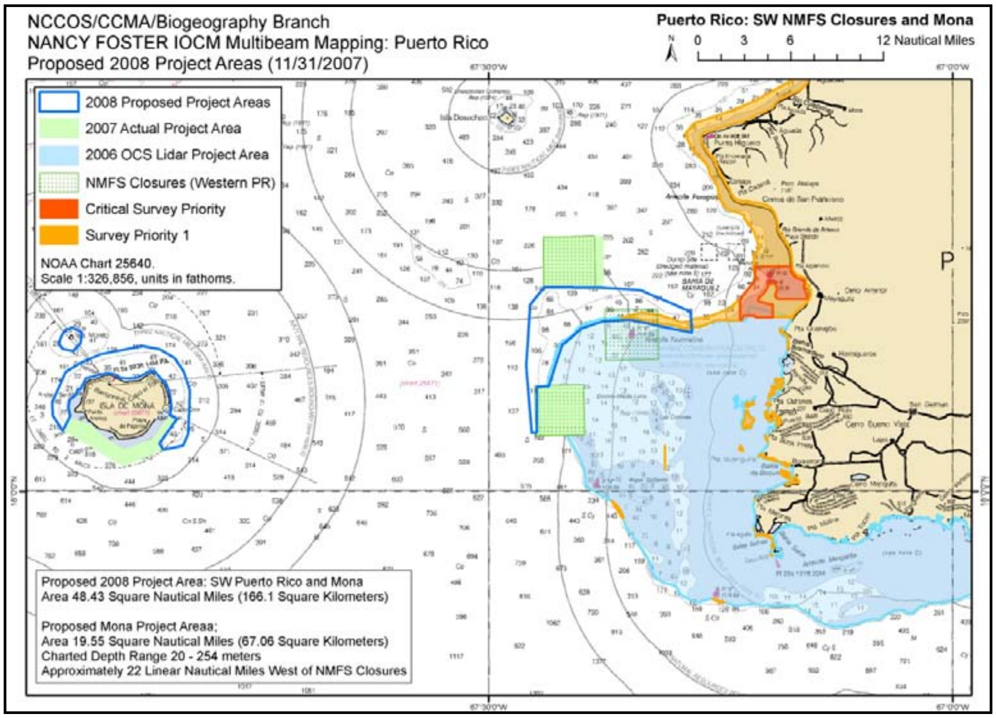


Figure 6. Western Puerto Rico priority mapping areas (blue outline) as identified in the NF-08-04-USVI Cruise Instructions.

2.1.1 Methods

A 120 kHz Biosonics split beam transducer was mounted on the hull of the ship and transmitted at 6 pings per second with a pulse width of 0.4 msec to a depth of 100m (see Appendix A for details on system configuration). Acoustic survey lines followed multibeam track lines.

Transects were reviewed to identify bad data regions. A threshold of -70dB was used to examine the raw data variable Sv (volume backscattering) while synchronized with the cruise track. The threshold for viewing single target detection echograms was set at -55dB while each transect was examined for evidence of red hind columns (Johnston et al.2006) and other features indicative of spawning aggregations. Volume backscattering was echo-integrated for each 100m segment of transect and at various depth intervals. Mean volume backscatter (Sv_mean) and individual fish tracks were exported for further analysis and mapping.

After reviewing all fisheries acoustics transects for appropriate depth ranges, time frames and continuous, reliable data, survey transects were chosen for further analysis (Table 3). Three nights of transecting at Tourmaline Bank (February 26-27; February 29-March 1; March 1-2) spanned roughly the same time period and collectively provided extensive coverage of Tourmaline Bank (Figure 7, right). Due to an equipment failure on March 3, 2008, only one hour of useable data from Mona Island was collected and analyzed (Figure 7, left). A full moon occurred on February 20, 2008. Sunset was at 1830 on February 29, 2008.

Table 3. Fisheries acoustics surveys analyzed 2008

Location	Start date	End date	Start time	End time	Approx. duration (hr)	Survey length (nmi)
Tourmaline Bank_1	2/26/08	2/27/08	16:30	05:45	11	70
Tourmaline Bank_2	2/29/08	3/1/08	23:00	07:30	8.5	46.5
Tourmaline Bank_3	3/1/08	3/2/08	23:00	05:00	6	31
Mona Island	3/3/08	3/3/08	20:45	21:35	0.8	6

Mona Island | Tourmaline Bank

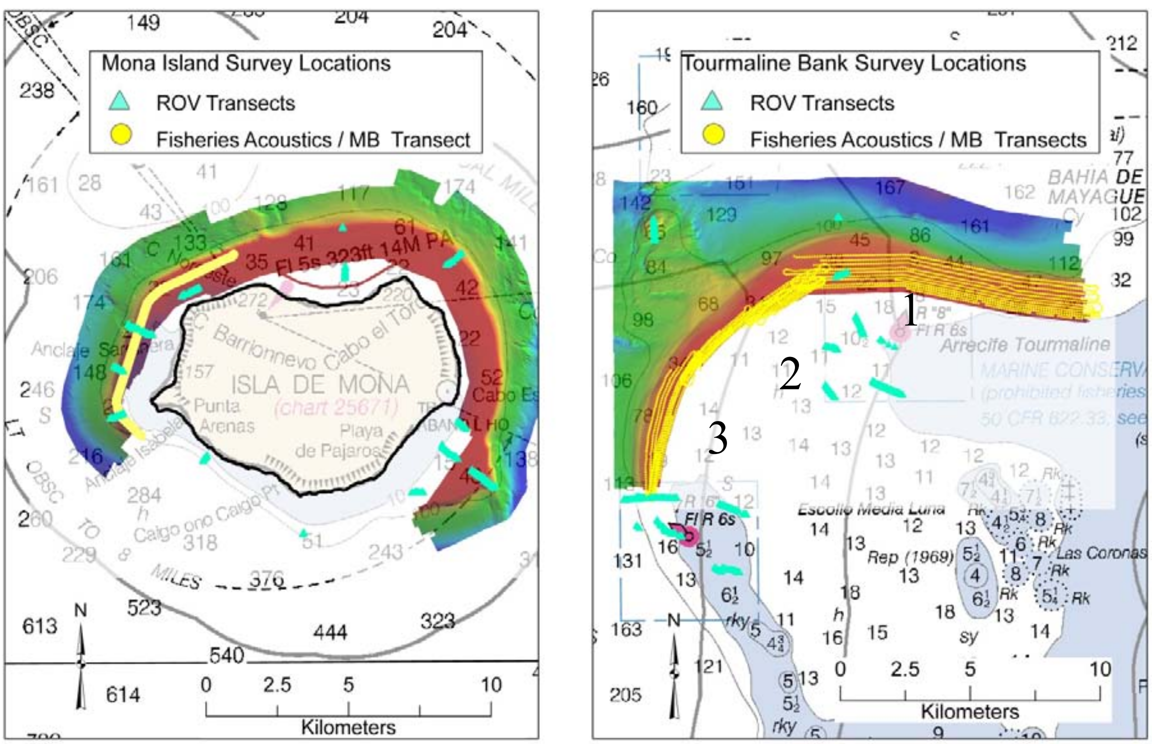


Figure 7. Maps of Mona Island and Tourmaline Bank showing simultaneous fisheries acoustics and multibeam transects (yellow), as well as ROV transects (blue). Survey track lines are overlaid on NOAA nautical charts, along with bathymetric data. Unless otherwise noted, the bathymetric color scale used in this document shows warmer colors for shallower depths. http://ccma.nos.noaa.gov/products/biogeography/benthic/htm/data.htm

2.1.2 Analysis and products

Acoustic backscatter data were analyzed in Echoview using echo integration based on the Sv echogram. In addition, single target detection algorithms, using both the TS split-beam and angular position echograms, were applied to generate fish tracks. Water column backscatter data were integrated using a minimum Sv threshold of -66dB and an uncompensated target strength threshold of -60dB (Rudstram et al.2009), then analyzed for each 100m segment of transect. For fish track detection, a threshold of -50dB was used to eliminate very small fish and noise. Various depth strata grids are used to partition the water column. For Tourmaline Bank, transect data were summarized at 100m intervals along the transect for various depth strata. In addition, targets were divided into size classes and mapped.

Information derived from acoustic surveys conducted at Mona Island and Tourmaline Bank:

- Interpolated maps of mean volume backscatter integrated through the water column, inclusive of 20m below the surface to the bottom, for each 100m section of transect at Tourmaline Bank (Figure 8). An interpolated surface resulting from kriging depicts the distribution of biomass as a continuous surface. Darker areas indicate higher estimates of biomass. Geostatistical approaches can be helpful in further defining the patchy nature of fish distributions depending on spacing between transects and the size of the aggregations being targeted (Taylor et al.2006).
- Fish density (fish/100m^2) at Tourmaline Bank based on single target detection (Figure 9). This map of fish density illustrates the spatial distribution of fish in the water column from 10m below the surface to the bottom with mean target strength > -50dB.
- Location of small (<11cm), medium (11-29cm), and large fish (>29cm) at Tourmaline Bank based on single target detection from 10m below surface to the bottom (Figure 10). The distribution of fish by size indicates that small and medium size fish are distributed throughout the survey area, whereas, large fish are found at fewer, specific locations.
- Potential spawning aggregations and other water column features. A qualitative visual examination of echograms from Mona Island and Tourmaline Bank indicate variation in marine seascapes with location and time of day. While some features within the water column were notable, there were no features that had definitive characteristics resembling those expected from spawning aggregations. However, the configuration of fishes in the water column and the spatial characteristics that result from various schooling, dispersion, or refuge behaviors may have ecological and bioenergetic implications (Kracker 2004) and may be indicative of the association between biomass and benthic features or habitat types (Kracker et al.2008).

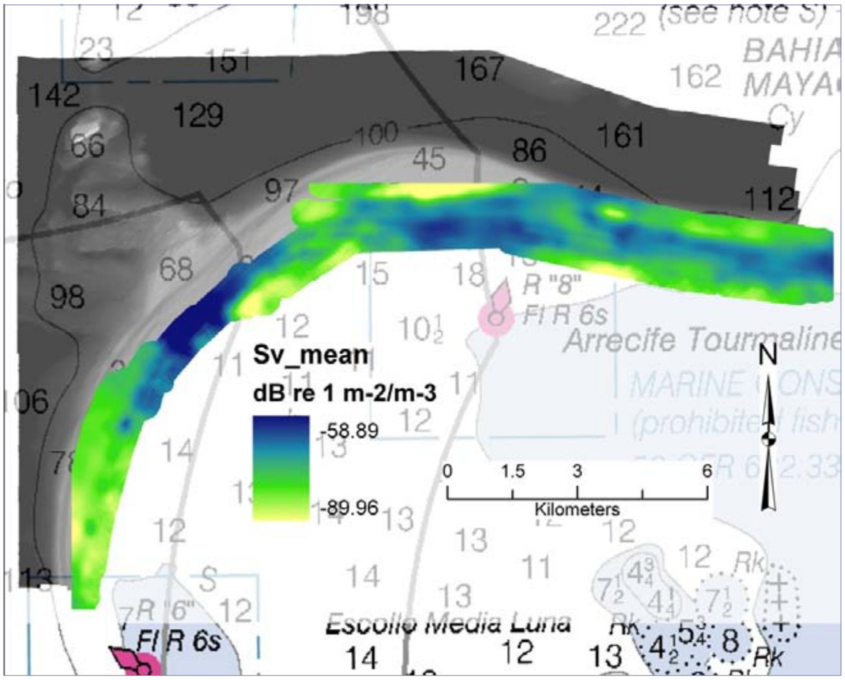


Figure 8. Mean volume backscatter (Sv_mean) is proportional to biomass. Sv_mean was integrated at 100m intervals and interpolated across the survey area at Tourmaline Bank to depict the distribution of biomass in the water column from 20m below surface to the bottom. [Ordinary kriging, exponential variogram model, lags = 12, lag size = 400m, nugget = 24.4882; range = 3567m, mean std error = 0.00028, RMSE = 0.9728].

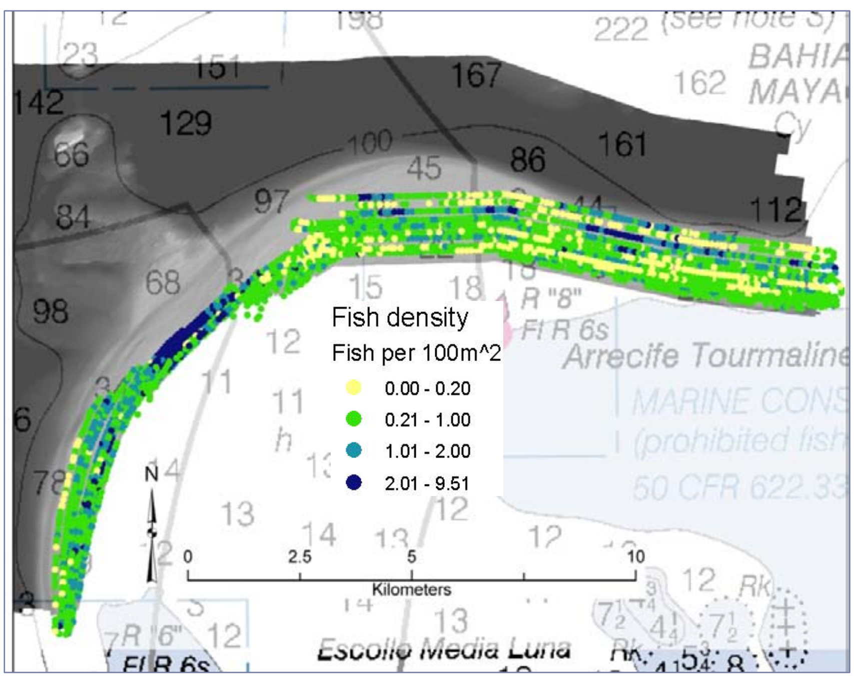


Figure 9. Fish density (fish/100m^2) at Tourmaline Bank based on single target detection where target strength > -50dB from 10m below surface to the bottom.

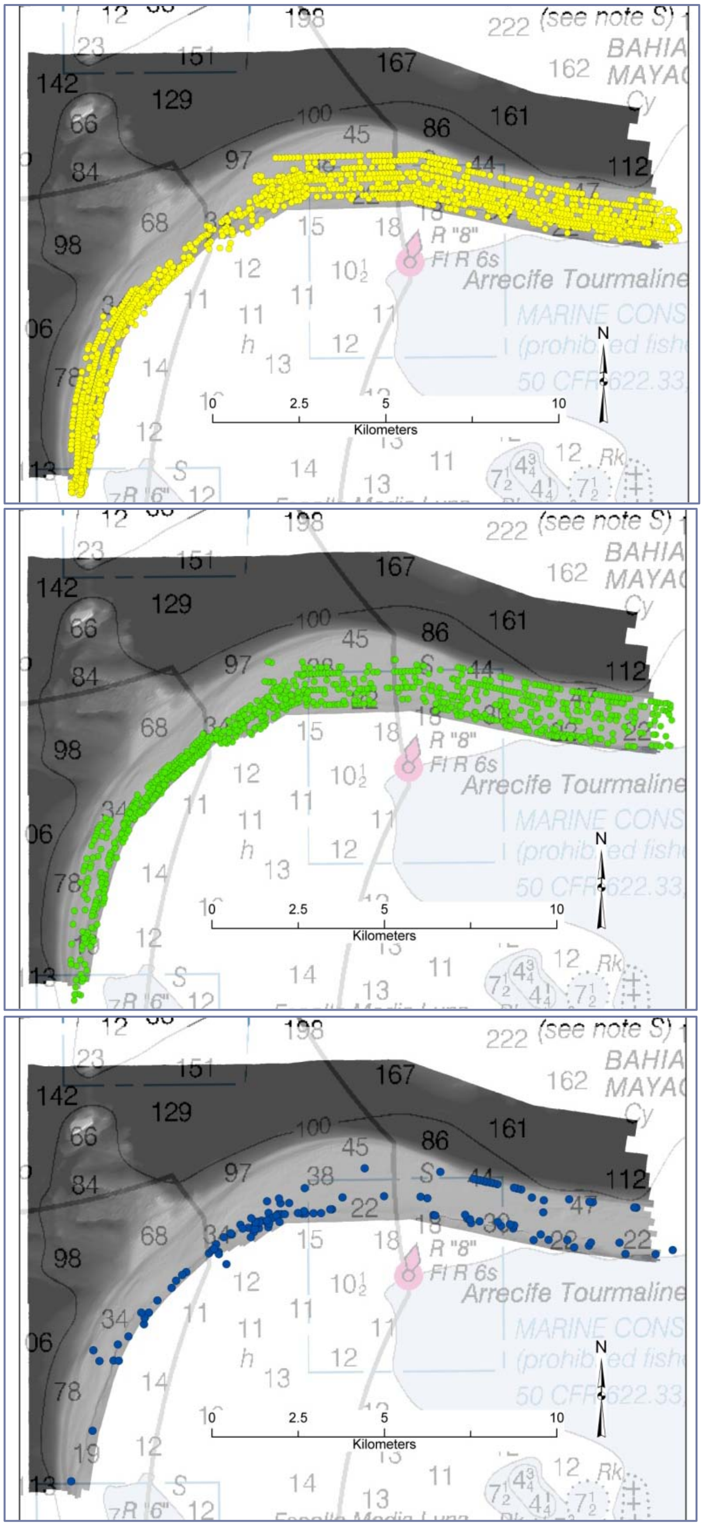


Figure 10. Location of small (< 11cm, top), medium (11-29cm, middle), and large fish (> 29cm, bottom) at Tourmaline Bank based on single target detection from 10m below the surface to the bottom. Love equation (1977) for target strength-length relationship was used to estimate fish size.

2.2 Vieques and El Seco, Puerto Rico (NF-08-06-SEAS, NF-09-01-USVI)

In 2008 and 2009, areas around Vieques were identified as priority areas for benthic habitat mapping based on historic spawning sites and the location of the Red Hind Conservation Area (Figure 11). Acoustic surveys targeted yellowfin grouper, tiger grouper and red hind aggregations. Split-beam acoustics were run simultaneously with multibeam operations.

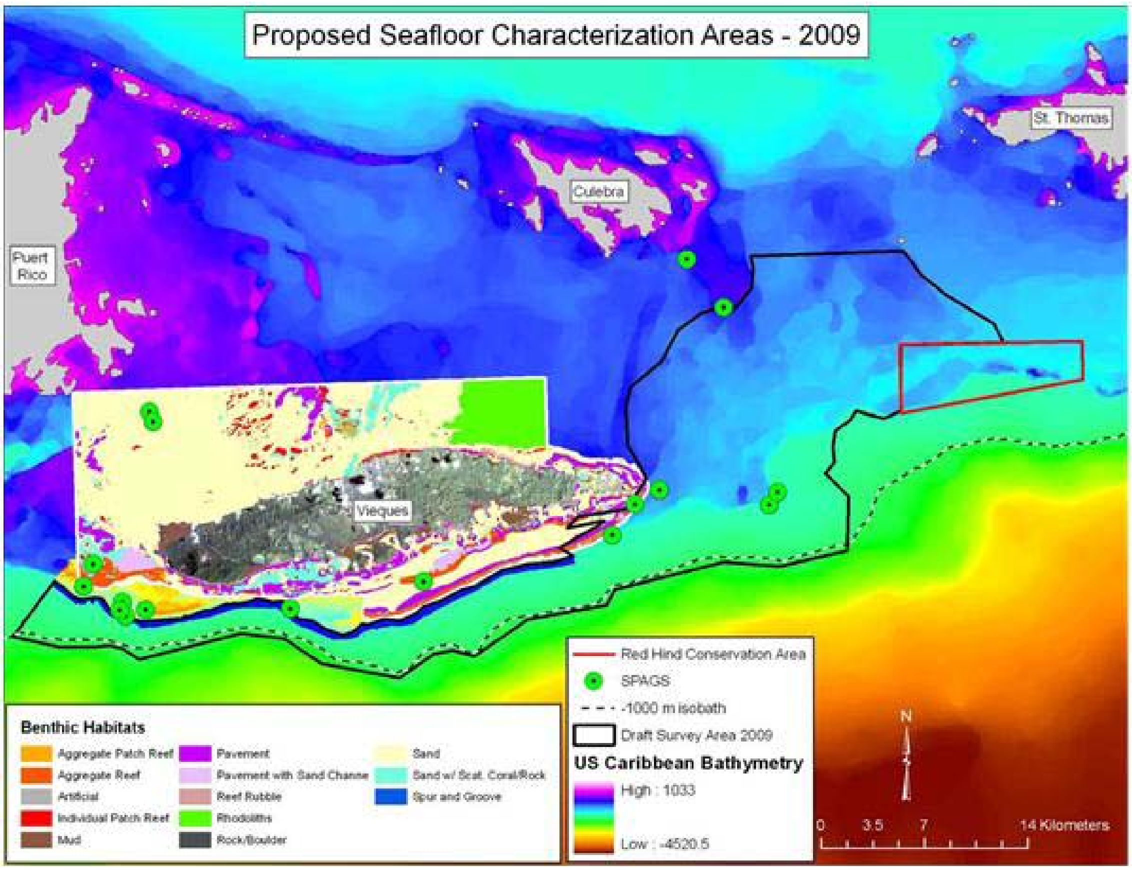


Figure 11. Vieques priority areas for benthic habitat characterization as identified in the NF-09-01-USVI Cruise Instructions. Green dots indicate known spawning aggregation sites.

2.2.1 Methods

A Simrad EK-60 120 kHz split beam transducer was pole mounted and attached to the moon pool on the hull of the NOAA ship *Nancy Foster* in 2008 (Figure 12 – left). In 2009, the EK-60 120kHz transducer was attached to a flange alongside a Reson 7125 multibeam system (200,400 kHz) and attached to the moon pool (Figure 12 – right). 2009 was the first year of operation with the 7125 system. A hydrographic survey report entitled Report on Benthic Habitat and Hydrographic Survey Project is available at: http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF-09-01_DAPR.pdf This system did not perform as expected; therefore, multibeam mapping was accomplished using the Simrad EM 1002 system on board as in previous years.

Acoustic survey lines followed multibeam track lines at Vieques and El Seco. Areas surveyed are shown in Figure 13. Details on the configuration of the split-beam system used in 2008 and 2009 are provided in Appendix A.

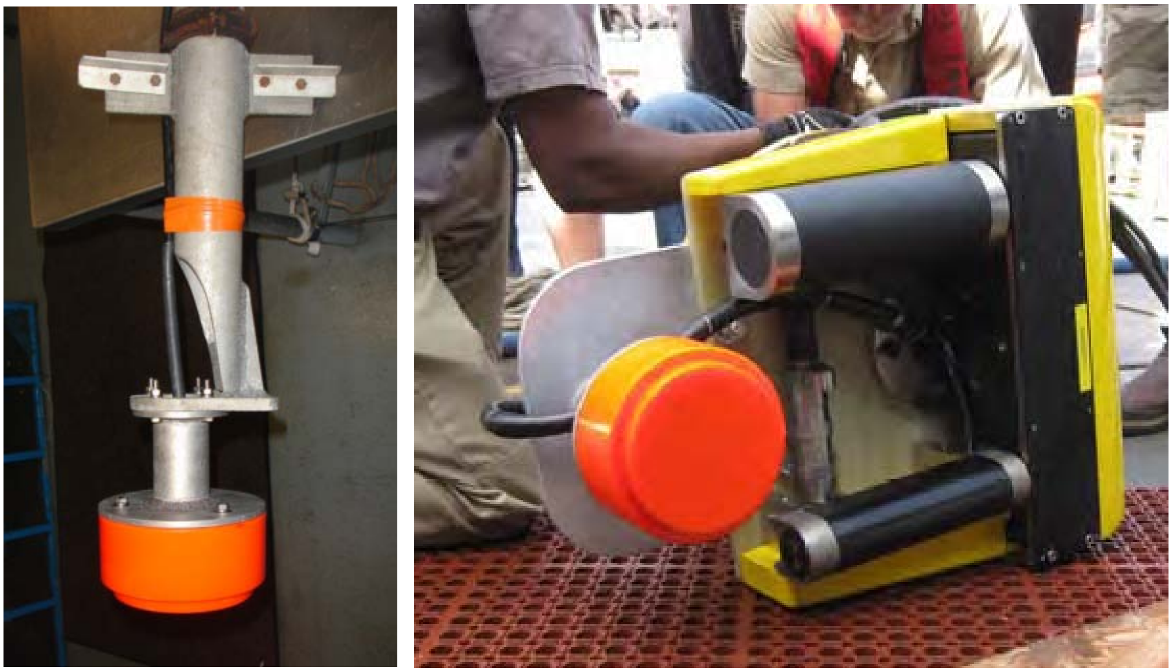


Figure 12. Deployment of Simrad EK-60 120 kHz transducer for fisheries acoustic surveys in 2008 (left) and 2009 (right).

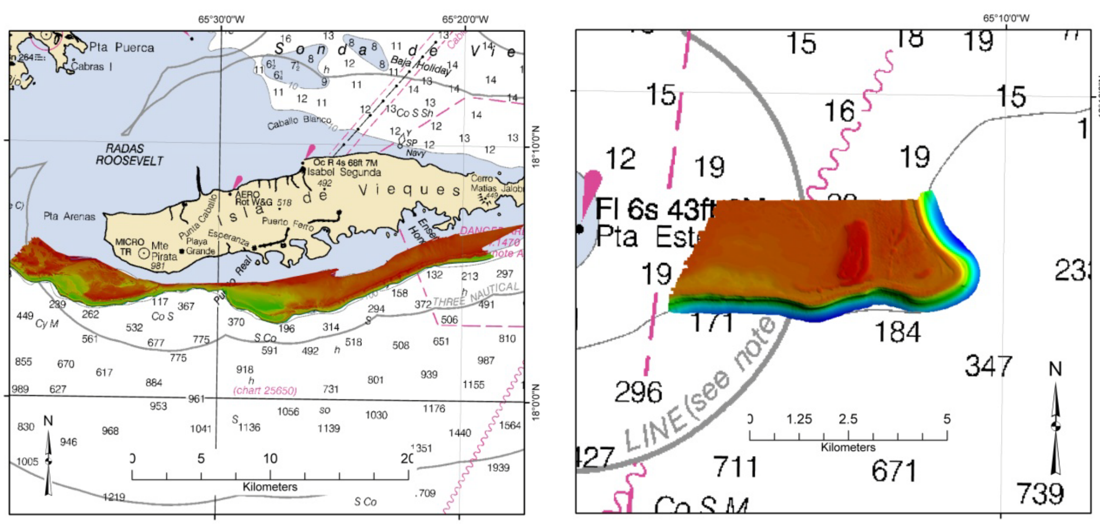


Figure 13. Areas surveyed at Vieques, PR March 26 through April 3, 2008 (left) and El Seco, PR March 26 through April 2, 2009 (right).

2.2.2 Analysis and products

Acoustic backscatter data were analyzed in Echoview, which included editing bottom lines and identifying bad data regions. Single target detection algorithms were applied to the TS split-beam and angular position echograms to generate fish tracks. Fish density (fish/100m^2) was calculated at 100m intervals along the transect. An examination of fish distribution from survey data collected at Vieques in 2008 indicated that 90% of fish were found within 10m of the bottom (Figure 14). Therefore, the water column was partitioned horizontally and fish density was mapped for both the entire water column (Figure 15) and for the portion of the water column within 10m of the bottom (Figure 16) for medium (11-29cm) and large (>29cm) fish. Estimates of fish density derived from acoustic surveys conducted near El Seco in 2009 were mapped similarly (Figure 17-18).

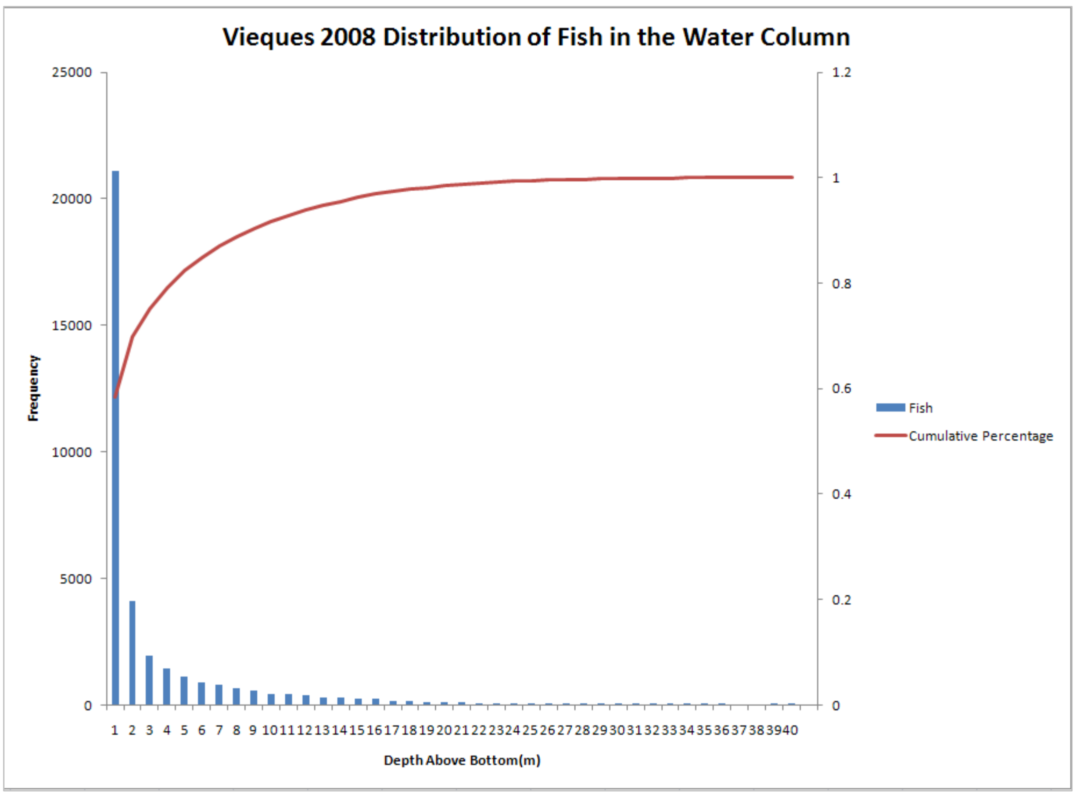
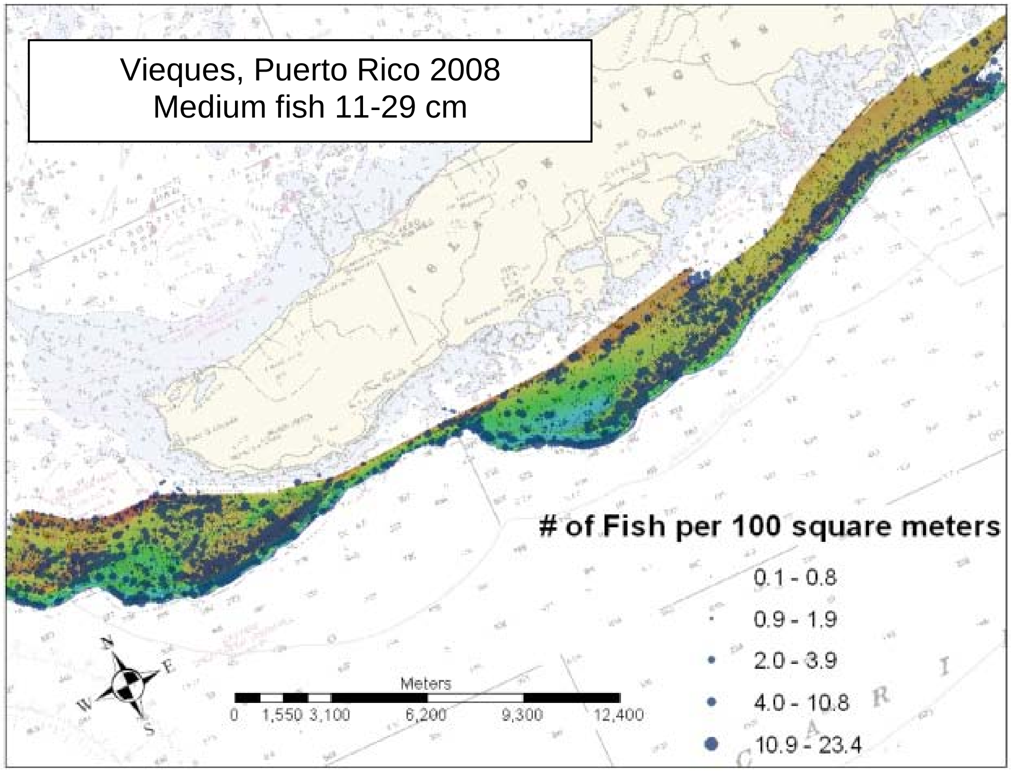


Figure 14. Cumulative distribution of fish targets by depth at Vieques in 2008.



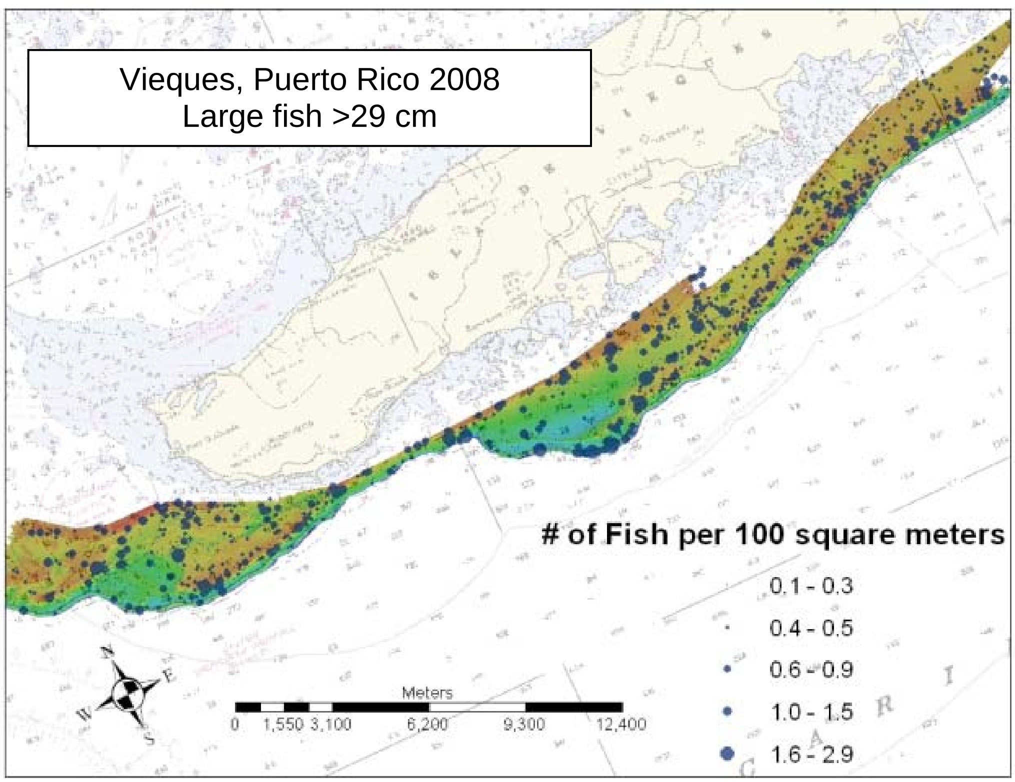
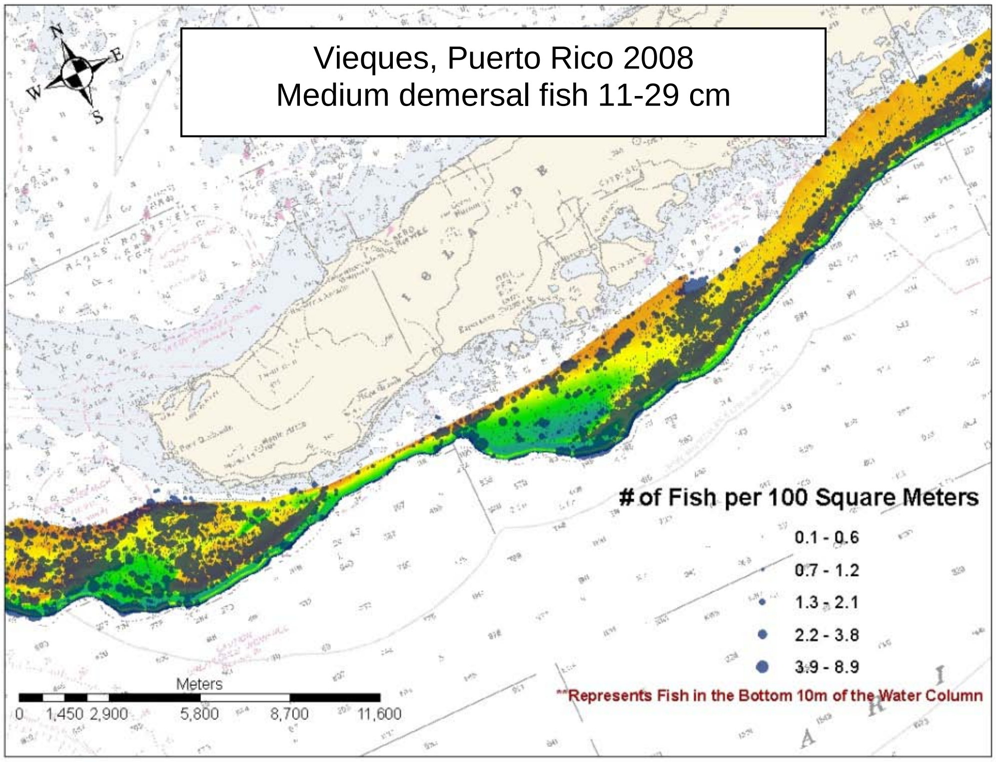


Figure 15. Fish density at Vieques of medium (11-29cm) and large fish (>29cm) for the entire water column.



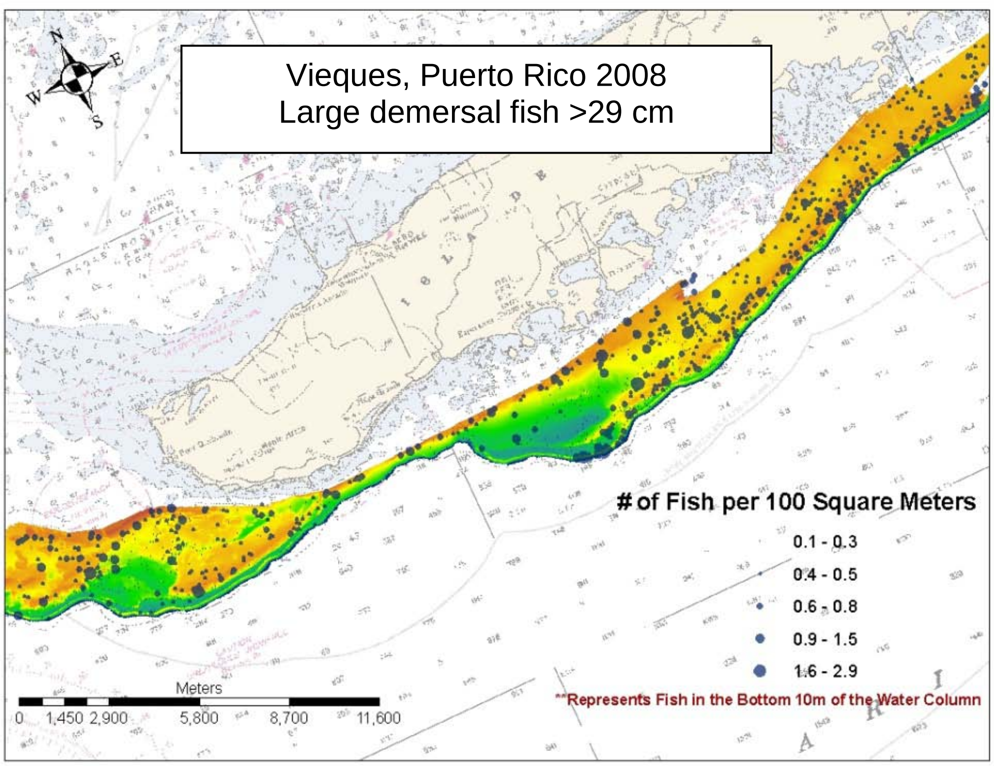
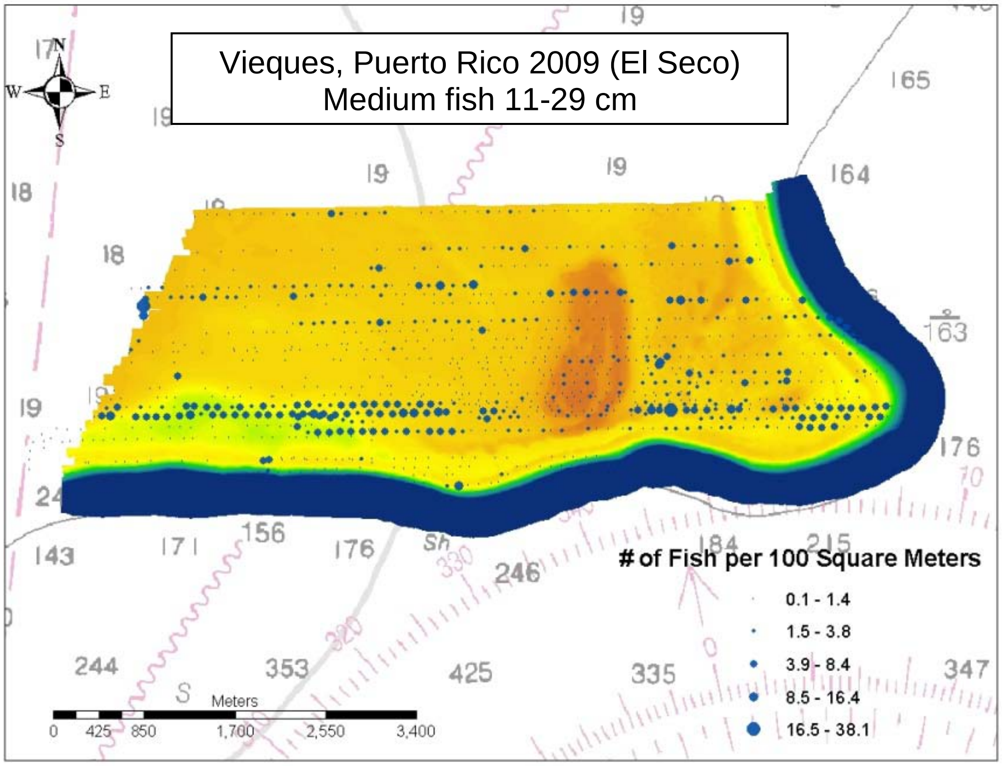


Figure 16. Fish density at Vieques of medium (11-29cm) and large fish (>29cm) for the portion of the water column within 10m from the bottom.



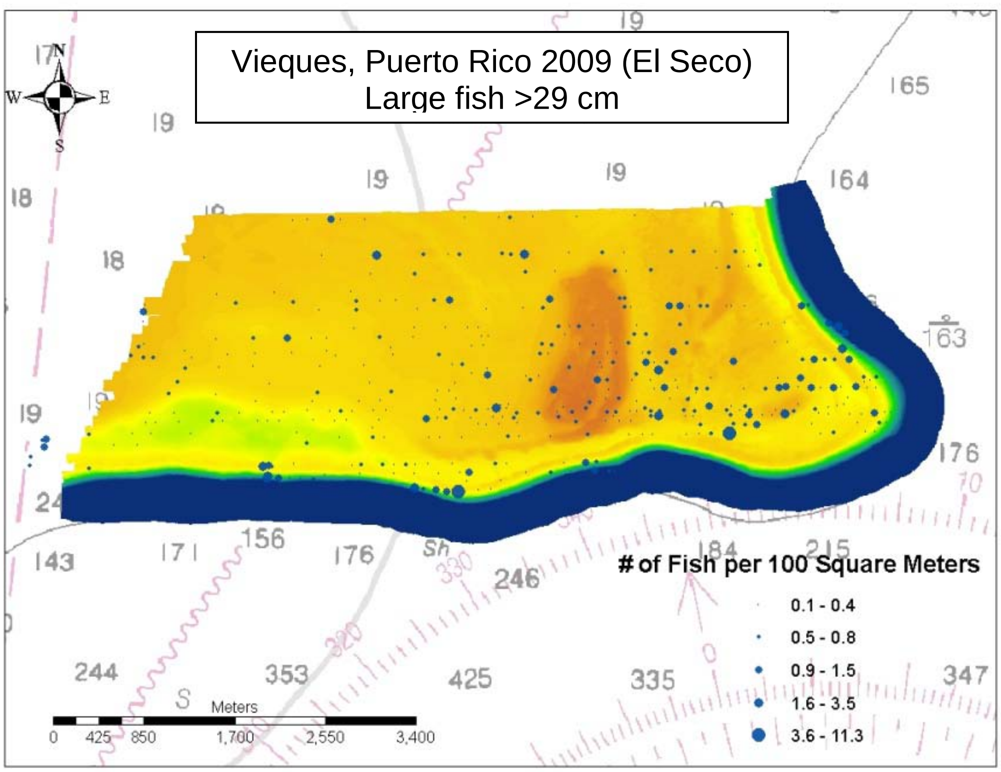
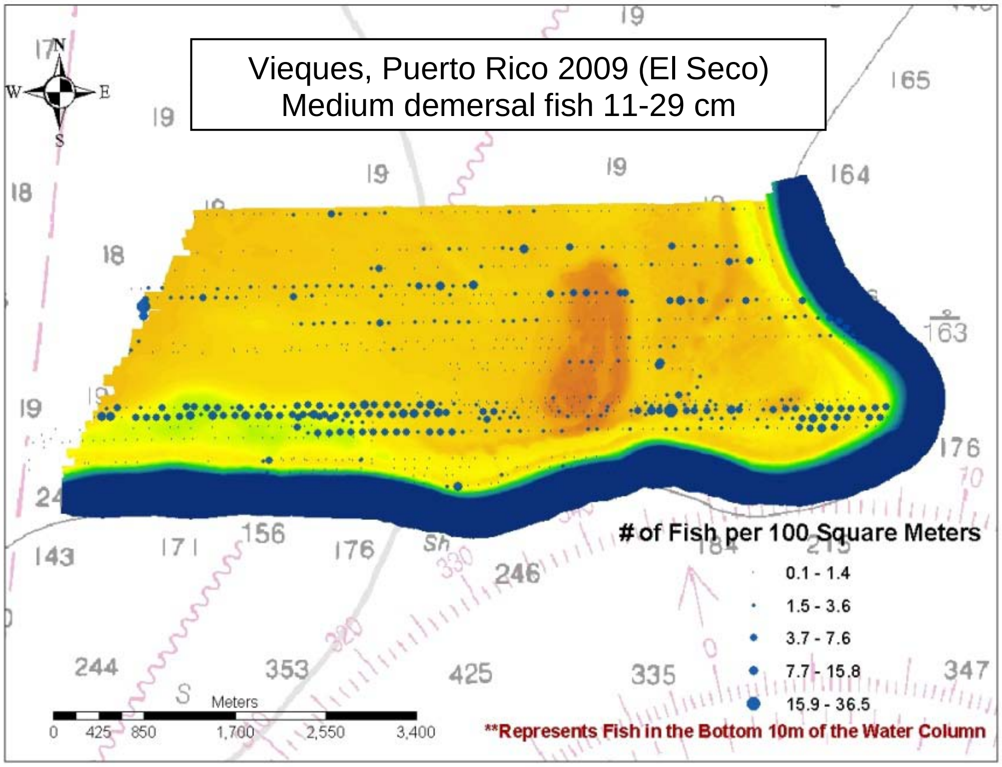


Figure 17. Fish density at Vieques El Seco of medium (11-29cm) and large fish (>29cm) for the entire water column.



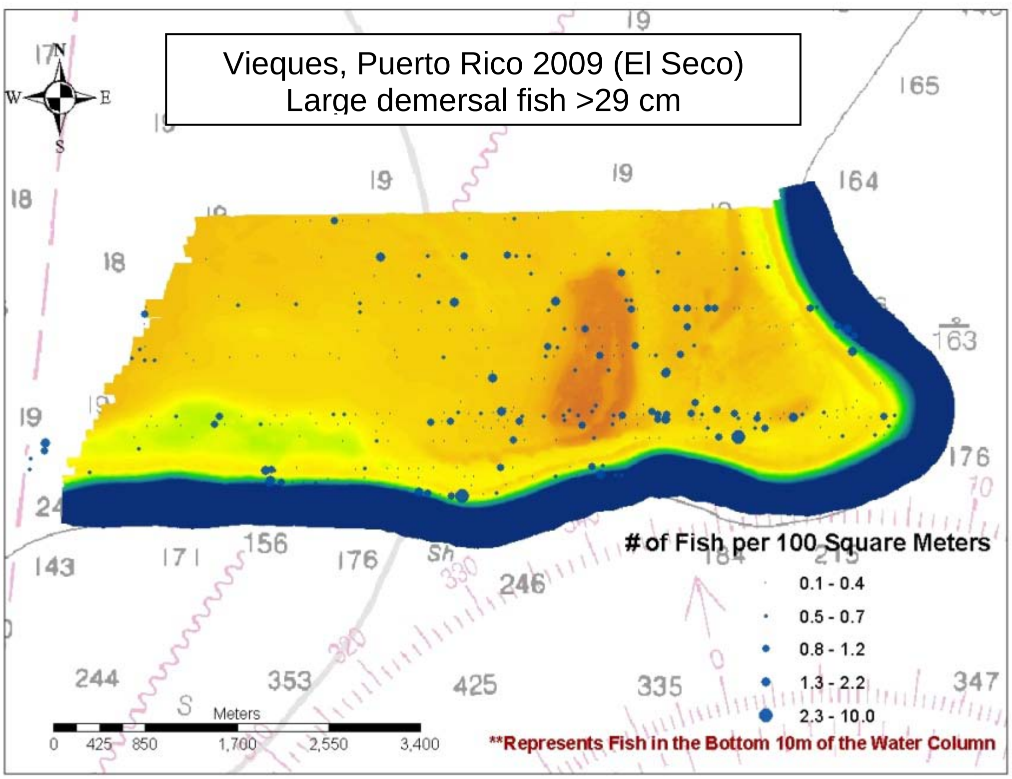


Figure 18. Fish density at Vieques El Seco of medium (11-29cm) and large fish (>29cm) for the portion of the water column within 10m from the bottom.

2.3 Virgin Passage and St. John Shelf (NF-10-03-USVI)

In 2010, two locations in the USVI were identified as priority areas for benthic habitat mapping - Virgin Passage near St. Thomas and the St. John Shelf (Figure 19 – black polygons). Acoustic surveys targeted known grouper spawning sites, including yellowfin grouper. Two operating days were dedicated to known and candidate fish aggregation sites at Grammanik Bank and Tampo.

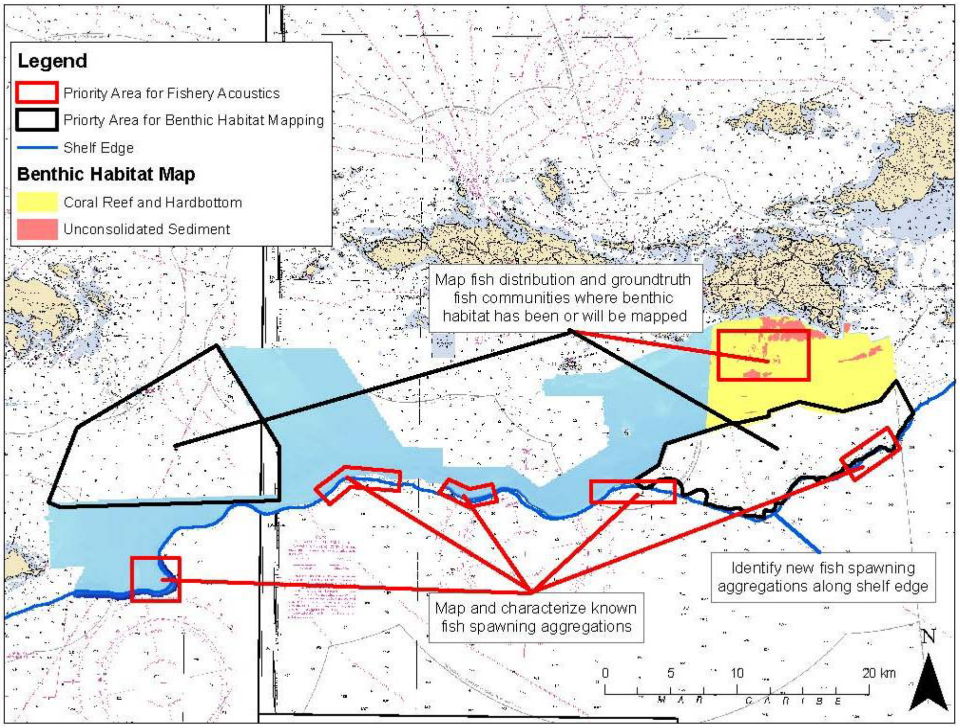


Figure 19. St. Thomas and St. John priority areas (black polygons) for benthic habitat characterization as identified in the NF-10-03-USVI Cruise Instructions. The blue regions indicate areas mapped prior to 2010.

2.3.1 Methods

A split-beam, two frequency (38/120 kHz) Simrad system was attached to a sled alongside the Reson 7125 multibeam system and mounted on the hull of the NOAA ship *Nancy Foster* (Figure 20 - left). Spilt-beam data acquisition was handled through Simrad ER-60 software. Both the 38kHz and 120kHz were set at a ping interval of 0.12 or approximately 8 pings per second when the multibeam was not operating (See Appendix A for details on system configuration). When the multibeam was operating, an inline switch triggered ping control from the Reson to the Simrad transceivers to alternate pings between systems. Survey lines followed planned multibeam track lines. During the day, ROV surveys were conducted to validate benthic habitat types derived from multibeam data.

Split-beam and multibeam surveys were conducted from March 18, 2010 to April 5, 2010 covering Virgin Passage and St. John shelf (Figure 21). Split-beam surveys conducted on April 4-5, 2010 focused on expected fish aggregation locations at Grammanik Bank and Tampo (Figure 22). ROV surveys at these sites included the deployment of a video camera and DIDSON high resolution sonar attached to the ROV (Figure 20 – right) to provide complementary data at Tampo and Grammanik Bank.

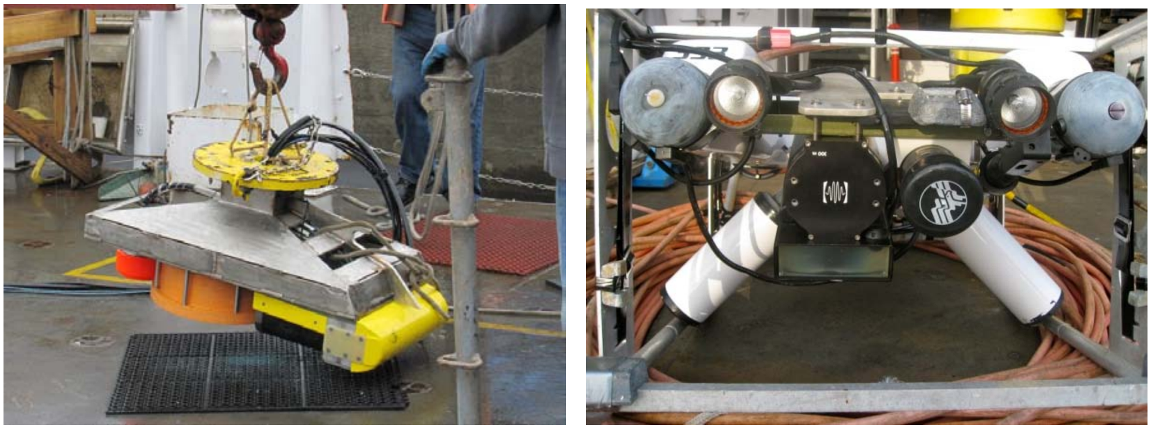


Figure 20. Simrad 38/120 kHz system deployed alongside Reson 7125 prior to mounting on the hull of the NOAA ship *Nancy Foster* (left). Phantom 2 ROV with video camera and DIDSON high resolution sonar as deployed at dedicated fish survey sites (right).

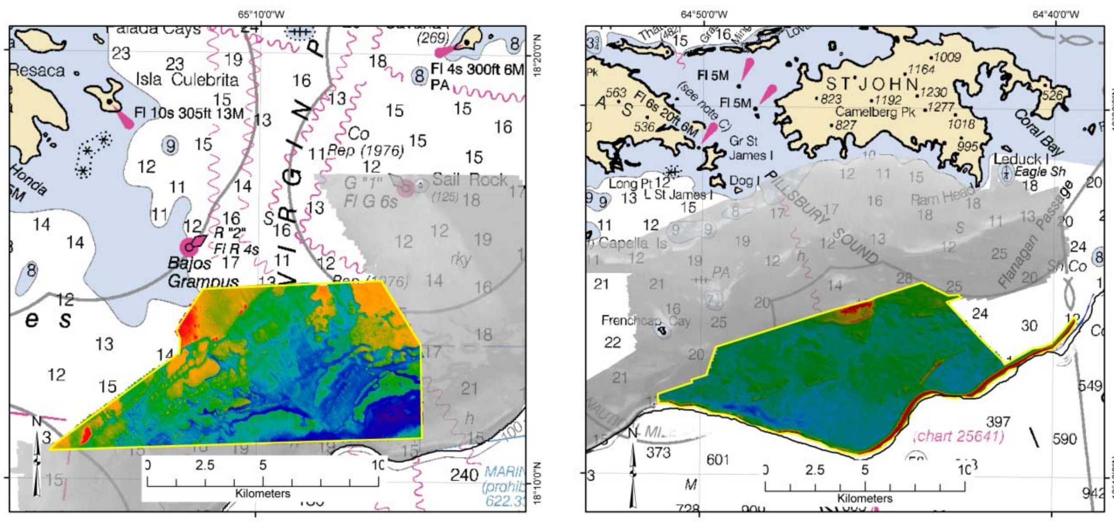


Figure 21. Areas mapped for benthic habitat classification using multibeam at Virgin Passage southwest of St. Thomas (left) and St. John shelf (right).

Targeted fish acoustics surveys at Grammanik Bank and Tampo consisted of several passes over the area (Figure 22). Video ROV and high resolution sonar surveys were also conducted at these locations to provide insight into species present at the time. An acoustic survey was conducted at Grammanik Bank from 12:25 to 20:40 on April 3, 2010 followed by a high resolution sonar and video ROV survey from 20:45 to 23:25. Acoustic surveys at Tampo were run in the afternoon and evening of April 4, as well as the early morning of April 5, 2010, allowing for temporal comparisons to be made. High resolution sonar data and video were collected during an ROV survey at Tampo on April 4, 2010 from 18:50 to 20:45.

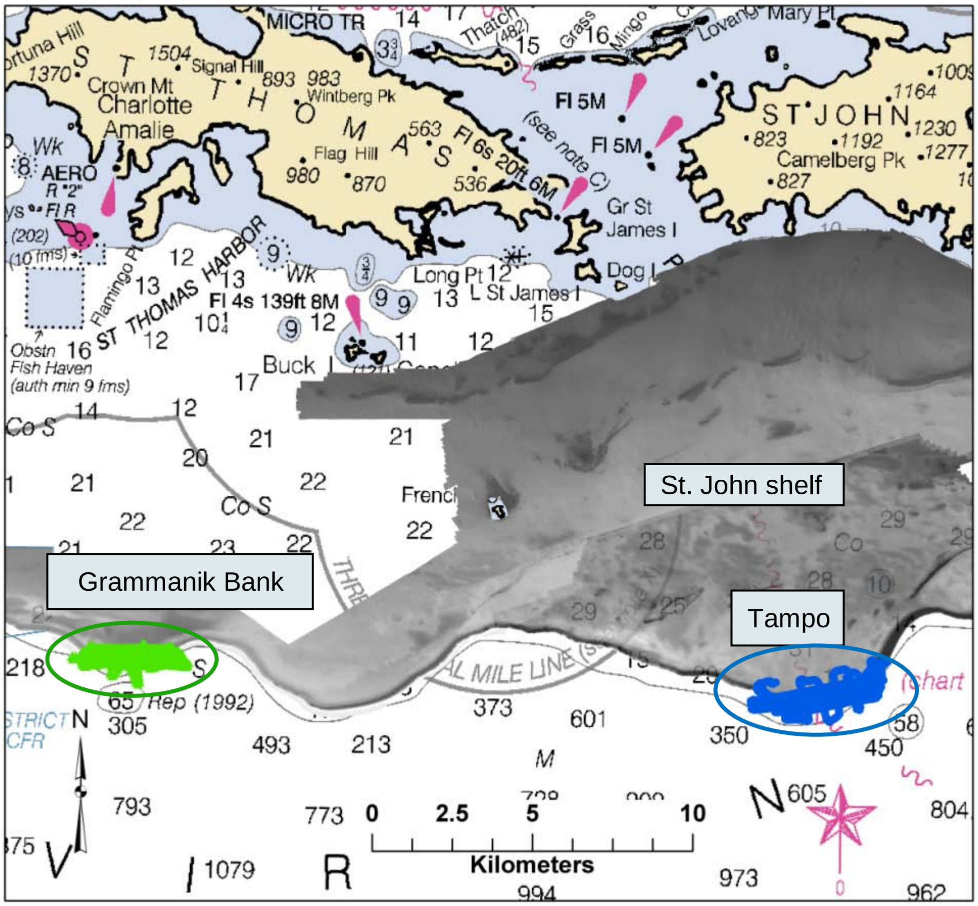


Figure 22. Location of dedicated fish surveys conducted at Grammanik Bank and Tampo in 2010.

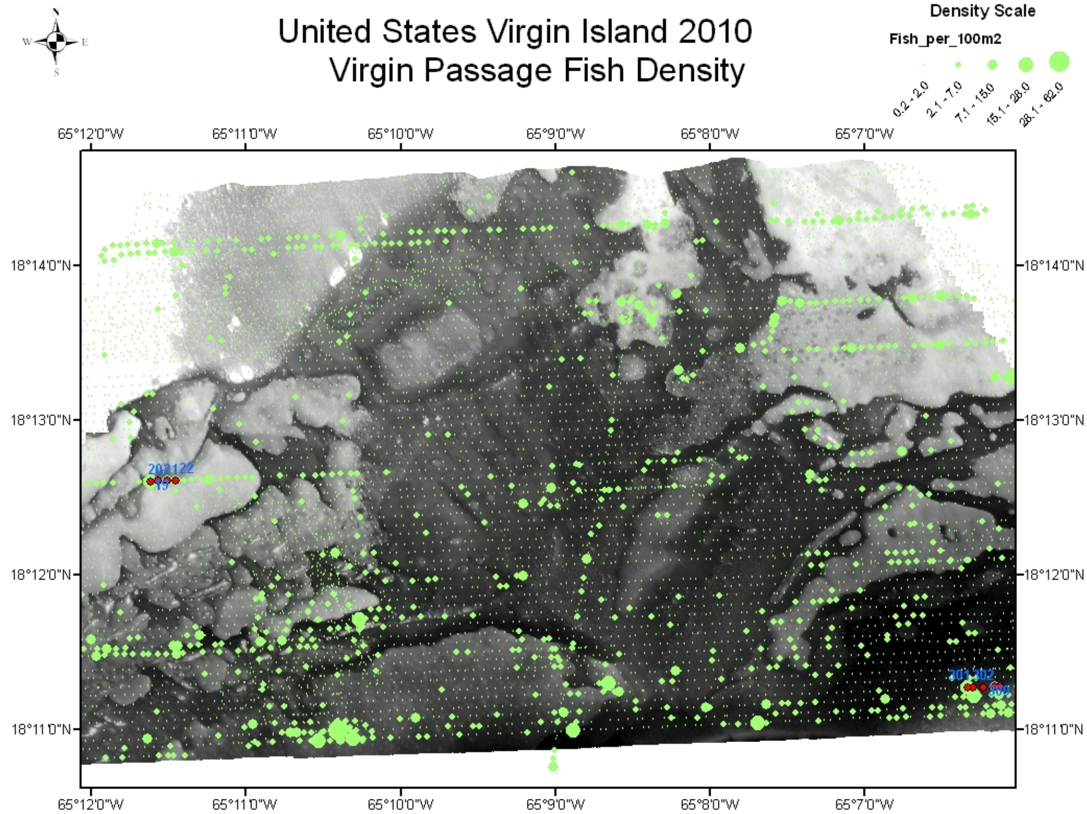
2.3.2 Analysis and products

Acoustic backscatter data from surveys conducted in 2010 were processed in Echoview and converted to fish densities as outlined in Figures 3 and 4. Several approaches for examining the spatial and temporal distribution of fish throughout the survey area were applied.

- Fish density (fish/100m^2) was calculated every 100m along all transects at Virgin Passage and St. John shelf (Figure 23). Fish density mapped at Virgin Passage appears to show a rather consistent spatial distribution with a few spots of high density; whereas, the map of St. John shelf shows large, localized areas of high fish density, particularly in the north-central part of the shelf and near the shelf ledge toward the southwest.
- Fish density was also mapped by size class at Virgin Passage (Figure 24) and St. John shelf (Figure 25). Size classes were divided into small (<11cm, top), medium (11-29cm, middle), and large (>29cm, bottom) fish. The general equation of Love (1977) for target strength-length relationship was used to estimate fish size. At Virgin Passage, patterns in fish density of small and medium fish may be related to time of survey (see Figure 26). High densities of

large fish are located at specific locations across the region. At St. John shelf, high fish densities of small and medium fish were found primarily in the north-central region and near the ledge along the southwest. High densities of large fish were primarily found near the shelf edge and the promontory at Tampo.

- Diel patterns (dawn/dusk versus nighttime) were examined in each of the two survey areas (Figure 26). Daylight hours (08:00-16:00) were typically dedicated to ROV surveys to validate the multibeam data. Therefore, dawn and dusk acoustic surveys conducted before and after daytime ROV operations are considered daytime transects. These time periods include acoustic transects run between 05:00-08:00 and 16:00-19:00. Night time densities are based on transects run from 19:00 to 05:00. Sunrise occurred at 06:20 and sunset was at 18:38 local time on March 31, 2010. While observed patterns of fish density mapped across the region are due, in part, to the time of survey at any given location, these patterns suggest that areas of higher fish density at Virgin Passage occur during the daytime or crepuscular periods. Maps of temporal patterns at St. John shelf indicate that areas of high fish density occur in the same southwest region during both daytime and nighttime surveys.



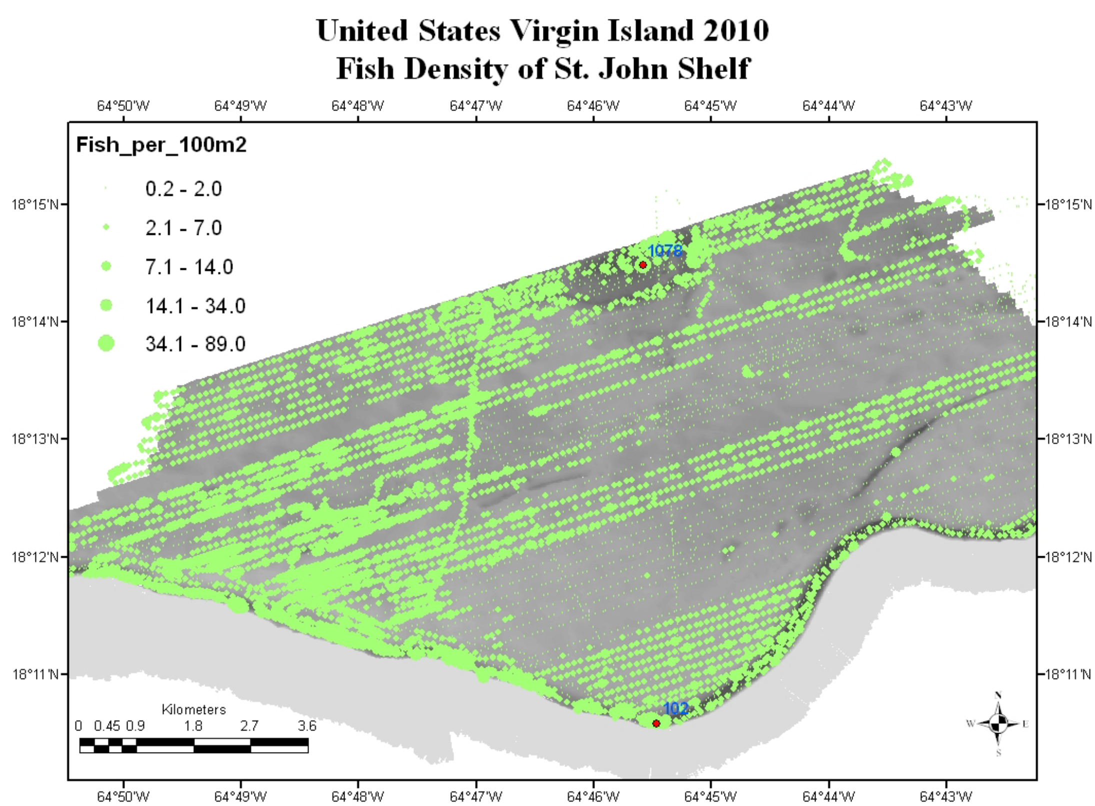


Figure 23. Fish density (fish/100m^2) at Virgin Passage (upper) and St. John shelf (lower).

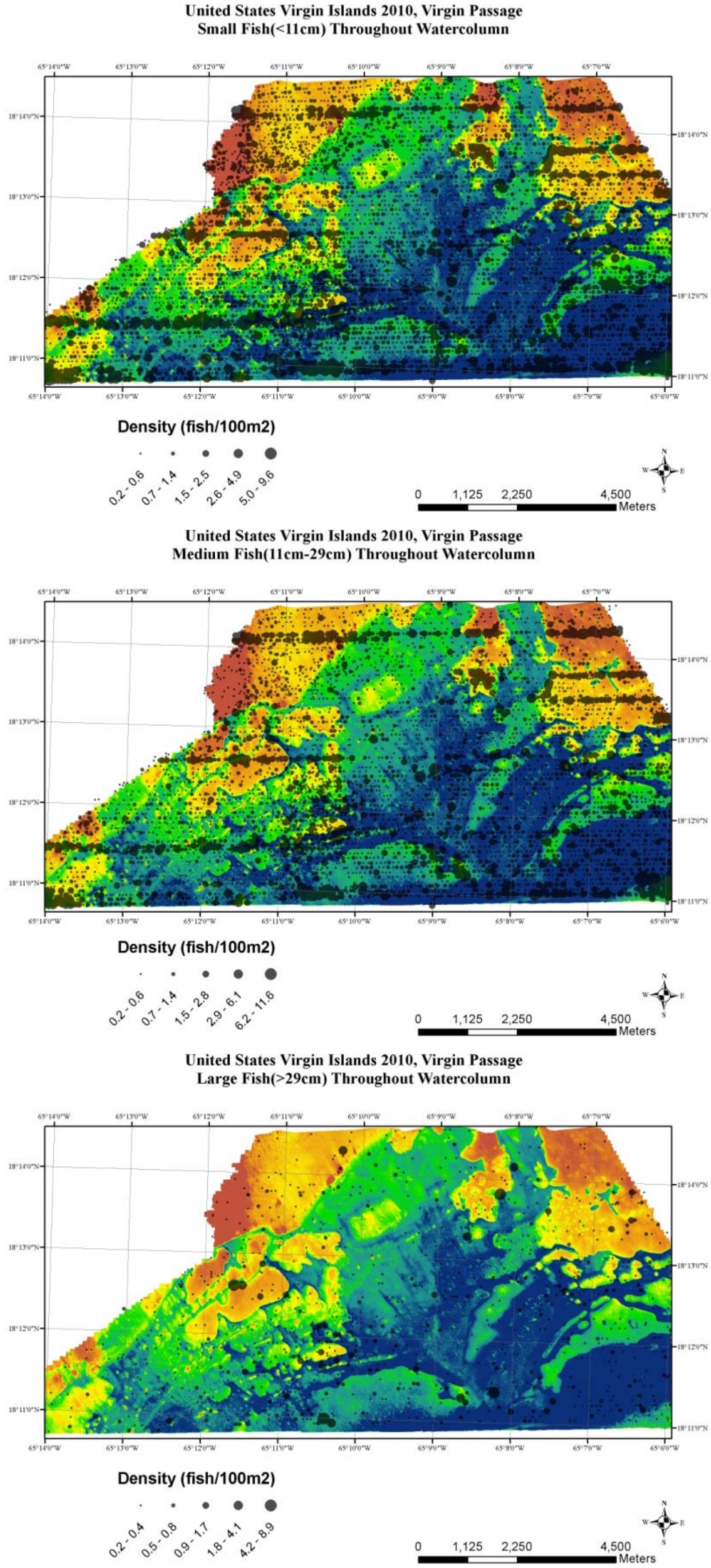


Figure 24. Fish density by size class at Virgin Passage. Size classes are: small (< 11cm, top), medium (11-29cm, middle), and large fish (>29cm, bottom). The general equation of Love (1977) for TS-length relationship was used to estimate fish size.

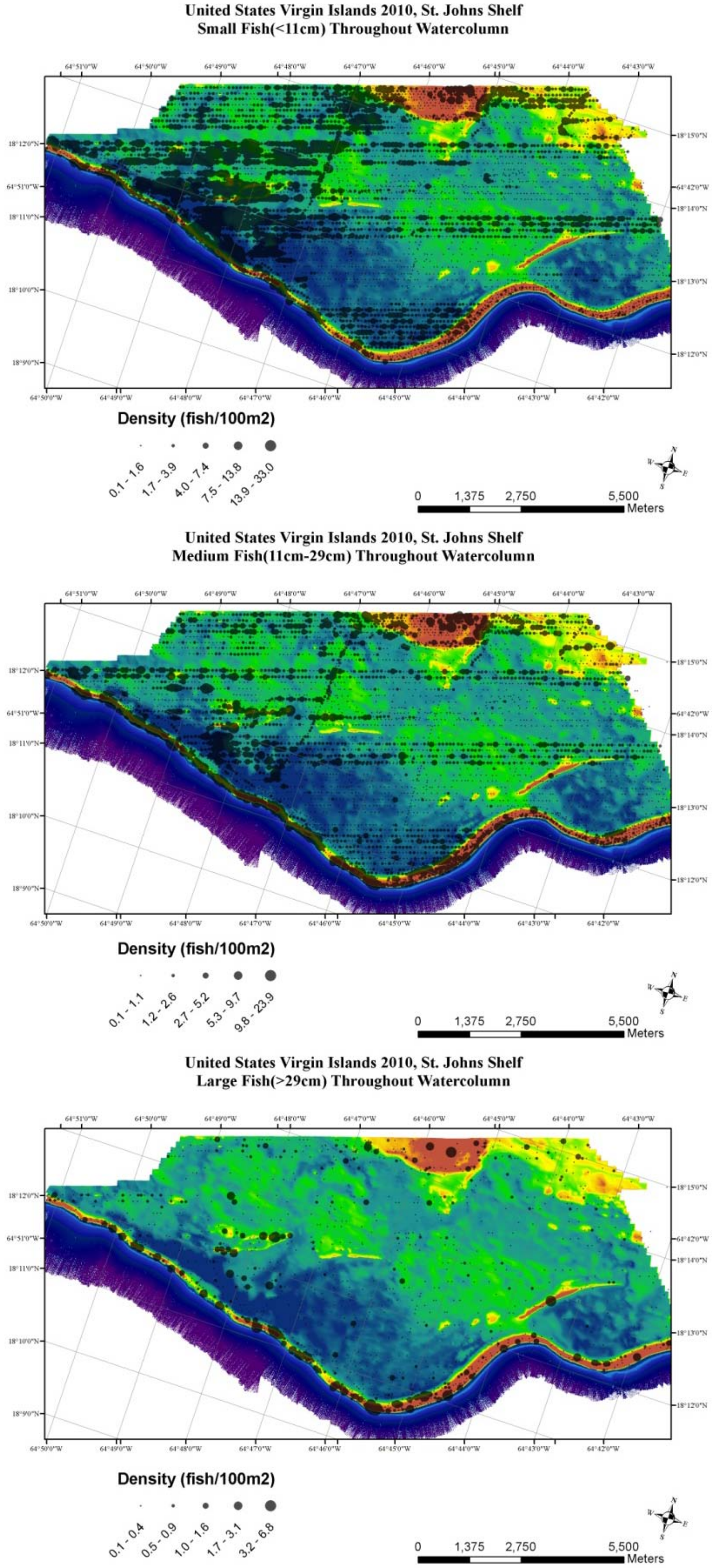


Figure 25. Fish density by size class at St. John shelf. Size classes are: small (< 11cm, top), medium (11-29cm, middle), and large fish (> 29cm, bottom). The general equation of Love (1977) for target strength-length relationship was used to estimate fish size.

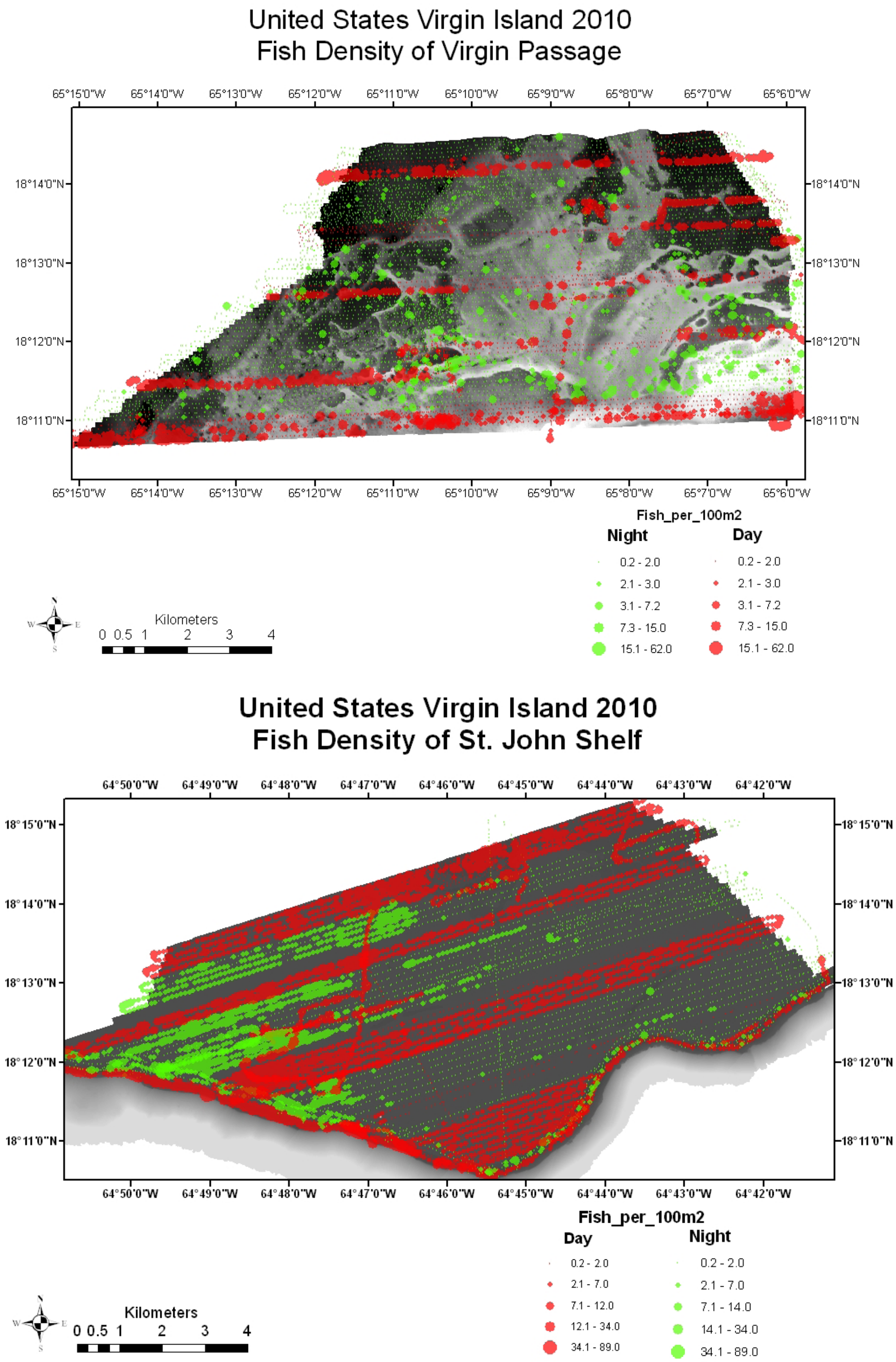


Figure 26. Diel patterns (dawn/dusk versus nighttime) of fish density at Virgin Passage (upper) and St. John shelf (lower). Day or dawn/dusk hours include acoustic transects run between 05:00-08:00 and 16:00-19:00. Nighttime densities are from transects run from 19:00 to 05:00. Sunrise was at 06:20; sunset at 18:38 local time on 31 March 2010.

Targeted split-beam acoustic surveys were conducted at two specific locations - Grammanik Bank which previously had been identified as a historic fish spawning location and Tampo which was identified as a potential new fish spawning aggregation site. Split-beam acoustic surveys at Grammanik Bank were run on 3 April 2010 from 12:25 into the night, followed by an ROV survey with video and DIDSON high resolution sonar. Survey results from Grammanik Bank are presented as fish density (fish per $100m^2$) mapped over three time periods. In addition, large fish (>29cm) were mapped and spatial analysis applied to detect aggregations of large fish. Further, ROV video was reviewed for targeted species and echograms examined for indications of fish aggregations in the water column.

- Maps of fish density derived from acoustic surveys conducted throughout the day and into the night at Grammanik Bank indicate rather persistent areas of high fish density, especially near the shelf edge (Figure 27).
- Maps depicting the size-specific distribution of large fish (>29 cm) were produced to assess patterns of large fish abundance and possible locations of spawning aggregations at Grammanik (Figure 28). A cluster statistic was applied in ArcMap (Anselin 1995, local Moran's I, IDW^2, 250m threshold, alpha=.05) to test the degree of spatial similarity of fish lengths using transect intervals of 100m where large fish (>29cm) were found. Locations that indicate significant clustering of large fish length were identified and mapped (Figure 29). Furthermore, an examination of echograms from acoustic surveys and video from the ROV survey conducted on the same day resulted in evidence of fish aggregations on the echogram and video identification of yellowfin grouper (*Mycteroperca venenosa)*, both within 500m of where spatial pattern analysis indicated significant clustering (Figure 29).

Split-beam acoustic surveys at Tampo were run in the afternoon and evening of April 4 and early morning on April 5, 2010. ROV surveys with video and DIDSON high resolution sonar were conducted between the first and second set of split-beam acoustic surveys. Maps and graphs of fish density, as well as corresponding images from ROV video and echograms are presented here.

- Results from surveys targeting aggregations at Tampo (Figure 30) were used to map fish density at two different time periods. Split-beam transects were run in afternoon of April 4, 2010 (14:45 to 16:25 – Figure 31, left) and at dawn on April 5, 2010 (05:45 to 07:45 – Figure 31, right). Mapped results suggest higher fish densities in the afternoon surveys compared to surveys conducted at dawn on the following day.
- Temporal changes in fish density were examined at Tampo, specifically near the shelf edge (Figure 32). A change in fish density occurs moving from the afternoon (17:00) to late evening (23:00) as fish density concentrates near the promontory of Tampo. In the pre-dawn hours (05:00) high fish density is also observed near the tip of Tampo.
- Based on patterns of high fish density near the shelf edge, echograms were examined for fish aggregations (Figure 33). Echograms associated with the highest fish density observed in the Tampo transects illustrate the various configurations of fish distribution observed at a scale of 200-300m. These echograms can be further analyzed, in conjunction with the ROV data to document and compare the characteristics and configuration of fish aggregations (Figure 34).

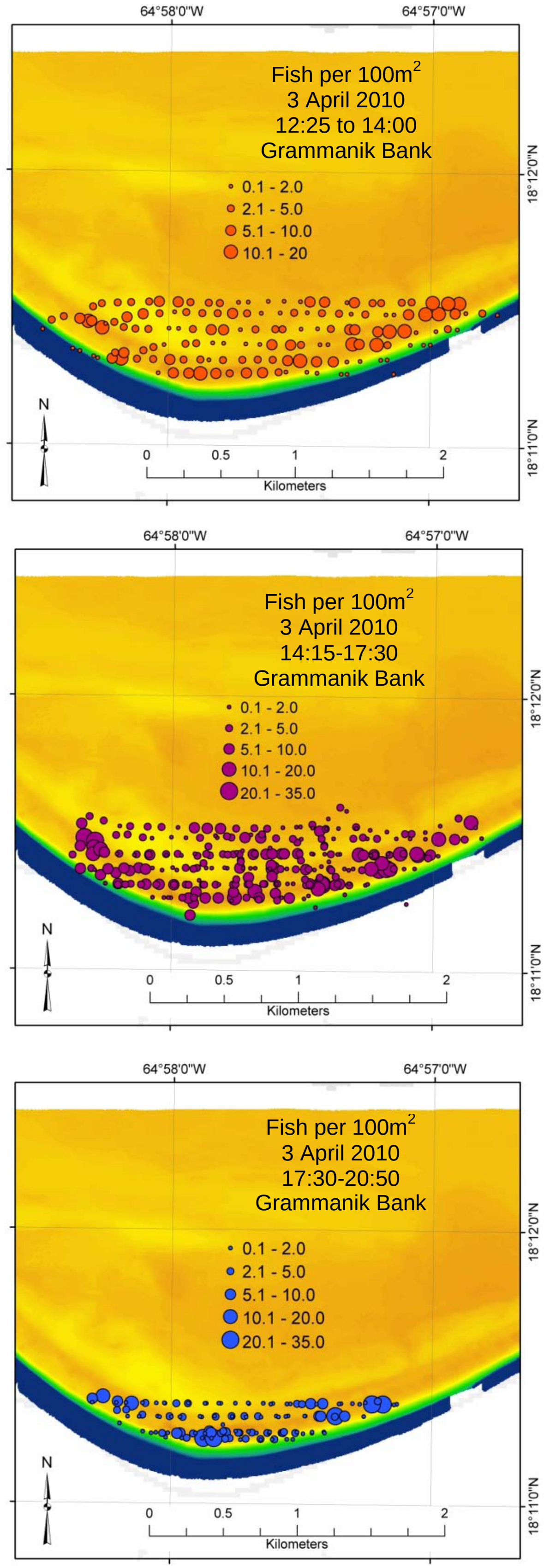


Figure 27. Fish density (fish per 100m^2) derived from acoustic surveys targeting fish aggregation sites at Grammanik Bank 3 April 2010.

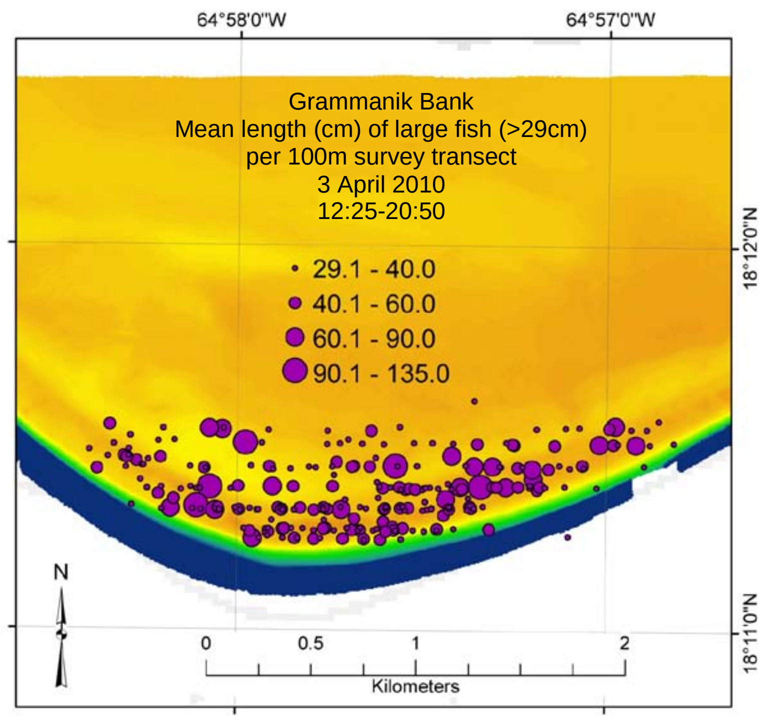
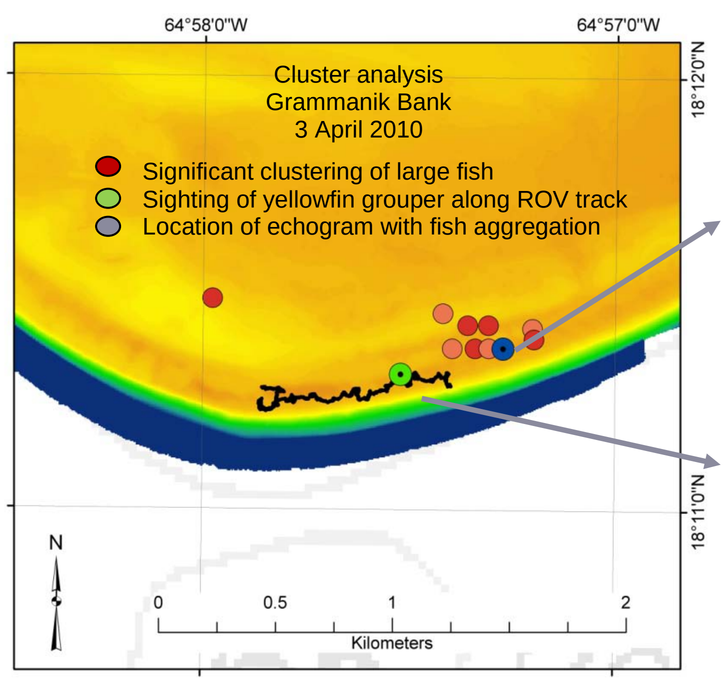
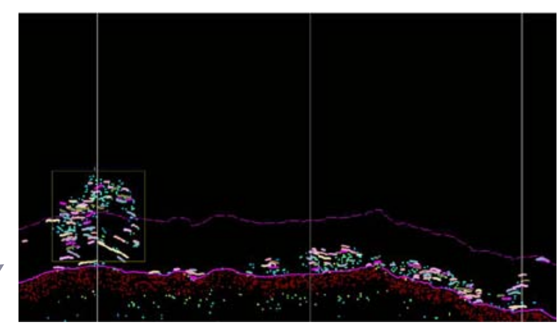


Figure 28. Mean length of large fish (>29cm) at Grammanik Bank
3 April 2010 12:25 to 20:50.





Echogram depicting fish aggregation
along acoustic survey transect
3 April 2010 13:27

One of many yellowfin grouper *Mycteroperca venenosa* detected along ROV transect
3 April 2010 22:52

Figure 29. Cluster analysis (local Moran's I) of large fish from acoustic survey with fish aggregations on echogram and video observations of yellowfin grouper (*Mycteroperca venenosa*) along ROV track.

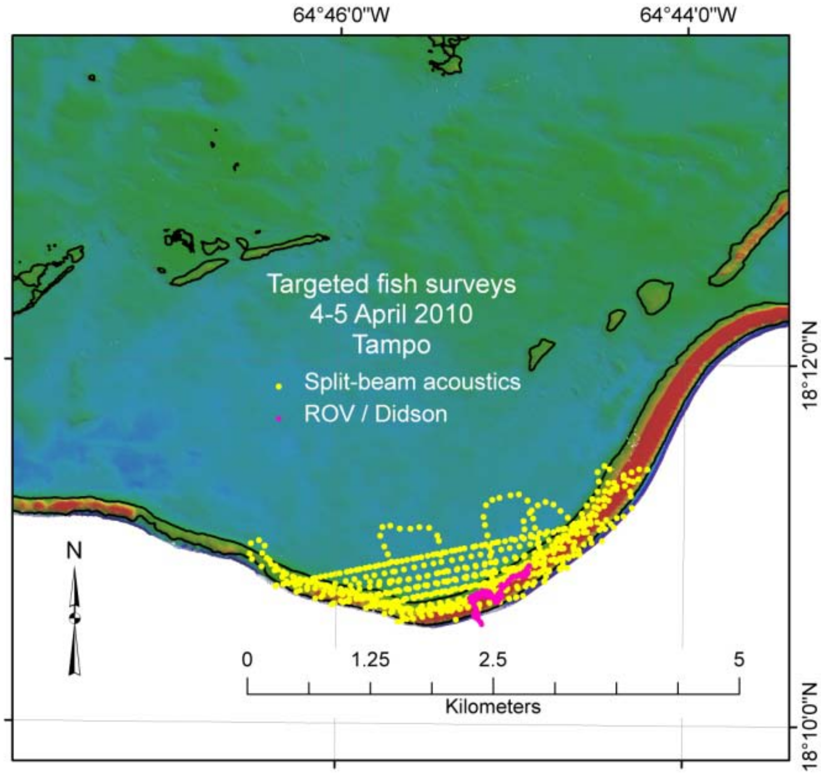


Figure 30. Location of acoustic surveys targeting fish aggregation sites at Tampo (yellow). The high resolution sonar/ROV track to be used for analysis of fish species present at the time of surveys is shown in pink.

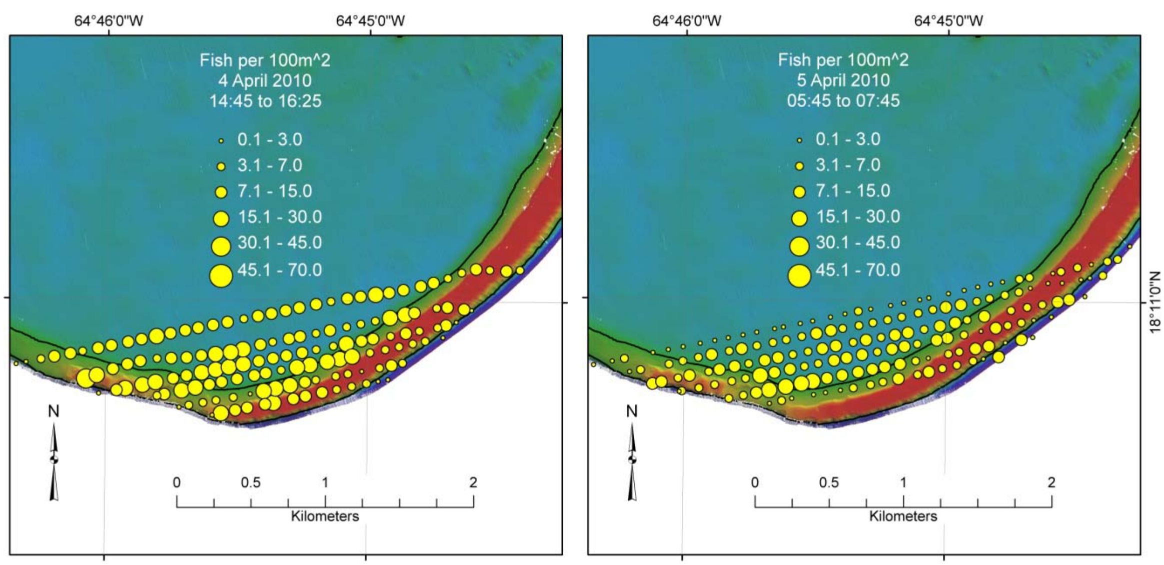


Figure 31. Fish density at Tampo 4 April 2010 14:45 to 16:25 (left) and 5 April 2010 05:45 to 07:45 (right).

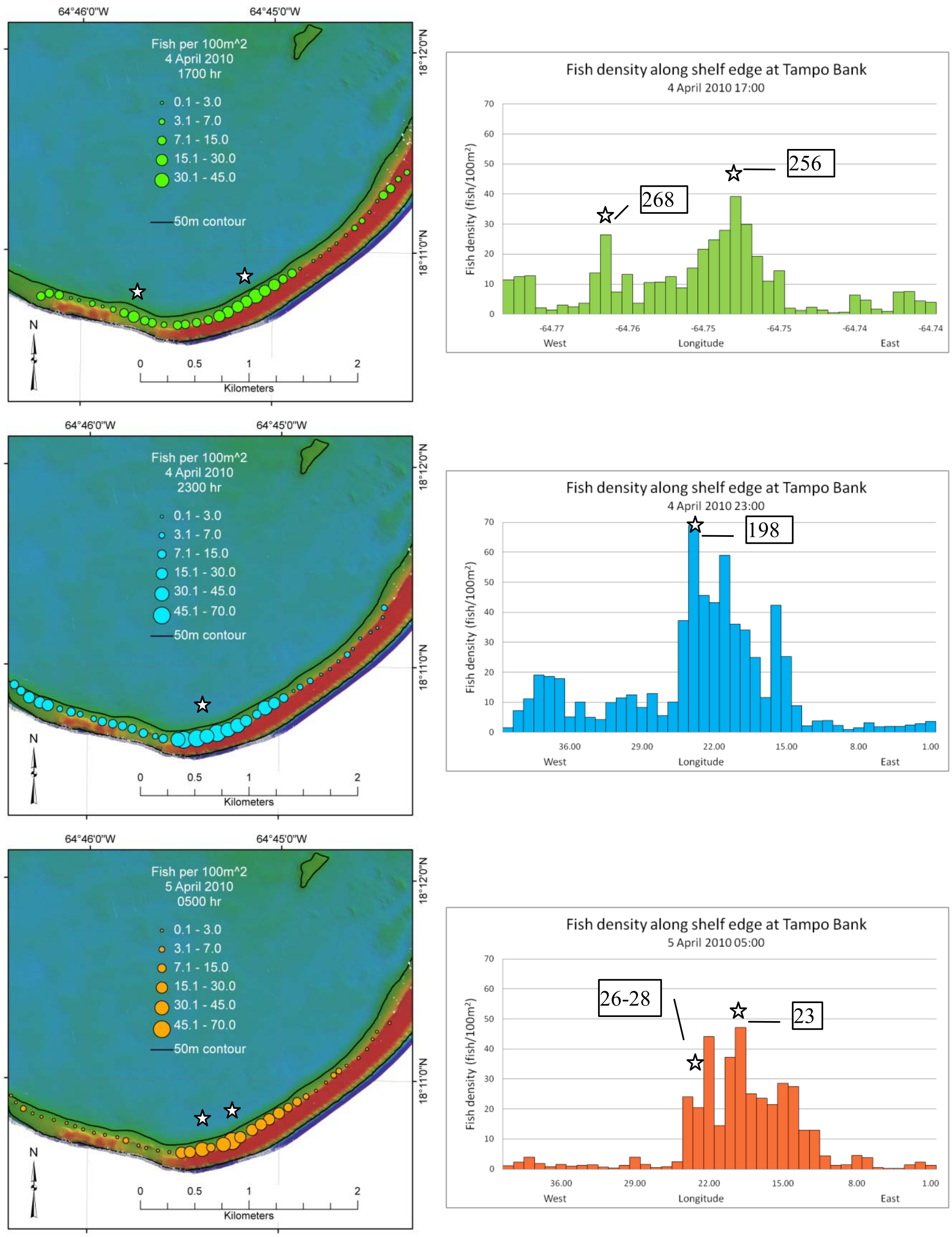
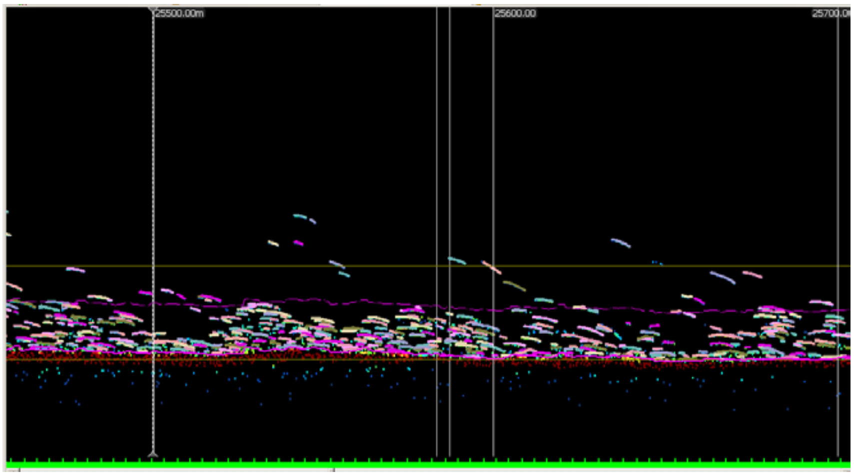
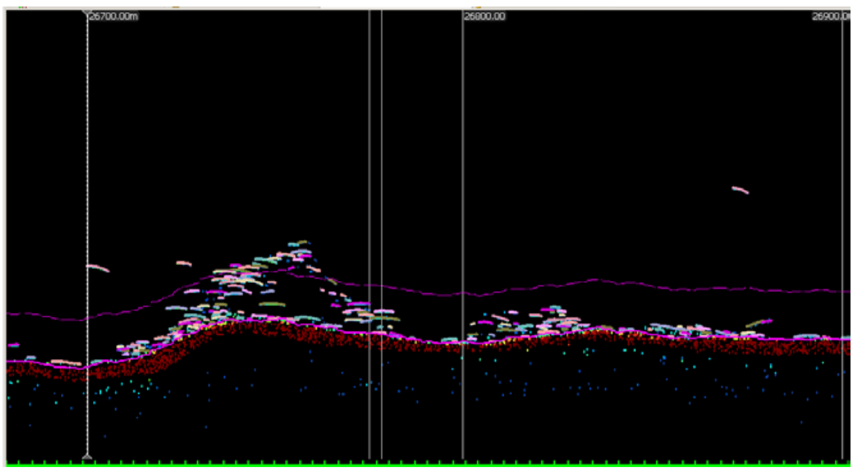


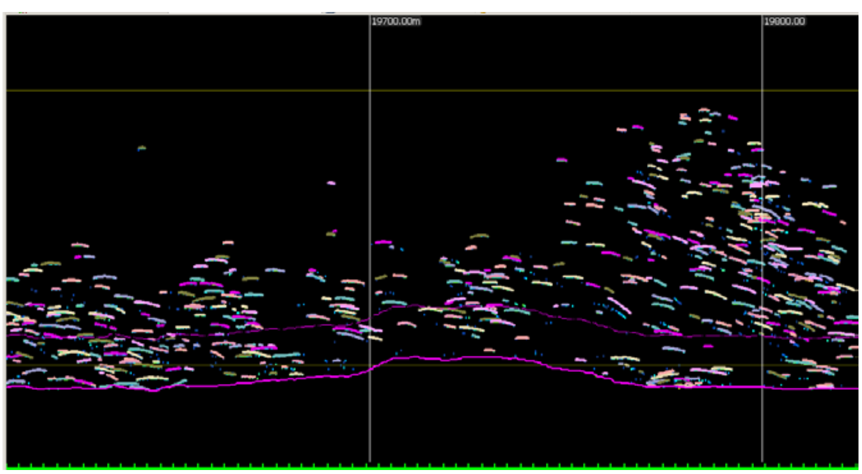
Figure 32. Temporal changes in fish density at Tampo near shelf edge: 4 April late afternoon ~17:00 (top), 4 April late evening ~23:00 (middle), and 5 April pre-dawn ~05:00 (bottom). ☆ matches approximate mapped location with fish density bar on graph. See also associated echograms in Figure 33 noted by interval numbers.



Interval 256 16:57 4 April 2010.

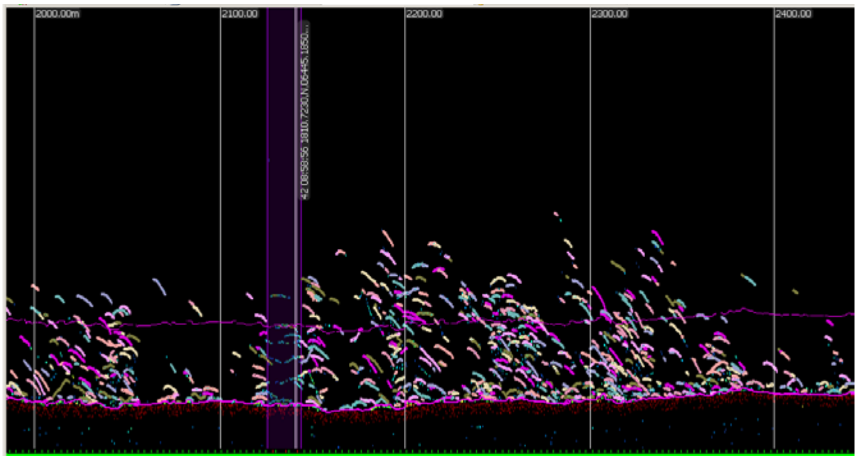


Interval 268 17:02 4 April 2010.

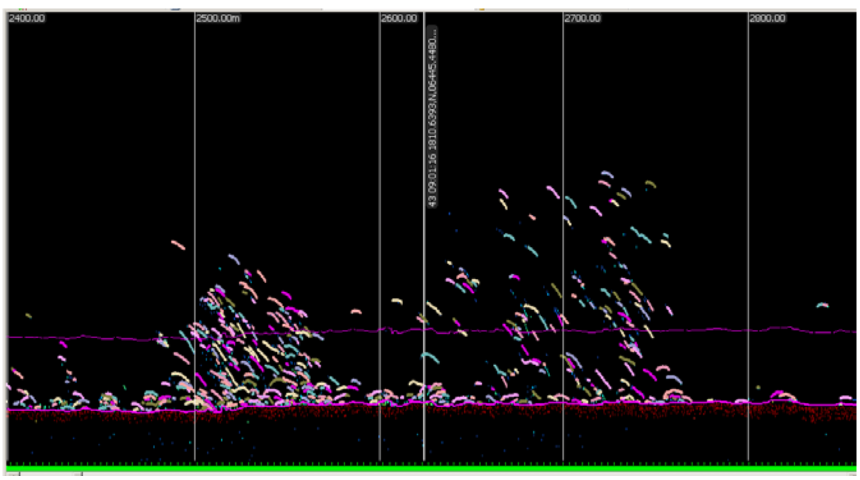


Interval 198 23:19 4 April 2010.

Figure 33. Echograms related to the areas of highest fish density along the near-edge transect at Tampo. These echograms depict variation in the configuration and arrangement of fish in the water column at various times of day. Intervals are noted by ☆ on graphs in Figure 32. (Figure continues on next page).



Interval 22-23 04:59 5 April 2010.



Interval 26-28 05:00 5 April 2010.

Figure 33. (Figure continued from previous page). Echograms related to the areas of highest fish density along the near-edge transect at Tampo. These echograms depict variation in the configuration and arrangement of fish in the water column at various times of day. Intervals are noted by ☆ on graphs in Figure 32.

Figure 34. School of Carangidae observed on ROV video between the first and second dedicated fish acoustic surveys at Tampo (18:57:36 4 April 2010).

3 Summary

This report summarizes mapping efforts and results from surveys near Puerto Rico (southwestern PR, Vieques and El Seco), St. Thomas and St. John, using multibeam techniques to classify bottom habitats concurrent with split-beam fisheries acoustics to quantify and map biota in the water column. Maps of fish density provide a snapshot in time of fish distribution throughout the survey area. Repeated sampling at targeted fish aggregation sites, video from ROV surveys, review of echograms, and spatial analysis provide further insight into the location, timing and configuration of fishes.

Technically and logistically, there were no major conflicts between multibeam and fisheries acoustics surveys that would preclude running both operations simultaneously. Interference between the multibeam and split-beam systems, generally, was not a problem. Daytime hours were primarily dedicated to nearly stationary ROV operations for ground truthing of multibeam data, limiting the amount of fisheries acoustics data obtained during daylight hours. Options should be explored for developing procedures to utilize daytime surveys to determine species composition, interpreting the acoustic signal in regards to TS-fish length relationships for particular species, and examining fish behavior to aid in the interpretation of acoustic surveys. Incorporating ROV operations, diver surveys, high resolution sonar imaging, or other methods of ground truthing to determine species composition should be given ample consideration in survey planning. Regarding survey design, where multibeam mapping is given priority, multibeam tracklines are not necessarily the preferred design for fisheries acoustics surveys but still provide an excellent platform for mapping biological resources in the water column. Fisheries acoustics transects often are run perpendicular to ledges and several passes are made over features of interest to detect temporal and spatial patterns related to fish utilization of benthic habitats. In spite of these compromises, the ability to efficiently capture large amounts of data and produce maps of fish size and distribution concurrent with multibeam surveys facilitates the identification of highly productive habitats. Moving forward, testing options and developing procedures for incorporating supplemental survey techniques to validate the acoustic data is a top priority, as is standardizing procedures and documenting all stages of acoustic survey data development.

While limitations such as species identification exist, there are a variety of products that can be developed from fisheries acoustics surveys to assist resource managers. This document provides examples of the information that can be derived from fisheries acoustics surveys to characterize important habitats and points to further analyses that can be performed. For example, as habitat classification maps from multibeam become available, analyses testing the spatial relationships and scale at which benthic habitats are coupled with biology would provide resource managers tools to assist in delineating marine protected areas. Furthermore, analysis to quantify the configuration and spatial characteristics of fish schools may provide insight into questions of behavior and ecological strategies.

This report continues the discussion regarding the best methods for acquiring, processing, interpreting, and reporting data from fisheries acoustic surveys. The use of acoustics for mapping fish distributions presents unique challenges; and the implementation of these methods changes with the aim of each mission. The integration of fisheries acoustics and multibeam missions yields new opportunities when conducting concurrent water column and benthic mapping. Not only do integrated surveys leverage organizational resources, but they directly tie benthic habitat information with information on organisms using those habitats.

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Appendix A Data acquisition and processing

There are many steps involved in collecting and interpreting acoustic survey data. Options related to data acquisition, processing, mapping and reporting are dependent upon the study area, species of interest, operational priorities, and research and management questions. The process described in this document should be considered a starting point to be modified as conditions warrant. The entire process includes equipment preparation and calibration, data acquisition, data review and processing, data analysis, and map production and reporting. The survey methods reported here are suited to fisheries acoustics surveys conducted concurrent with multibeam mapping in the USVI and Puerto Rico in support of the Coral Reef Ecosystem benthic habitat mapping effort. These procedures can be applied to current and future data collected under the Coral Reef Conservation Program in the USVI and Caribbean, as well as other surveys conducted on the NOAA ship *Nancy Foster*, with regard for the needs and objectives of future missions.

Environmental and system configuration parameters

	2008 NF-08-01-USVI	2008 NF-08-06-SEAS	2009 NF09-01-USVI	2010 NF-10-03-USVI
Acoustic split-beam system	Biosonics DT-X	Simrad ES60 GPT; ES120-7C transducer	Simrad ES60 GPT; ES120-7C transducer	Simrad EK-60
Frequencies (kHz)	120	120	120	38//120
Calibration offset	0	0	0	0
Sound velocity (m/s)	1536.59	1540.73	1536.7	1541.0
Absorption (dB/m)	0.04924	0.0455984	0.0365207	0.0059821/0.446234
Threshold (dB) for collection (min/max)	-75/99	-70/99	-70/99	-70/99//-70/99
Pulse duration (ms)	.4	0.256	0.128	0.128 / 0.256
Ping per second repeat	6	8	8	8
Stop depth (m)	100	60	60	100
Beam width (deg)	7.4	7.0	7.0	7.0//7.0
Transmit power (W)	1000	500	500	600 / 500

Data processing parameters used to create Sv echograms, bottom detect algorithms and fish tracks in Echoview.

	2008 Biosonics	2008 Simrad	2009 Simrad	2010 Simrad
Parameters used to create Sv echograms				
Minimum Threshold (dB)	-66	-60	-60	-77
Maximum threshold (dB)	99	99	99	99
Minimum TS threshold (dB)	-60	-70	-70	-70
Parameters used in bottom detect algorithm				
Algorithm	best bottom candidate			
Start/Stop depth (m)	5/100	5/60	5/60	5/100
Minimum Sv for good pick (dB)	-70	-60	-60	-70
Backstep discrimination level (dB)	-50	-45	-45	-45
Backstep range (m)	-0.50	-0.01	-0.01	-0.01
Peak threshold (dB)	-50	-50	-50	-50
Maximum dropouts (samples)	2	2	2	2
Window radius (samples)	8	8	8	8
Minimum peak asymmetry	-1.0	-1.0	-1.0	-1.0
Parameters used to create fish tracks				
Algorithm	2D (range and time)			
Alpha	0.7			
Beta	0.5			
Exclusion distance (m)	0.1			
Missed ping expansion	0			
Range	40			
TS	0			
Ping gap	0			
Minimum number of single targets in a track	3			
Minimum number of pings in track (pings)	3			
Maximum gap between single targets (pings)	1			

Appendix B Links to cruise summaries

2010. NF-10-03 USVI. Characterization of Seafloor Habitats of the U.S. Caribbean
Cruise instructions:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/nf2010_cruise_plan.pdf
Mission webpage:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/nf2010.html

2009. NF-09-01-USVI. Characterization of seafloor habitats of Vieques, Puerto Rico
Cruise instructions:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF-09-01-USVI_Cruise_Plan.pdf
Mission summary:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF2009.pdf
Hydro survey report:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF-09-01_DAPR.pdf

2008. NF-08-04-USVI. Characterization of midwater seafloor habitats of western Puerto Rico
Cruise instructions:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF-08-04-USVICruise.pdf
Mission summary:
http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/pdf/NF2008.pdf

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