Acoustic Survey of Fishes in the Chukchi Sea Environmental Studies Program in 2012

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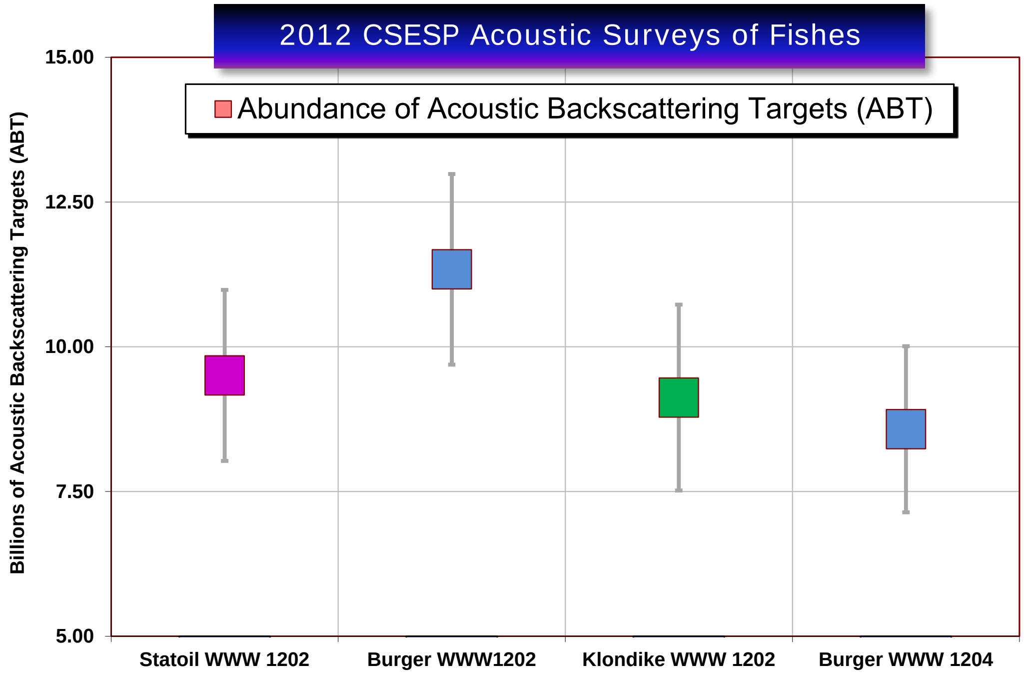
EXECUTIVE SUMMARY

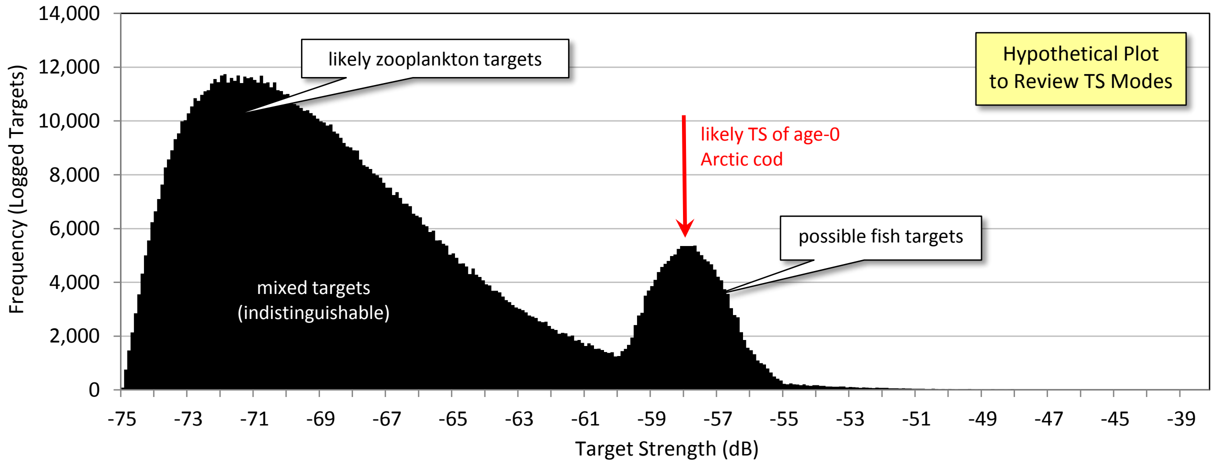
Acoustic fish data was collected on three cruises of the R/V *Westward Wind* from 16 August through 3 October, 2012 as part of the Chukchi Sea Environmental Studies Program (CSESP). The area surveyed covers a portion of Hanna Shoal in the Chukchi Sea with an area of special focus on three study areas at oil and natural gas lease sites (boxes) named Klondike, Burger and Statoil. The boxes are of highest interest to the project sponsors; ConocoPhilips (Klondike), Shell (Burger) and Statoil (Statoil). The entire study area (Greater Hanna Shoal Study Area), including the boxes, extends over a linear distance of ~200 nm, in an offshore region from west of Point Franklin to northwest of Point Barrow. It is ~75 nm wide (Figure 1). Natural Resources Consultants, Inc. (NRC) was contracted to summarize the compiled raw data which was obtained and initially processed by Aldrich Offshore Services (AOS).

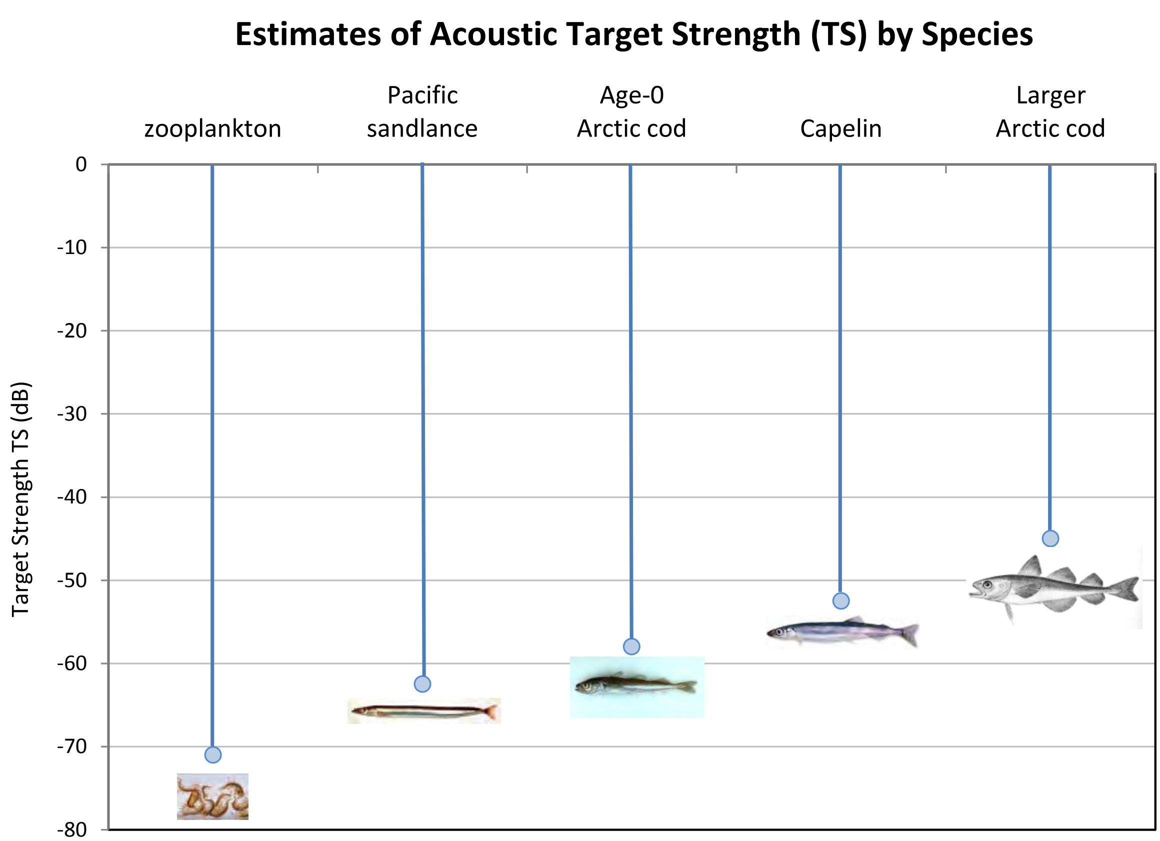
NRC summaries of acoustic target data show an important baseline can be established from the data collected during 2012 CSESP surveys. Organisms that were recorded as targets during the acoustic surveying were able to be quantified with relatively high precision and consistent methods, and should prove to be repeatable in future surveys in the area. A lack of information on target strength (TS) did not allow for specificity of quantified organisms to be completed at this time, but the systematic acoustic survey provided important data to begin building on the limited understanding of the presence and abundance of acoustic targets in the Chukchi Sea and GHS Study Area. Acoustic targets in this report are quantified as unspecified fish and invertebrates that were filtered during data processing to be included as verified targets in final summary data as acoustic backscattering targets (ABT). Acoustic backscatter is the amount of power scattered by a target in the direction of the transmitting transducer. Differences in the amount of power scattered by a target can allow for identification of that target.



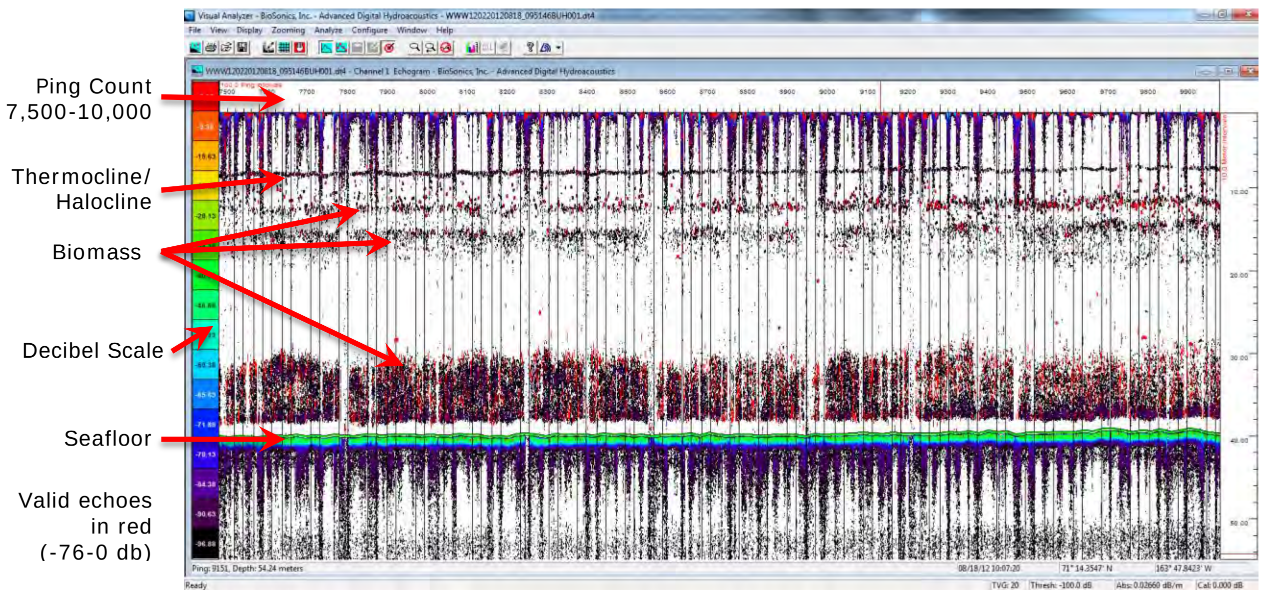
The figure above shows the estimates that were completed for abundance of ABT for each of the study boxes. Abundance estimates were completed for all three study boxes (Statoil, Burger and Klondike) from data collected during the first cruise (WWW1202), and for only the Burger Study Box from data collected during the third cruise (WWW1204). Abundance of ABT ranged from 8.6 $x10^9$ to 11.3 $x10^9$ targets and 95% confidence intervals were in the range of +/- 15%. The spatial distribution of measured ABT over the areas surveyed appears to exhibit low patchiness with only one potential high density area that was found in the Klondike box.

An evaluation of TS from individual acoustic target records was completed from recorded data to potentially apply TS separation to portions of the data. Frequency distributions of TS can show modes that may be indicators for groups of acoustic targets that have apparent spatial separation. We completed the review of TS with some expectation to see modes in the TS frequency distribution for specific use in identifying age-0 Arctic cod. The plot below shows a hypothetical frequency distribution from data similar to the 2012 CSESP acoustic data with a mode appearing around the expected TS range for identifying age-0 Arctic cod and other small fish. The large portion of the distribution is for lower TS values that correspond to mixed targets and to a mode at about -71 dB, which are likely zooplankton. The actual TS distributions reviewed are detailed further in the results and unfortunately did not show any modes to assist in using TS to identify fish aggregations, for finer scale spatial separation of data summaries, or for further specificity for abundance estimates by species. Some TS estimates available from prior Arctic fish research are also shown below.

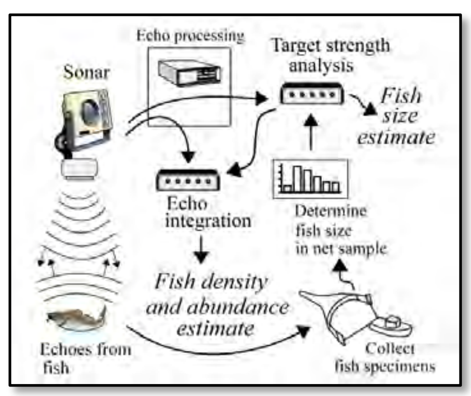




A BioSonics Inc. DT-X echo-sounder operated at 122 kHz and collected all acoustic data during surveying. Acoustic survey transects were sampled during most of the CSESP cruises although acquisition of usable summary data varied per cruise and area. Echograms from the data were reviewed concurrent with data processing and some data summaries, and data from some transects were not processed, although it was collected, because the data were found to be poor. Abundance estimation of targets was completed for all filtered data for areas and cruises with summary data at a high level of coverage (approximately 70%). An example echogram from processed data with identification of important parameters for filtering the initial data and summarizing the final data is shown below.



There are several important standards for conducting successful acoustic fish surveys. Full methodology is described below but the diagram (Crawford and Jorgenson 1996) here summarizes the main steps of fish acoustics and highlights what precautions or other steps need to be considered to end up with valid survey results when conditions are not ideal. Without a contemporaneous fishes survey to physically sample from acoustic targets, no information directly available from the 2012



CSESP surveys allowed for known target strengths (TS) to be applied to summaries. However, prior CSESP research in the Chukchi Sea and other Arctic research suggest that age-0 Arctic cod, capelin and jellyfish species may possibly be separated by TS, including applying TS information to data from prior surveys once some TS dynamics of specific fish targets in an area are better understood. TS for recorded ABTs during the 2012 CSESP surveys were evaluated for the various depths observed and by frequency distribution. There was no apparent separation of the TS range of interest by depth and no modal separation in frequency distributions. Relative densities expressed as targets per unit area (FPUA – which is targets per square meter) and abundance estimates are reported in ABT with no further application of TS to separate summaries by species.

The objectives of the CSESP acoustic survey of fishes in 2012 included:

1. Successfully recording of acoustic fish target data concurrent to other CSESP disciplines,
2. Processing raw acoustic target data according to standard methods to produce a composite database of all valid cruise data for immediate use and archives for future use,
3. Estimating abundance and biomass of acoustic organisms identified with as much specificity as possible.
4. Evaluating TS information recorded during surveying to assess if collected TS information is immediately useful or requires pairing with other surveys/TS information,
5. Establishing some baseline information within the study boxes that can be used as a reference for future acoustic surveys of fishes.

CSESP goals of building an understanding of baseline environmental conditions that exists prior to industrial development in the GHS Study Area were partially met by the completion of the acoustic survey of fishes in 2012. Important improvements were made over similar work completed in 2011, and identical methods described below can be used to process data from 2013 and beyond. Trends within ecosystems usually require many repeated experiments, surveys, documenting natural events, or other data points to make progress in understanding the dynamics of nature. Sponsor goals will be further met by continuation of CSESP acoustic surveying of fishes and subsequent data summaries. For further understanding of the general summary of methods and utility of resulting data, several slides are attached at the end of this report.

INTRODUCTION

Recent sales of oil and natural gas (ONG) resource lease-sites in the Arctic have spurred exploration, research, and interest to access those resources. The Chukchi Sea Environmental Studies Program (CSESP) has collected data on oceanographic and biological resources in the northeastern Chukchi Sea since 2008 with the goal of improving understanding of baseline environmental conditions that exists prior to industrial development. The development of infrastructure, drilling, and production in the study area is pending. The CSESP studies (2008−present) are yielding important information that will be useful for both state and federal agencies that are responsible for both permitting and managing the natural resources in the Arctic.

Natural Resources Consultants, Inc. (NRC) was contracted by Olgoonik Fairweather, LLC to complete summaries of acoustic data acquired during surveys conducted in 2012 in an oil and gas lease area in the northeastern Chukchi Sea. The acoustic survey methodology and data collection followed prior CSESP acoustic surveys and was completed by Aldrich Offshore Services (AOS). Raw acoustic data collected were processed by AOS and provided to NRC for analysis, summarization and reporting. The proposed summary by NRC was to provide estimates of relative abundance and biomass of targets organisms, if possible, by species or species group (when verifiable) within the study area. Results in this report provide relative densities of measured acoustic targets and abundance estimates, but not to the species level. The spatial dynamics of the unspecified acoustic data, however, do show some important trends and relationships with other CSESP data. This report provides a brief description of methods for data collection, analyses and reporting. It also provides results, discussion of the results and our conclusions and recommendations for further acoustic survey work that may continue as part of CSESP research. References cited are not exhaustive, but several relevant research summaries of fisheries acoustics are included.

The entire survey area is known as the Greater Hanna Shoal (GHS) Study Area, ~11,000 NM^2, within which greater sampling effort focused on three study-area boxes (Klondike, Burger, and Statoil). Of the three prospect areas in the northeastern Chukchi two of them, Klondike and Burger, are of similar size and configuration. Each is 30x30 nm and both include 16 north-south primary transect lines and 15 north-south secondary transect lines (for marine mammal and seabird surveys). The Statoil Study Box is adjacent to the northwest corner of Burger and also includes an area of approximately 900 square nm. However, it is of irregular shape having a maximum length of 30 nm north-south and 37.5 nm east-west. Statoil includes 19 high priority transect lines, and 19 low priority transect lines. The transitional area between the northeast corner of Klondike and the southwest corner of Burger was identified in 2009 as an area of significant scientific variance. Science cruise 1 (WWW1202) was conducted from August 15 through August 27; science cruise 2 (WWW1203) was conducted from August 31 through September 16; science cruise 3 (WWW1204) was conducted from September 17 through October 4.

Acoustic surveys to identify and quantify organisms have evolved greatly since their inception but some principles pertinent to conducting accurate, reliable and repeatable surveys remain the same. Ongoing research on the physics of sound in water has been paralleled by improvements in marine technology, electronics and computers – all lending to improving the ability to quantify distribution and abundance of fish deep under the surface with sound. Standard operating procedures for acoustic surveys still rely, however, on a few key principles to direct successful surveys. Those principles include: choosing a deployment method, choosing a suitable survey design, calibrating the echo-sounder instrumentation, testing the echo-sounder in the survey environment in the proximity of other machinery or instruments, testing the echo-sounder's sensitivity to vessel speed, recording passive data while at survey speed (i.e. not emitting energy and setting the transducer to "listen" only), and collecting stationary data to test for bubble attenuation and to measure the range of target strength (TS) values from a single fish (Parker-Stetter et al. 2009) in order to ground truth the future data collected.

Collecting data on known targets allows for future data correlation and increased detail in abundance estimates. Acoustic surveys of fishes face a variety of challenges to obtain usable data and end up with quantifiable results that are reliable - especially when the survey is in a new area and little is known about the fish resources. The CSESP research has addressed most of these issues as much as possible while conducting their acoustic surveys to date. Some improvements have been made and current methods are closer to standards, with some known sources of uncertainty.

METHODS

DATA COLLECTION

Vessel and Recording Logistics

This CSESP acoustic survey program ran from 15 August 2012 through 2 October 2012, in conjunction with physical, biological, and chemical studies simultaneously conducted onboard the R/V *Westward Wind*. Because the acoustic survey was done on an opportunistic basis, complete coverage of the study area was not possible. Most of the area sampled was along and concurrent with the bird and mammal survey transects and sometimes passed over the benthic and zooplankton sampling stations as well as being run concurrently with benthic and zooplankton sampling during the night operations. Vessel speed during data collection was preferably 7.5 to 8.0 knots. Transects completed at night time and those with vessel speeds higher or lower than the target speed were expected to have some data omitted. Some limiting factors were anticipated during collection of the acoustic data including rough weather and required changes in vessel speed. Vessel speed changes were required when the vessel turned and where new transects began. Before data acquisition began the system was powered on and tested multiple times, in order to optimize the quality of data recorded. To verify accuracy the transducer was calibrated, per manufacturer specifications, prior to data acquisition and after completion of the survey.

Acoustic Survey Instruments & Software

The echo-sounder used during 2012 CSESP acoustic surveys was the same as used during 2011 CSESP surveys - a BioSonics Inc. DT-X. Transducer frequency was 122 kHz, transmit source level was 220.7 dB/uPa, and receive sensitivity was -48.2 dBC/uPa. The beam width was 7.4 degrees. In 2012 the transducer was mounted from a fixed bracket off the port side, mid-ship, adjacent to a crane pedestal. This was a change from prior CSESP surveys during which a tow fish was used for transducer deployment.

BioSonics Inc. software (Visual Analyzer and Visual Acquisition) were used for collecting and processing all 2012 CSESP acoustic data (BioSonics 2004). Since this survey was undertaken to measure total abundance of targeted organisms, if possible, most of the settings were not manipulated during data acquisition. Acoustic target data is measured in negative decibels and the lower data threshold used for collection was -130 dB. The entire range of target data available for collection encompasses all target signals from 0 to -130 dB. The depth range of data collection started 1 meter below the echo-sounder transducer, ending well below the sea floor. These settings were chosen to ensure that no boat wake or other surface interruption was being recorded which could inadvertently skew the data. The depth range extended beyond the sea floor in order to ensure that the sea floor was recognized and included in the data collection.

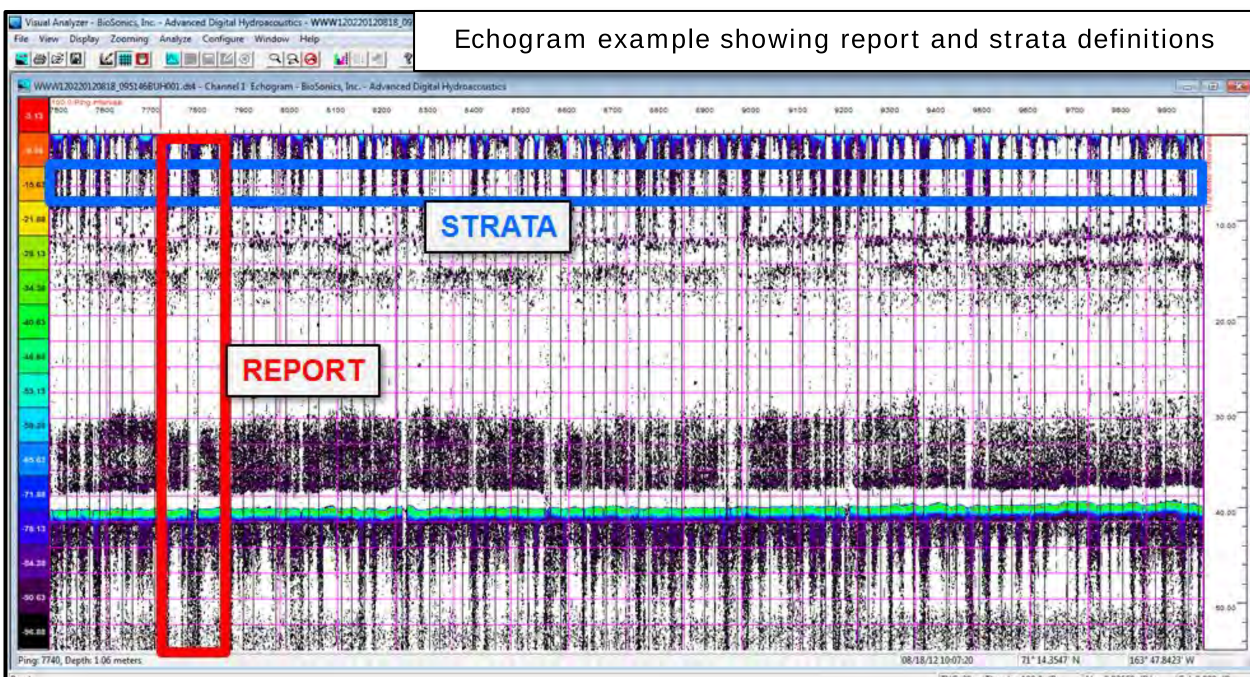
Ping rates from the transducer varied from 10 to 15.15 pings per second (pps) with the majority of the data collected at 15.15 pps. A standard water temperature, salinity, and sound velocity of 4^0 C, 31 ppt, and 1461.55 m/s, respectively, were used during data collection. Visual Acquisition software used these values to compute sound speed and absorption coefficient. These values are important because the absorption coefficient is the rate of absorption per unit distance. The absorption coefficient gives the attenuation of the sound level in dB/m during the transmission of the signal through water. The Visual Acquisition software automatically ends each compiled data file after 30 minutes of data collection. Each data file was 30 minutes long unless ended before the 30 minute period was reached. With the variable ping rates, there was a range from approximately 13,000 pings to approximately 24,000 pings per file. Compiled data files were consistently identified and archived following a scheme that included vessel name, cruise name and date, local time, transect line surveyed and the file type. Each processed file could then be tracked by its filename to raw files with the same root name.

DATA PROCESSING

Processing Acoustic Summary Files

Several important steps which are documented in the BioSonics Inc. software were followed for data processing methods and some additional details are available from CSESP data acquisition reporting. Summary of the preliminary and final processed 30-minute data files was an iterative process. This process followed consistent methodology but required some changes to acoustic processing parameters. Bottom tracking and identification required a blanking area of 50 cm above sea floor to be input. This is referred to as the dead zone and is the volume of the transducer beam where echoes from the sea floor overlap echoes from near-bottom targets. Some acoustic interference near the surface required the minimum depth limit near the surface to be set to 4 meters. This was approximately 2.5 meters below the transducer which was mounted 1.5 meters below the surface. Some files required data to be excluded down to 10 meters depth to remove interference. Based on information known about likely species target strengths, the summary of echo recognition for final processed data was completed using a lower threshold of -76 dB, meaning that targets with a target strength ranging from 0 to -76 dB were analyzed. This value was also used to exclude other noise in the files such as vessel noise and other echo-sounder noise in an attempt to only analyze echoes that were being generated from organisms within the water column. A review of preliminary composite results (all of the 30-minute files combined) was completed three times to verify the ranges of expected values of the metrics for acoustic back scattering targets - "Fish per Unit Area" (FPUA), and the distribution of measured target strengths (TS). All counts of acoustic targets were completed following

BioSonics Inc. Visual Analyzer standard echo integration, not single target counting methods. Echo integration was chosen as the analysis technique after visually inspecting the collected echograms. Echo integration methodology is used to relate measured energy return for a given volume of water to estimate fish populations. The average energy of each user defined bin was scaled by environmental and calibration parameters to provide an estimate of backscattering strength (Sv). This allowed for a mean backscattering cross section value to be obtained for each stratum (a user defined delineation of section throughout the water column based on depth). The backscattering cross section was then applied to each stratum to estimate the absolute density of fish or Fish Per Cubic Meter (FPCM). Finally, the absolute density of each report (user defined delineation of sections across the file based on distance) is multiplied by the interval thickness, or stratum) and then multiplied by the proportion of the interval sampled to produce the estimate of fish in the water column or FPUA. The final parameters for processing were to choose the number of reports and strata for each output file. This created a grid of the file where reports represented the distance traveled per report and the strata represented the depth category. For final processing, a 20 X 20 grid (20 reports and 20 strata) was chosen to summarize the data (see echogram below).



Echogram example showing report and strata definitions

The 20 x 20 grid was used consistently throughout all data processing, even for short files, in order to maintain consistency for data manipulation in the working databases. All data files were combined into two working databases; one for review and summary of measured target densities and one for review and summary of measured target strengths.

Biological Information and Summary

The final data summarized from the processed database provided densities of acoustic backscattering organisms that are representative of fish and invertebrates showing as echoes. Two metrics were provided in the summary outputs from the acoustic data processing software; our summaries focus on one of those (FPUA) that represents the measure of fish or targets identified/unit area (targets per square meter). Our application and analysis of target strength (TS) by species is limited in this report, but is provided here for further clarification of acoustic back scatterers that are potentially comprised of fish and not jellies. Our methods for summary of TS per species rely on information that age-0 Arctic cod (the likely fish target in the GHS Study Area) have a target strength of -58 to -55 dB (Parker-Stetter et al. 2011). Further information on TS of different species was available from unpublished NOAA fisheries survey results that were obtained in the Chukchi Sea in 2012, in proximity to 2012 CSESP surveys. NOAA measured target strengths (from trawl sampling) that are also used to inform our review of some processed acoustic target strengths (DeRobertis pers. comm. 2013).

Although hardware and software are different for CSESP and NOAA acoustic fish surveys in the Chukchi Sea, NRC summaries of CSESP acoustic data follow NOAA methods as much as possible (NOAA 2013). Final methods for biological summary were planned to include detailed coordination of NOAA and CSESP acoustic summaries, overlaying comparative acoustic survey results for NOAA and CSESP acoustic survey of fishes.

DATA ANALYSIS

Six summary databases were developed (two for each 2012 CSESP cruise) based on an aggregation of all 30-minute acoustic summary reports (Table 1). Three summary databases were developed from approximately 1,200 transect summary reports that provide summary for both horizontal and vertical distribution of acoustic information recorded. The aggregated summary report database is a flat file with 159,600 records for all reports (horizontal summary) and strata (depth summary) (Table 2). Three other files were also assembled from target strength distribution summaries by depth.

Abundance Estimation

Methods for abundance estimation relied on the echo-integration outputs from the BioSonics Inc. software and followed methods of summation over a rectangular grid (Dalen and Nakken 1983; Simmonds and MacLennan 1988, 2005; Johanneson and Mitson 1983). The FPUA value from each summary file represented a measured density of acoustic backscattering targets (ABT). This measured density included everything that was counted as an echo-integrated target after all filtering and was estimated by the BioSonics software in targets per square meter. No definitive identification of species was completed during processing of survey data and ABT includes all species that provided an acoustic backscatter to register as a target. Each summary file FPUA value was expanded by calculating the transit distance for that summary multiplied by the width of the transducer swath across the seabed – which was then multiplied by the FPUA value to provide an estimate of abundance for the area covered. A summary grid was developed to aggregate the acoustic summary files into a set of 381 cells, each measuring 100 square km (Figure 1). All transect summaries that fell within a cell were grouped and the average acoustic target density (FPUA) value was computed. The average FPUA value was expanded across the cell area to provide estimates of abundance of ABT per cell. Each cell in the Statoil, Burger and Klondike Study Boxes were summed per area to yield a study-area estimate of ABT. Abundance estimation for each study box is dependent on coverage from acoustic transects and the collection of viable summary data.

Target Strength Evaluation

The 2012 CSESP acoustic surveys of fishes did not sample with physical methods to verify acoustic targets. Target strength (TS) was measured by the transducer and recorded in two files by BioSonics Inc. software – the composite output files and a separate text log of all targets recorded during surveying. NRC summaries include a review of TS distribution by depth strata and a modal evaluation of TS frequency distributions from a subsample of the individual target log.

RESULTS

LOGISTICS & DATA PROCESSING

In 2012, CSESP acoustic surveys of fishes were conducted over 44 days, accounting for approximately 528 h of acoustic sampling covering the GHS Study Area and Statoil, Burger and Klondike Study Boxes (Figure 2). The collection of acoustic data during the surveys was successful and better stability with the fixed transducer mount provided higher quality data than prior CSESP acoustic surveys. The BioSonics transducer performed consistently with approximately 30 million pings during surveying, more than 10 million individual targets were logged by TS, and approximately 1,200 transect reports were recorded, processed and assembled to provide a summary database with 159,600 summary records.

The collection of viable acoustic summary data varied for each cruise and area covered (Figure 3). The first cruise (WWW1202) accounted for 43% of all viable data and most of the data available for abundance estimation within the Statoil, Burger and Klondike Study Boxes. Acoustic survey summary data covered 83% of the summary grid cells in the Statoil, Burger and Klondike Study Boxes (92 of 111) during the first cruise. The coverage for the second and third cruises (WWW1203 and WWW1204) was much lower than for the first cruise. For WWW1203, 19, 9, and 19 summary grid cells were covered in Statoil, Burger and Klondike Study Boxes, respectively. There were 52 summary grid cells with data from WWW1203 in transition area stations within the GHS study area. For WWW1204, 4, 25, and 3 summary grid cells were covered in Statoil, Burger and Klondike Study Boxes, respectively. There were 33 summary grid cells with viable summary data from WWW1204 in transition area stations within the GHS study area.

The difference between initial acoustic transect coverage and resulting viable acoustic summary data was due to some significant filtering of data during processing. Turbulence and bubble attenuation near the transducer were directly related to weather which was a significant limiting factor for data acquisition when rough sea conditions increased turbulence near the transducer. More collected data was filtered out from the second and third cruises when weather was more severe, influencing acoustic data collection. Not all data collected during night operations were usable. Occasionally the echo-sounder was left collecting data while the vessel was stationary. The data collected between sampling stations was useable and often collected off the survey transects. Some transects were run at slower speeds. The average speed for daylight hours during cruise WWW1203 and WWW1204 was ~5 m/s. Some visual analysis during data processing of acoustic summary screens showed unknown sources of interference which were likely related to other instrumentation running on the research vessel. Some segments of these transects showed erroneous acoustic data and were also omitted from the final summary. A thorough review of the acoustic interference in the shallow water layer during processing also led to some data omission. The final summary data outputs were completed with an exclusion of the top portion of the water-column down to 4 meters for most transects. For some transects, data was excluded for up to 10 meters below the transducer due to surface interference

DATA ANALYSIS & ABUNDANCE ESTIMATION

From the acoustic summary data for each cruise, the relative density (FPUA) at each summary file location was plotted by its recorded positional information within the GHS study area to provide visual inspection of the data (Figures 4-6). An initial review of TS strengths by depth strata for all cruises showed the highest frequency of specific TS ranges of interest were found to be in the deeper water surveyed (~25-45m). Plots of relative density include an overlay from CSESP CTD temperature plots for each cruise to evaluate apparent relationships between measured target density and near bottom water temperatures. Plotting of initial viable data revealed sufficient coverage for cruise WWW1202 for abundance estimation in all three study boxes (Klondike, Burger and Statoil). Viable data coverage for WWW1203 was not sufficient for abundance estimation and for WWW1204 coverage allowed for abundance estimation for the Burger Study Box alone.

Abundance estimation was completed using a standard summary grid where all summary file values of FPUA that fell within a cell grid were averaged and then multiplied by the area of the grid to expand to total targets. Expanded abundance of ABT for each grid cell in each cruise was plotted (Figures 7-9). For all cruises, the scale for the expanded abundance was standardized for comparison of cell values across cruises. The transect lines (accumulated dots for each report) are also plotted to coincide with the grid cells they fall in. Abundance estimation was reviewed for nine possible area-cruises, one for each cruise for Statoil, Burger and Klondike Study Boxes. If coverage reached 70% of grid cells then abundance was estimated. The level of viable data coverage for all cells in all cruises allowed for 4 out of 9 abundance estimates to be completed; 3 for cruise WWW1202, 0 for cruise WWW1203 and 1 for cruise WWW1204. For the abundance estimates in the area-cruises completed, there were some grid cells without average FPUA values (i.e. no transect coverage across the cell). For those cells, adjacent grid cell average FPUA values were used to assign a FPUA value. Table 3 (WWW 1202) and Table 5 (WWW 1205) report the number of grid cells without FPUA average values and Figure 7 (WWW 1202) and Figure 9 (WWW 1204) show these grid cells inside the study boxes as empty cells.

Abundance estimates for cruise WWW1202 showed that total ABT ranged from about 9 to 11 billion, with 95% confidence intervals (CI) of about +/- 15% (Table

3). Approximately 1,000 summary records were used to compute abundance estimates in all three study boxes during this cruise. The Burger Study Box had the highest abundance estimate at 11.339 x 10^9 ABT and the lowest CI at +/- 14%. Statoil and Klondike Study Boxes had abundances of 9.506 x 10^9 and 9.122 x 10^9 ABT, respectively. For cruise WWW1203, no abundance estimates were able to be completed due to low grid coverage (25-52%) and therefore inadequate (Table 4).

The fourth abundance estimate was for the Burger Study Box, based on data collected during cruise WWW1204. Summary grid cell coverage with suitable data was nearly 70% from (25 of 36 summary grid cells). The abundance estimate for the Burger Study Box on cruise WWW1204 was 8.576 x 10^9 ABT with a 95% CI of +/- 17% (Table 5). This abundance estimate was 24% lower than the Burger Study Box estimate from data collected on cruise WWW1202.

TARGET STRENGTH ANALYSIS & REVIEW

Target strength information from two specific BioSonics Inc. summary outputs was summarized and reviewed. The first summary provided information to evaluate depth dependent target distributions and to determine if results near the TS range of interest (-55 dB to -65dB) would show separation of TS by depth strata. The second summary provided an expansive log of all targets recorded by target strength that was summarized to see if TS frequency distributions showed multiple modes, including modes near TS ranges of interest. Both reviews were completed as further detailed below, and neither supported a further use of TS information to refine abundance estimates by species (i.e. split out total ABT into age-0 Arctic cod and other targets)

The BioSonics Inc. processed files categorized TS levels into two dB increments in files separated by depth strata. We plotted TS values from the first cruise, with the most complete data, in the three study boxes within the GHS Study Area by depth strata (Figure 10). The purple line represents TS of -58 dB and does not show a relative difference from other TS plots by depth. If there had been a difference in the average depth of this TS range then a further, smaller spatial scale data summary could be reviewed to locate likely fish targets within the survey data. The Figure 10 plot shows the TS range where age-0 Arctic cod would be evident from acoustic backscatter is mixed with other TS values near it (at both low frequency for shallower depths, and high frequency for deeper depths).

A second review of possible separation in TS was completed by plotting about 45% of all individual TS values logged during the first cruise to evaluate possible modes in TS frequency distribution (Figure 11). If there were modes in a plot of TS frequency distribution (as depicted in hypothetical TS plot in Executive Summary), then a smaller spatial scale data summary could be reviewed to locate likely fish targets within the survey data, and potentially further refine abundance estimation. More than 5 million TS records plotted sequentially show a very smooth distribution, skewed toward the lower processing TS threshold value of -76 dB, in each case with a single mode around -71 dB. Figure 11 also includes a red arrow in each frequency distribution at the -58 dB TS value, showing that no TS value near -58 dB is modal.

DISCUSSION

Both the abundance estimation and the TS results from 2012 CSESP acoustic surveys of fishes show some promise toward acoustic monitoring of fish and invertebrate species in the GHS Study Area in the Chukchi Sea. CSESP surveys are multi-disciplinary to take advantage of the limited research window in the Arctic which can be problematic for the consistency of acoustic methods utilized. Some interference from the vessel noise or other instruments and machinery on the vessel may have caused some data loss in 2012. The changes to the hardware mounting in 2012 appear to have increased the quantity and quality of data collected but some transects completed still did not yield viable data, and 5 of 9 abundance estimates for area-cruises could not be completed. The completion of the Burger Study Box abundance estimates from two cruises is a useful starting point to evaluate changes across and within a study area of interest.

The summary grid was developed to allow for straight forward analyses of acoustic transect data where no elaborate or subjective interpolation steps are involved. A number of grid cell sizes were created and reviewed for coverage of transects and to determine how the summary files might be grouped at different grid sizes. The final grid with 10 km grid edges and 381 grid cells closely overlaps the GHS Study Area. There were one or two north-south transect lines per cell. Grid cell sizes could be changed easily for future reporting and easily applied to historical data.

The primary metric from the BioSonics Inc. software was an acoustic target density expressed in fish per unit area (FPUA). This metric was reviewed closely during three iterations of data processing. A brief review of preliminary compiled data from early processing by BioSonics personnel recommended re-processing data to filter FPUA outputs at lower values to improve accuracy of the overall data. For the final summary data, only a very small percentage of FPUA values were higher than 10 targets per unit area – a threshold of higher uncertainty noted by BioSonics where the processing software is counting erroneous data as valid targets. FPUA values in the processed data approached but did not reach zero. There were always acoustic backscatter items that were counted as echo-integrated targets to bring the FPUA integrated average completed, over the reporting period (the 30 minute files), above zero. Confidence intervals around the completed abundance estimates show relatively good precision and reflect low patchiness and few high density areas. Only one possible high density area appears from visual inspection of processed data in the southwest portion of Klondike Study Box during cruise WWW1202 (summary grid cell 2—7).

Interpretation about target strength is limited in any acoustic survey where no pelagic survey trawl is utilized to verify species in the water-column (McClatchie et al. 2000, Foote 1987). From prior CSESP research, Arctic cod in the GHS Study Area are mostly age-0 and very small. Jelly species make up a large proportion of the few pelagic trawl tows that have been completed. The nearest other systematic acoustic survey of fish suggested that the best estimate for TS of age-0 Arctic cod is -58 dB, but can range from -55 dB to -60 dB (Parker-Stetter et al. 2011).

Acoustic surveys undertaken by NOAA suggest that age-0 Arctic cod and jellies overlap significantly in TS ranges -55 dB to -65 dB and that assignment of acoustic signal strength can be difficult (DeRobertis 2013). Other research reiterates the compounded difficulty when the TS of jelly species overlap with that of TS ranges for fish species and the survey environment has a high proportion of jellies (Colombo et al. 2009, Klevjer et al. 2009). The frequency distribution plots of TS completed for this summary suggest that no reliable species separation of TS can be done at this time.

CONCLUSIONS AND RECOMMENDATIONS

The summaries completed by NRC for 2012 CSESP fish surveys are for all ABT and are not separated by species. It can be assumed that ABTs are comprised of mostly jellies, some Arctic cod and likely a few capelin. Future application of TS information to these data could be done with TS measurements taken from trawl surveys used closely during reprocessing of raw acoustic data, including visual inspection of acoustic displays, otherwise, results could be grossly inaccurate. Regardless, the TS frequency distributions, normal distributions of FPUA values and the relatively low confidence intervals around the abundance estimates completed suggest that the measured ABT from 2012 CSESP acoustic fish surveys were quantified successfully. The acoustic data collected, processed and summarized is useful as a basis for future comparisons completed using similar methods. Reliable data coverage is directly related to consistent collection and processing methods where problems are minimized (DeRobertis et al. 2008, Ona and Traynor 1990). The R/V *Westward Wind* cruises in 2012 CSESP methodology for acoustic surveys of fish was improved, more area was surveyed and more high quality data was acquired.

The CSESP's broad coverage and relatively high sampling density over the GHS Study Area, from past and future acoustic surveys of fishes will be important in establishing some larger scale and more defensible baselines for the abundance and biomass of fishes and other species in the water-column. NOAA's recent presence in the Chukchi and commitment to survey Arctic areas is very coarse in comparison and may have less utility identifying smaller spatial dynamics. However, coordinating with their surveys, data processing and comparison of results should be more closely pursued as even small pieces of information with minimal overlap may prove useful toward CSESP goals. As participants in CSESP sampling and reporting in 2011–2013, we recognize that the acoustic monitoring of the abundance and biomass of fishes in the northeastern Chukchi Sea, with or without trawls, are providing valuable information toward sponsor goals. In the bigger picture of sponsor goals and environmental monitoring of the Chukchi lease sites, we would recommend that continued acoustic fish surveying will help to complete the picture of the ecosystem, regardless of some uncertainties inherent in acoustic data collection.

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Table 1. Example of acoustic survey data summary outputs from BioSonics Inc. software from data collected during CSESP acoustic survey of fishes, 2012.

HORIZONTAL INTEGRATION RESULTS

REPORT	TIME AND DATE	Depth	Latitude	Longitude	Sv (dB)	Applied Sigma	FPUA
1	09/01/12 09:19:10	43.71			-5.81E+01	3.01E-06	7.78
2	09/01/12 09:20:40	43.82	70° 45.8111' N	164° 12.1022' W	-5.64E+01	3.01E-06	10.76
3	09/01/12 09:22:10	43.83	70° 45.9901' N	164° 12.1039' W	-5.54E+01	3.01E-06	13.27
4	09/01/12 09:23:40	43.97	70° 46.1658' N	164° 12.0983' W	-5.57E+01	3.01E-06	10.65
5	09/01/12 09:25:10	44.04	70° 46.3443' N	164° 12.1028' W	-5.64E+01	3.01E-06	10.58
6	09/01/12 09:26:40	43.79	70° 46.5245' N	164° 12.0855' W	-5.56E+01	3.01E-06	12.67
7	09/01/12 09:28:10	43.71	70° 46.7080' N	164° 12.0958' W	-5.66E+01	3.01E-06	10.16
8	09/01/12 09:29:40	43.47	70° 46.8831' N	164° 12.0912' W	-5.75E+01	3.01E-06	8.31
9	09/01/12 09:31:10	43.12	70° 47.0668' N	164° 12.0706' W	-5.95E+01	3.01E-06	5.38
10	09/01/12 09:32:40	43.01	70° 47.2432' N	164° 12.0457' W	-5.65E+01	3.01E-06	10.5
11	09/01/12 09:34:10	42.91	70° 47.4174' N	164° 12.0260' W	-5.81E+01	3.01E-06	7.25
12	09/01/12 09:35:40	43	70° 47.5932' N	164° 12.0294' W	-5.65E+01	3.01E-06	10.58
13	09/01/12 09:37:10	43.37	70° 47.7636' N	164° 12.0452' W	-5.80E+01	3.01E-06	7.47
14	09/01/12 09:38:40	43.64	70° 47.9361' N	164° 12.0411' W	-5.60E+01	3.01E-06	11.62
15	09/01/12 09:40:10	43.63	70° 48.1119' N	164° 12.0225' W	-5.78E+01	3.01E-06	7.97
16	09/01/12 09:41:40	43.81	70° 48.2881' N	164° 12.0328' W	-5.94E+01	3.01E-06	6.03
17	09/01/12 09:43:10	43.75	70° 48.4641' N	164° 12.0066' W	-5.72E+01	3.01E-06	9.04
18	09/01/12 09:44:40	43.53	70° 48.6357' N	164° 11.9988' W	-5.75E+01	3.01E-06	8.41
19	09/01/12 09:46:10	43.38	70° 48.8096' N	164° 11.9800' W	-5.83E+01	3.01E-06	6.99
20	09/01/12 09:47:40	43.43	70° 48.9856' N	164° 11.9684' W	-5.67E+01	3.01E-06	9.88

VERTICAL INTEGRATION RESULTS

STRATA	TOP	BOTTOM	Sv (dB)	Applied Sigma	FPCM
1	1.99	4.63	-4.42E+01	1.20E-05	3.1831
2	4.63	7.28	-6.06E+01	6.20E-06	0.1397
3	7.28	9.94	-7.03E+01	2.35E-06	0.0401
4	9.94	12.58	-7.25E+01	2.22E-06	0.0252
5	12.58	15.24	-7.50E+01	2.03E-06	0.0155
6	15.24	17.88	-7.77E+01	2.55E-06	0.0066
7	17.88	20.54	-7.92E+01	3.03E-06	0.004
8	20.54	23.19	-7.75E+01	1.97E-06	0.009
9	23.19	25.85	-7.73E+01	1.80E-06	0.0103
10	25.85	28.49	-8.04E+01	1.71E-06	0.0053
11	28.49	31.13	-8.16E+01	1.86E-06	0.0037
12	31.13	33.79	-8.22E+01	1.58E-06	0.0038
13	33.79	36.44	-8.07E+01	1.63E-06	0.0052
14	36.44	39.1	-7.52E+01	2.21E-06	0.0136
15	39.1	41.74	-7.40E+01	3.31E-06	0.012
16	41.74	44.4	-7.15E+01	1.72E-06	0.0411
17	44.4	47.04	-6.46E+01	1.00E+00	0
18	47.04	49.7	0.00E+00	1.00E+00	0
19	49.7	52.34	0.00E+00	1.00E+00	0
20	52.34	54.99	0.00E+00	1.00E+00	0

TARGET STRENGTH DISTRIBUTION

STRATA	Found Targets	Sigma	Average TS
1	4192	1.20E-05	-53.61
2	1072	6.20E-06	-55.69
3	318	2.35E-06	-57.22
4	772	2.22E-06	-57.44
5	758	2.03E-06	-57.63
6	444	2.55E-06	-57.41
7	215	3.03E-06	-57.14
8	314	1.97E-06	-57.72
9	413	1.80E-06	-58.07
10	117	1.71E-06	-58.1
11	98	1.86E-06	-57.81
12	66	1.58E-06	-58.37
13	147	1.63E-06	-58.34
14	3435	2.21E-06	-57.35
15	4574	3.31E-06	-55.99
16	70	1.72E-06	-58.04
17	0	1.00E+00	0
18	0	1.00E+00	0
19	0	1.00E+00	0
20	0	1.00E+00	0

Table 2. Example of compiled database of acoustic fish target densities (FPUA) from BioSonics Inc. software from data collected during CSESP acoustic survey of fishes, 2012.

Report	Strata	Date Time	BtmDepth	Latitude	Longitude	Sv(dB)	Applied Sigma	FPUA	AvgDepth_m	FPCM	TopDepth	BottomDepth	Cruise
1	1	08/15/12 14:36:32	40.54	71.53922	-162.5124767	-8.13E+01	1.72E-07	2.0400	5.125	1.36E-01	3.98	6.27	1202
20	1	09/15/12 13:07:45	47.47	71.68812833	-160.1981383	-8.02E+01	3.25E-07	2.0000	7.46	2.52E-01	5.99	8.93	1203
1	1	09/19/12 15:38:10	38.4	71.60978333	-163.1933017	-7.87E+01	2.97E-07	2.5300	7.22	1.82E-01	6	8.44	1204
2	1	08/15/12 14:36:41	40.64	71.53922	-162.5124767	-7.66E+01	1.72E-07	4.6000	5.125	9.29E-01	3.98	6.27	1202
19	1	09/15/12 13:06:47	47.4	71.69028333	-160.1980617	-7.00E+01	3.25E-07	3.5700	7.46	2.38E-01	5.99	8.93	1203
2	1	09/19/12 15:39:40	38.36	71.60978333	-163.1933017	-7.88E+01	2.97E-07	2.5000	7.22	2.14E-01	6	8.44	1204
3	1	08/15/12 14:36:49	40.59	71.53953167	-162.512715	-8.28E+01	1.72E-07	1.4900	5.125	6.50E-02	3.98	6.27	1202
18	1	09/15/12 13:05:50	48.1	71.692425	-160.197435	-7.45E+01	3.25E-07	3.4000	7.46	1.77E-01	5.99	8.93	1203
3	1	09/19/12 15:41:10	38.28	71.60648667	-163.19357	-7.86E+01	2.97E-07	2.3600	7.22	2.00E-01	6	8.44	1204
4	1	08/15/12 14:36:58	40.8	71.53989	-162.5129317	-6.73E+01	1.72E-07	8.6100	5.125	2.83E-01	3.98	6.27	1202
17	1	09/15/12 13:04:53	47.45	71.69458	-160.19678	-7.67E+01	3.25E-07	2.5000	7.46	2.53E-01	5.99	8.93	1203
4	1	09/19/12 15:42:40	37.96	71.60321667	-163.1936467	-7.08E+01	2.97E-07	2.6400	7.22	2.34E-01	6	8.44	1204
5	1	08/15/12 14:37:06	40.71	71.54021	-162.5131017	-7.69E+01	1.72E-07	3.3700	5.125	6.44E-01	3.98	6.27	1202
16	1	09/15/12 13:03:55	46.98	71.69675167	-160.1960133	-7.89E+01	3.25E-07	2.5600	7.46	3.79E-01	5.99	8.93	1203
5	1	09/19/12 15:44:10	38.15	71.599935	-163.193575	-7.86E+01	2.97E-07	1.8900	7.22	1.16E-01	6	8.44	1204
6	1	08/15/12 14:37:15	40.74	71.54057	-162.5132717	-8.08E+01	1.72E-07	2.1000	5.125	2.16E-01	3.98	6.27	1202
15	1	09/15/12 13:02:58	47.7	71.69889833	-160.1952767	-8.04E+01	3.25E-07	1.9200	7.46	2.18E-01	5.99	8.93	1203
6	1	09/19/12 15:45:40	38.45	71.59669	-163.1940983	-7.69E+01	2.97E-07	2.4000	7.22	1.28E-01	6	8.44	1204
7	1	08/15/12 14:37:24	40.69	71.54092667	-162.51346	-8.02E+01	1.72E-07	2.4500	5.125	2.27E-01	3.98	6.27	1202
14	1	09/15/12 13:02:01	47.25	71.701045	-160.1945883	-7.91E+01	3.25E-07	2.3900	7.46	2.72E-01	5.99	8.93	1203
7	1	09/19/12 15:47:10	38.58	71.59338833	-163.1946117	-7.70E+01	2.97E-07	3.2600	7.22	2.79E-01	6	8.44	1204
8	1	08/15/12 14:37:32	40.68	71.541245	-162.513625	-8.02E+01	1.72E-07	2.1200	5.125	1.85E-01	3.98	6.27	1202
13	1	09/15/12 13:01:03	47.12	71.70322667	-160.1939133	-7.11E+01	3.25E-07	2.6300	7.46	3.42E-01	5.99	8.93	1203
8	1	09/19/12 15:48:40	38.79	71.59010667	-163.195115	-7.79E+01	2.97E-07	3.0500	7.22	3.09E-01	6	8.44	1204
9	1	08/15/12 14:37:41	40.76	71.54160167	-162.5138333	-7.59E+01	1.72E-07	4.8200	5.125	1.17E+00	3.98	6.27	1202
12	1	09/15/12 13:00:06	47.88	71.705375	-160.1931867	-7.23E+01	3.25E-07	4.5100	7.46	2.01E-01	5.99	8.93	1203
9	1	09/19/12 15:50:10	38.82	71.5868	-163.1956633	-7.64E+01	2.97E-07	3.1000	7.22	3.25E-01	6	8.44	1204
10	1	08/15/12 14:37:49	40.82	71.54191833	-162.5140217	-6.48E+01	1.72E-07	22.0000	5.125	1.69E-01	3.98	6.27	1202
11	1	09/15/12 12:59:09	47.26	71.707525	-160.1924683	-7.90E+01	3.25E-07	2.2800	7.46	2.97E-01	5.99	8.93	1203
10	1	09/19/12 15:51:40	38.95	71.583495	-163.19576	-7.80E+01	2.97E-07	2.9900	7.22	2.62E-01	6	8.44	1204
11	1	08/15/12 14:37:58	40.75	71.54227333	-162.5142433	-6.00E+01	1.72E-07	39.6000	5.125	3.62E-01	3.98	6.27	1202
10	1	09/15/12 12:58:12	47.13	71.70969667	-160.1918083	-7.84E+01	3.25E-07	2.3000	7.46	3.18E-01	5.99	8.93	1203
11	1	09/19/12 15:53:10	39.11	71.58020833	-163.1960583	-7.83E+01	2.97E-07	2.7500	7.22	1.90E-01	6	8.44	1204
12	1	08/15/12 14:38:06	40.82	71.54258833	-162.5144467	-5.82E+01	1.72E-07	48.6000	5.125	8.16E-01	3.98	6.27	1202
9	1	09/15/12 12:57:14	47.65	71.71184667	-160.1911133	-8.00E+01	3.25E-07	2.0100	7.46	2.19E-01	5.99	8.93	1203
12	1	09/19/12 15:54:40	39.38	71.576895	-163.196355	-7.91E+01	2.97E-07	2.4300	7.22	1.77E-01	6	8.44	1204
13	1	08/15/12 14:38:15	40.77	71.542945	-162.51467	-7.22E+01	1.72E-07	10.6000	5.125	2.34E+00	3.98	6.27	1202
8	1	09/15/12 12:56:17	47.32	71.71399167	-160.1905417	-8.14E+01	3.25E-07	1.3900	7.46	9.21E-02	5.99	8.93	1203
13	1	09/19/12 15:56:10	39.16	71.57359667	-163.1967633	-7.72E+01	2.97E-07	3.5500	7.22	2.60E-01	6	8.44	1204
14	1	08/15/12 14:38:24	40.67	71.54330167	-162.514895	-7.55E+01	1.72E-07	5.5800	5.125	1.24E+00	3.98	6.27	1202
7	1	09/15/12 12:55:20	47.09	71.7162	-160.1900617	-7.98E+01	3.25E-07	2.2600	7.46	3.00E-01	5.99	8.93	1203
14	1	09/19/12 15:57:40	38.81	71.57030833	-163.1970917	-7.52E+01	2.97E-07	4.3700	7.22	2.48E-01	6	8.44	1204
15	1	08/15/12 14:38:32	40.65	71.54362	-162.51509	-7.99E+01	1.72E-07	2.3300	5.125	3.16E-01	3.98	6.27	1202
6	1	09/15/12 12:54:22	46.94	71.71833833	-160.1894683	-5.54E+01	3.25E-07	2.1200	7.46	1.47E-01	5.99	8.93	1203
15	1	09/19/12 15:59:10	39.01	71.56698667	-163.1972	-7.43E+01	2.97E-07	4.1900	7.22	2.86E-01	6	8.44	1204
16	1	08/15/12 14:38:41	40.71	71.54397667	-162.5152983	-6.12E+01	1.72E-07	17.9000	5.125	1.16E+00	3.98	6.27	1202
5	1	09/15/12 12:53:25	46.82	71.72049667	-160.1889917	-7.86E+01	3.25E-07	2.8500	7.46	4.14E-01	5.99	8.93	1203
16	1	09/19/12 16:00:40	39.32	71.56365833	-163.1976317	-7.80E+01	2.97E-07	3.0100	7.22	2.25E-01	6	8.44	1204
17	1	08/15/12 14:38:49	40.67	71.54429	-162.5154933	-7.97E+01	1.72E-07	2.4800	5.125	3.57E-01	3.98	6.27	1202
4	1	09/15/12 12:52:28	46.9	71.72264167	-160.1884383	-6.76E+01	3.25E-07	1.6200	7.46	1.13E-01	5.99	8.93	1203
17	1	09/19/12 16:02:10	39.42	71.56032833	-163.1979883	-7.78E+01	2.97E-07	3.2900	7.22	3.13E-01	6	8.44	1204
18	1	08/15/12 14:38:58	40.59	71.54464333	-162.5157117	-8.03E+01	1.72E-07	2.2000	5.125	3.03E-01	3.98	6.27	1202
3	1	09/15/12 12:51:30	46.79	71.72482667	-160.1879233	-6.44E+01	3.25E-07	2.3200	7.46	1.85E-01	5.99	8.93	1203
18	1	09/19/12 16:03:40	39.38	71.55701167	-163.1984133	-7.82E+01	2.97E-07	2.8600	7.22	1.89E-01	6	8.44	1204
19	1	08/15/12 14:39:06	40.74	71.544955	-162.515915	-7.51E+01	1.72E-07	5.8300	5.125	1.49E+00	3.98	6.27	1202
2	1	09/15/12 12:50:33	46.86	71.72698	-160.1873717	-7.89E+01	3.25E-07	2.9000	7.46	3.77E-01	5.99	8.93	1203
19	1	09/19/12 16:05:10	39.34	71.55367333	-163.1986967	-7.67E+01	2.97E-07	3.0900	7.22	2.33E-01	6	8.44	1204
20	1	08/15/12 14:39:15	40.45	71.54530667	-162.5161333	-7.60E+01	1.72E-07	5.1800	5.125	1.06E+00	3.98	6.27	1202
1	1	09/15/12 12:49:36	46.75	71.72698	-160.1873717	-7.96E+01	3.25E-07	2.3400	7.46	3.02E-01	5.99	8.93	1203
20	1	09/19/12 16:06:40	39.18	71.55033333	-163.19873	-7.78E+01	2.97E-07	2.9700	7.22	2.03E-01	6	8.44	1204
1	1	08/15/12 18:44:40	42.94	71.20279	-162.609195	-8.22E+01	1.66E-07	1.6200	9.025	1.63E-02	7.98	10.07	1202
20	1	09/15/12 12:48:06	46.91	71.73251667	-160.1860483	-7.82E+01	3.55E-07	2.4800	7.46	3.50E-01	5.99	8.93	1203
1	1	09/19/12 16:08:10	39.49	71.543675	-163.19947	-7.77E+01	3.61E-06	2.7000	7.22	3.57E-01	6	8.44	1204
2	1	08/15/12 18:46:11	42.95	71.20279	-162.609195	-7.92E+01	1.66E-07	1.6900	9.025	5.77E-01	7.98	10.07	1202
19	1	09/15/12 12:46:36	46.85	71.735915	-160.1852767	-7.91E+01	3.55E-07	2.2500	7.46	2.86E-01	5.99	8.93	1203
2	1	09/19/12 16:09:40	39.61	71.543675	-163.19947	-7.72E+01	3.61E-06	2.6100	7.22	2.76E-01	6	8.44	1204
3	1	08/15/12 18:47:42	42.93	71.202805	-162.60897	-8.08E+01	1.66E-07	1.5400	9.025	6.90E-02	7.98	10.07	1202
18	1	09/15/12 12:45:06	46.76	71.73932167	-160.184425	-8.01E+01	3.55E-07	1.9300	7.46	2.42E-01	5.99	8.93	1203
3	1	09/19/12 16:11:10	39.49	71.540385	-163.2000783	-7.87E+01	3.61E-06	1.8700	7.22	1.43E-01	6	8.44	1204
4	1	08/15/12 18:49:13	42.74	71.20174333	-162.61234	-7.79E+01	1.66E-07	2.3300	9.025	1.55E-01	7.98	10.07	1202
17	1	09/15/12 12:43:36	46.82	71.74274	-160.1837183	-7.41E+01	3.55E-07	2.1700	7.46	2.71E-01	5.99	8.93	1203
4	1	09/19/12 16:12:40	39.2	71.53703167	-163.20062	-7.68E+01	3.61E-06	2.8100	7.22	2.74E-01	6	8.44	1204
5	1	08/15/12 18:50:44	42.62	71.199655	-162.6133517	-7.38E+01	1.66E-07	4.0500	9.025	2.78E-01	7.98	10.07	1202
16	1	09/15/12 12:42:06	46.57	71.74616	-160.1829933	-7.94E+01	3.55E-07	2.2400	7.46	3.20E-01	5.99	8.93	1203

Table 3. Abundance estimates of acoustic backscattering targets (ABT) for cruise WWW1202 derived from summary databases from 2012 CSESP acoustic survey of fishes applied to a rectangular summary grid system for the GHS Study Area.

WWW 1202 Abundance Estimates of Acoustic Backscattering Targets (ABT)

	Summary Grid (ESSR*) Cells			Acoustic Summary Data Available				ABT Abundance & CI	
Area	Total	with Transects	without Transects	Records	Minimum FPUA**	Average FPUA	Maximum FPUA	Pt. Estimate ABT (x 10^9)	95% CI ABT +/-
Statoil Study Area	39	31	8	983	0.59	2.59	9.75	9.506	1.477
Burger Study Area	36	28	8	1,007	0.29	3.10	9.96	11.339	1.647
Klondike Study Area	36	33	3	1,095	0.75	2.56	9.93	9.122	1.605
Transition Area	270	6	264	168	0.88	2.44	8.96	NA	NA
GHS Study Area	381	98	283	3,253	0.29	2.74	9.96	NA	NA

* ESSR refers to Elementary Statistical Sampling Rectangles, Johannesson and Milton 1983.

** FPUA refers to "Fish per Unit Area" as summarized by BioSonics Inc. acoustic processing software and represents the a density of acoustic fish targets per square meter.

Table 4. Abundance estimates of acoustic backscattering targets (ABT) for cruise WWW1203 derived from summary databases from 2012 CSESP acoustic survey of fishes applied to a rectangular summary grid system for the GHS Study Area.

WWW 1203 Abundance Estimates of Acoustic Backscattering Targets (ABT)

	Summary Grid (ESSR*) Cells			Acoustic Summary Data Available				ABT Abundance & CI	
Area	Total	with Transects	without Transects	Records	Minimum FPUA**	Average FPUA	Maximum FPUA	Pt. Estimate ABT (x 10^9)	95% CI ABT +/-
Statoil Study Area	39	19	20	512	0.00	2.55	9.52	NA	NA
Burger Study Area	36	9	27	162	1.02	3.59	9.89	NA	NA
Klondike Study Area	36	19	17	559	0.71	2.29	9.72	NA	NA
Transition Area	270	52	218	1,729	0.33	2.46	9.68	NA	NA
GHS Study Area	381	99	282	2,962	0.00	2.50	9.89	NA	NA

* ESSR refers to Elementary Statistical Sampling Rectangles, Johannesson and Milton 1983.

** FPUA refers to "Fish per Unit Area" as summarized by BioSonics Inc. acoustic processing software and represents the a density of acoustic fish targets per square meter.

Table 5. Abundance estimates of acoustic backscattering targets (ABT) for cruise WWW1204 derived from summary databases from 2012 CSESP acoustic survey of fishes applied to a rectangular summary grid system for the GHS Study Area.

WWW 1204 Abundance Estimates of Acoustic Backscattering Targets (ABT)

	Summary Grid (ESSR*) Cells			Acoustic Summary Data Available				ABT Abundance & CI	
Area	Total	with Transects	without Transects	Records	Minimum FPUA**	Average FPUA	Maximum FPUA	Pt. Estimate ABT (x 10^9)	95% CI ABT +/-
Statoil Study Area	39	4	35	60	0.19	1.79	4.36	NA	NA
Burger Study Area	36	25	11	632	0.91	2.12	9.71	8.577	1.434
Klondike Study Area	36	3	33	38	1.61	2.89	3.91	NA	NA
Transition Area	270	33	237	716	0.59	2.02	8.69	NA	NA
GHS Study Area	381	65	316	1,446	0.19	2.08	9.71	NA	NA

* ESSR refers to Elementary Statistical Sampling Rectangles, Johannesson and Milton 1983.

** FPUA refers to "Fish per Unit Area" as summarized by BioSonics Inc. acoustic processing software and represents the a density of acoustic fish targets per square meter.

Figure 1. Map of rectangular grid used for abundance estimation of acoustic backscattering targets (ABT) from 2012 CSESP acoustic survey of fishes data. Each grid cell is 100 square km, labeled to link with and identify acoustic transect data per grid cell, and counts of grid cells are shown in the legend per area.

Figure 2. Map of CSESP acoustic survey of fishes coverage in the GHS Study Area, 2012.

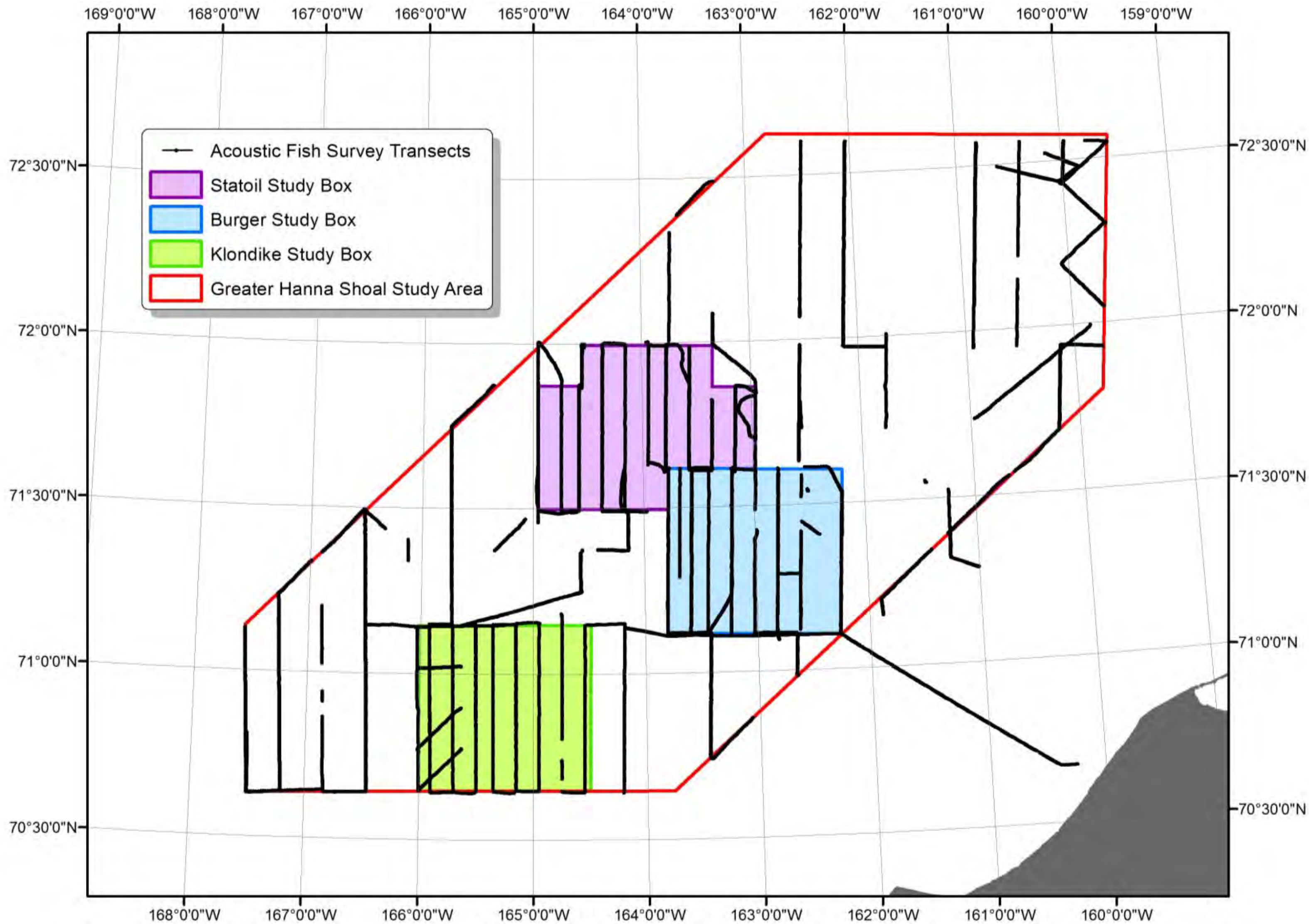


Figure 3. Map of CSESP acoustic survey of fishes coverage in the GHS Study Area for each cruise on the R/V *Westward Wind* (WWW), 2012 and bottom layer temperature plots per cruise.

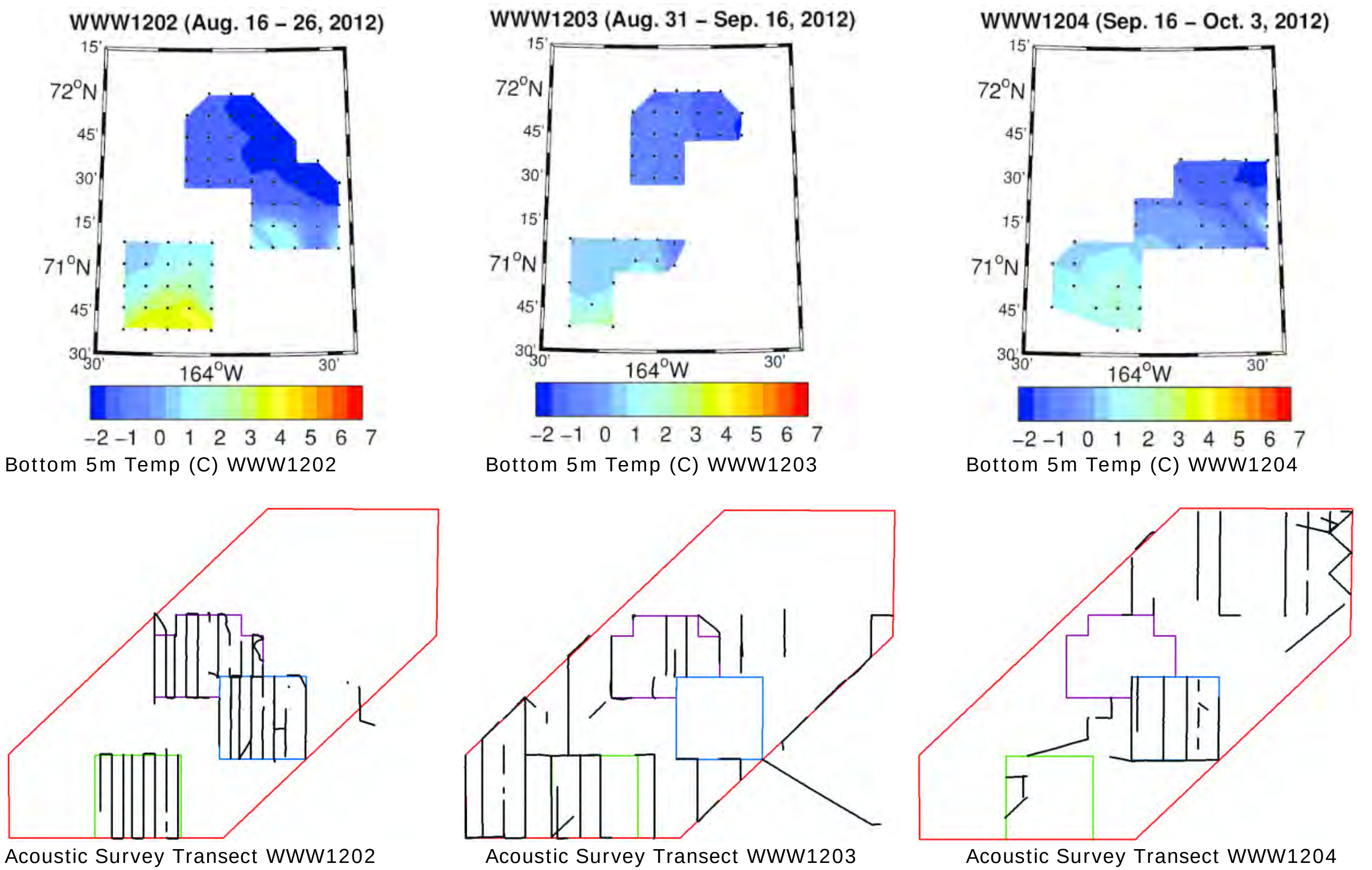


Figure 4. Plot of relative densities in fish per square meter (from FPUA) of acoustic backscattering targets (ABT) along transect lines from processed acoustic survey of fishes summary files collected during cruise WWW1202, CSESP 2012.

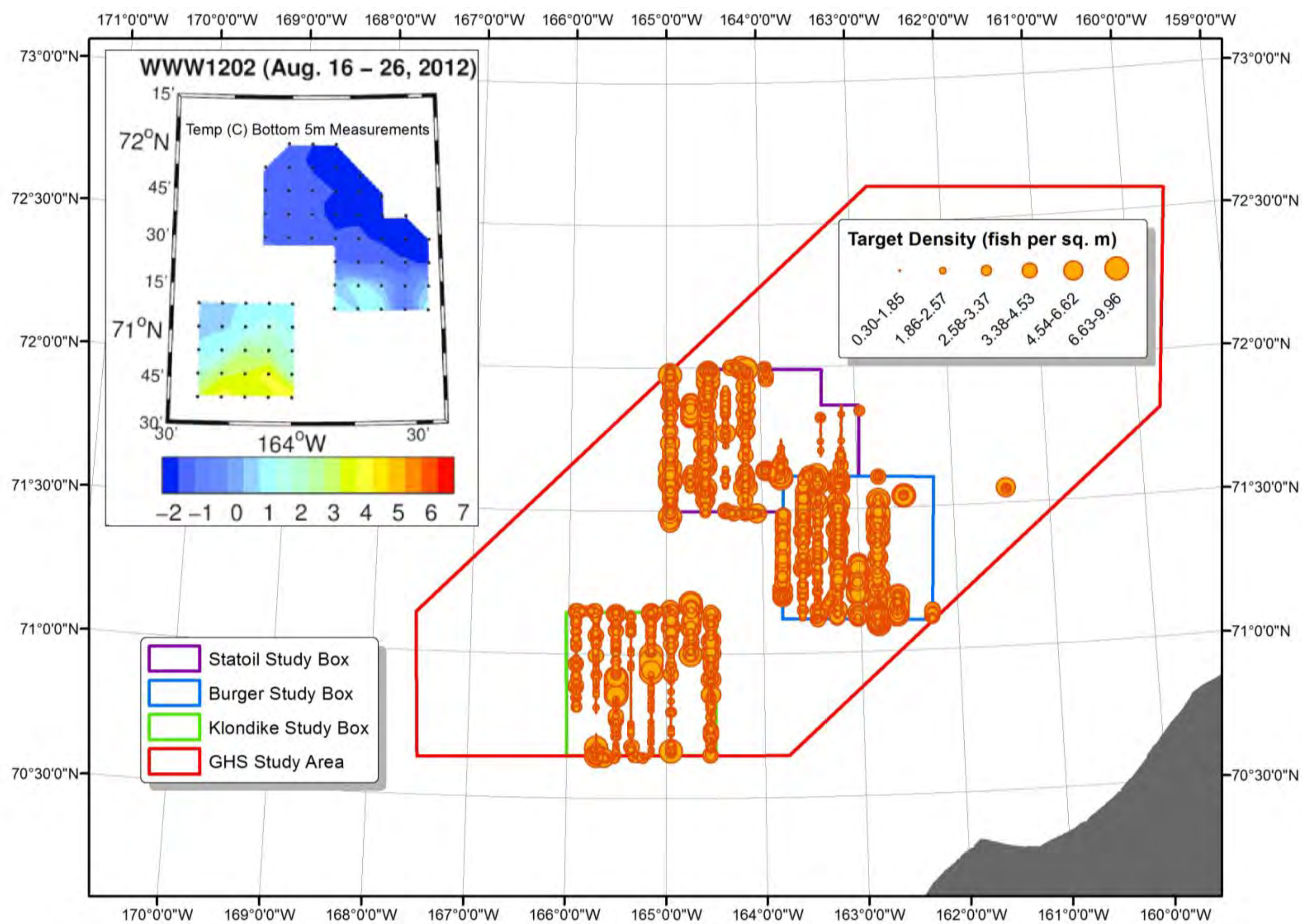


Figure 5. Plot of relative densities in fish per square meter (from FPUA) of acoustic backscattering targets (ABT) along transect lines from processed acoustic survey of fishes summary files collected during cruise WWW1203, CSESP 2012.

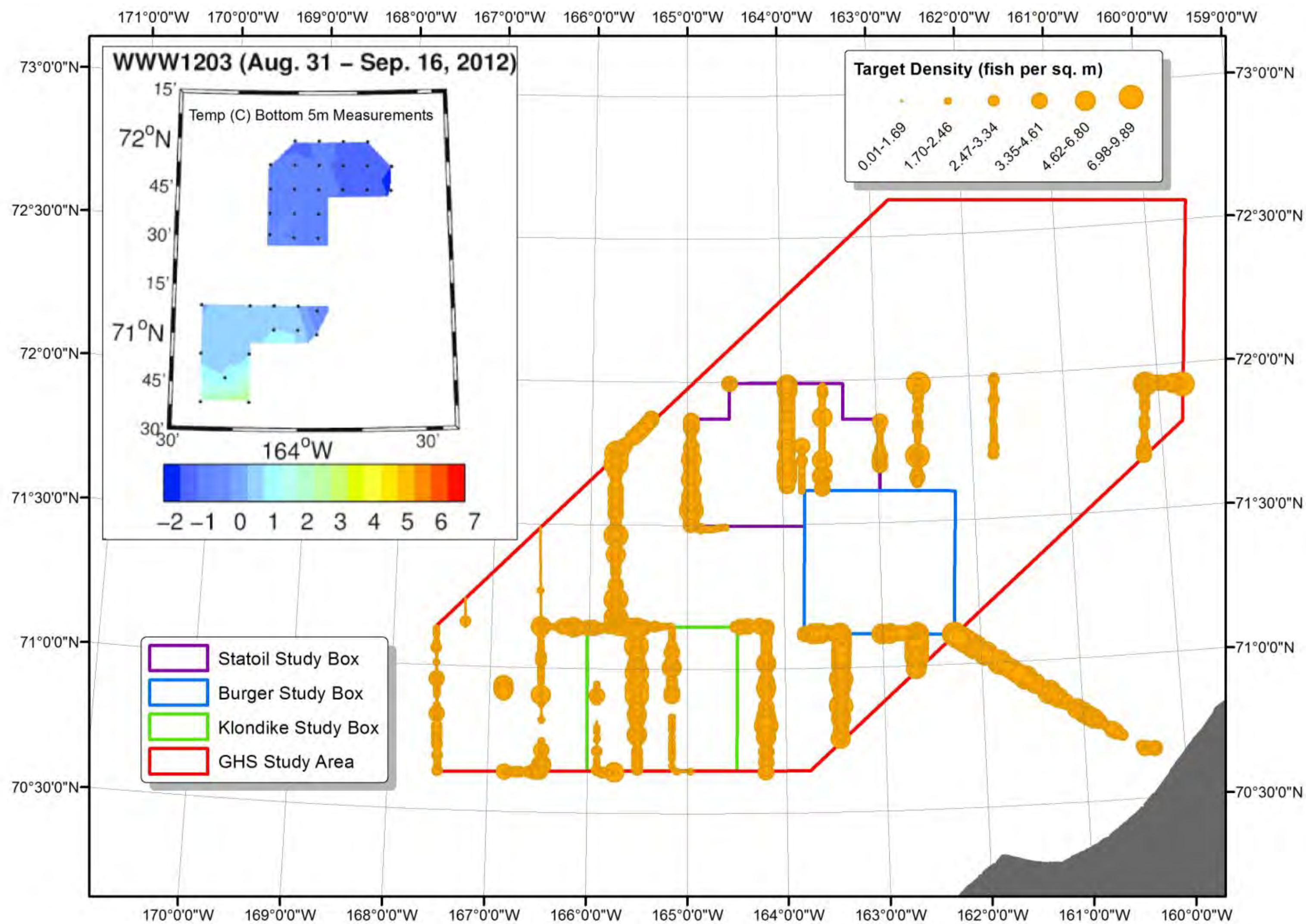


Figure 6. Plot of relative densities in fish per square meter (from FPUA) of acoustic backscattering targets (ABT) along transect lines from processed acoustic survey of fishes summary files collected during cruise WWW1204, CSESP 2012.

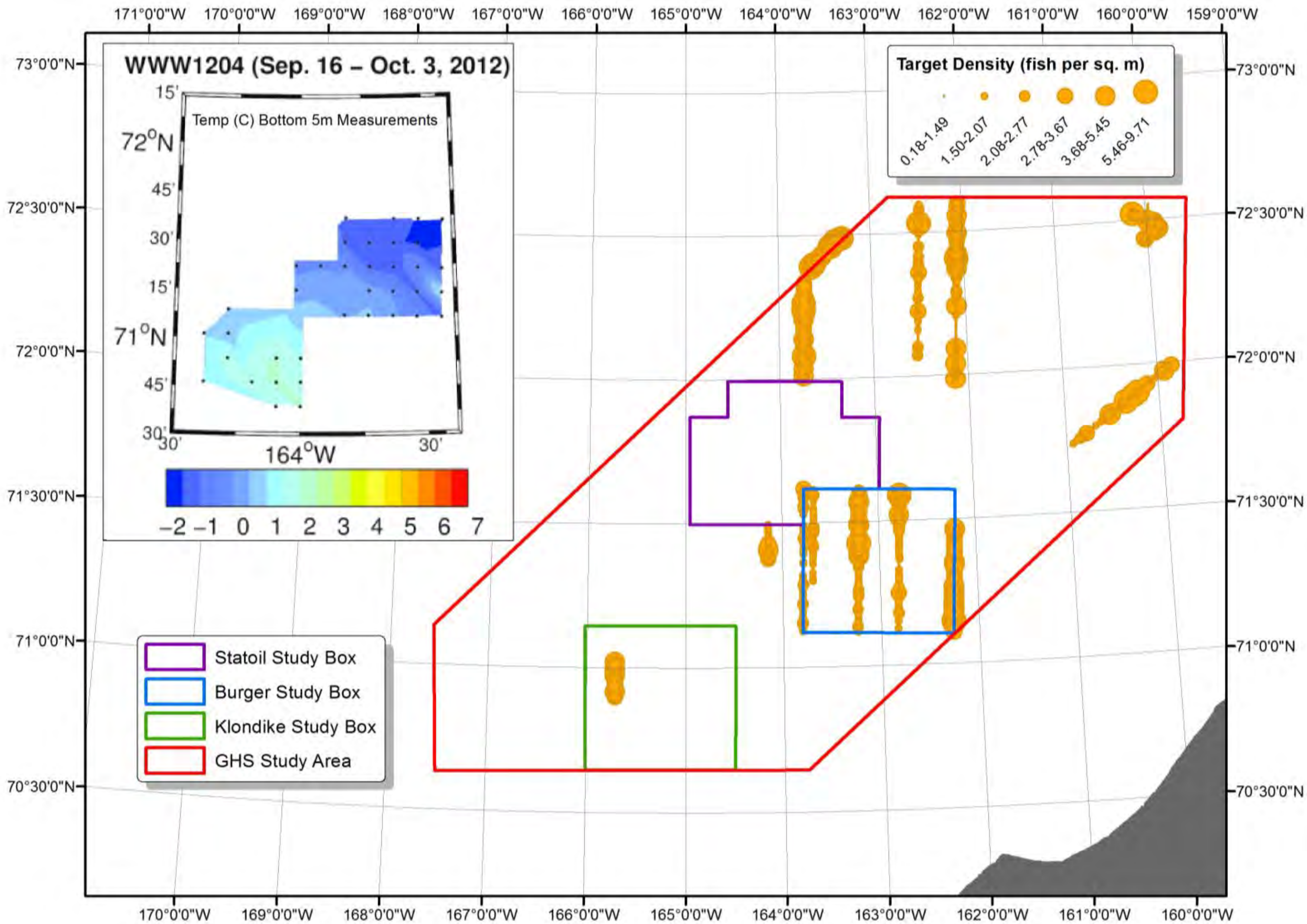


Figure 7. Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1202, CSESP 2012.

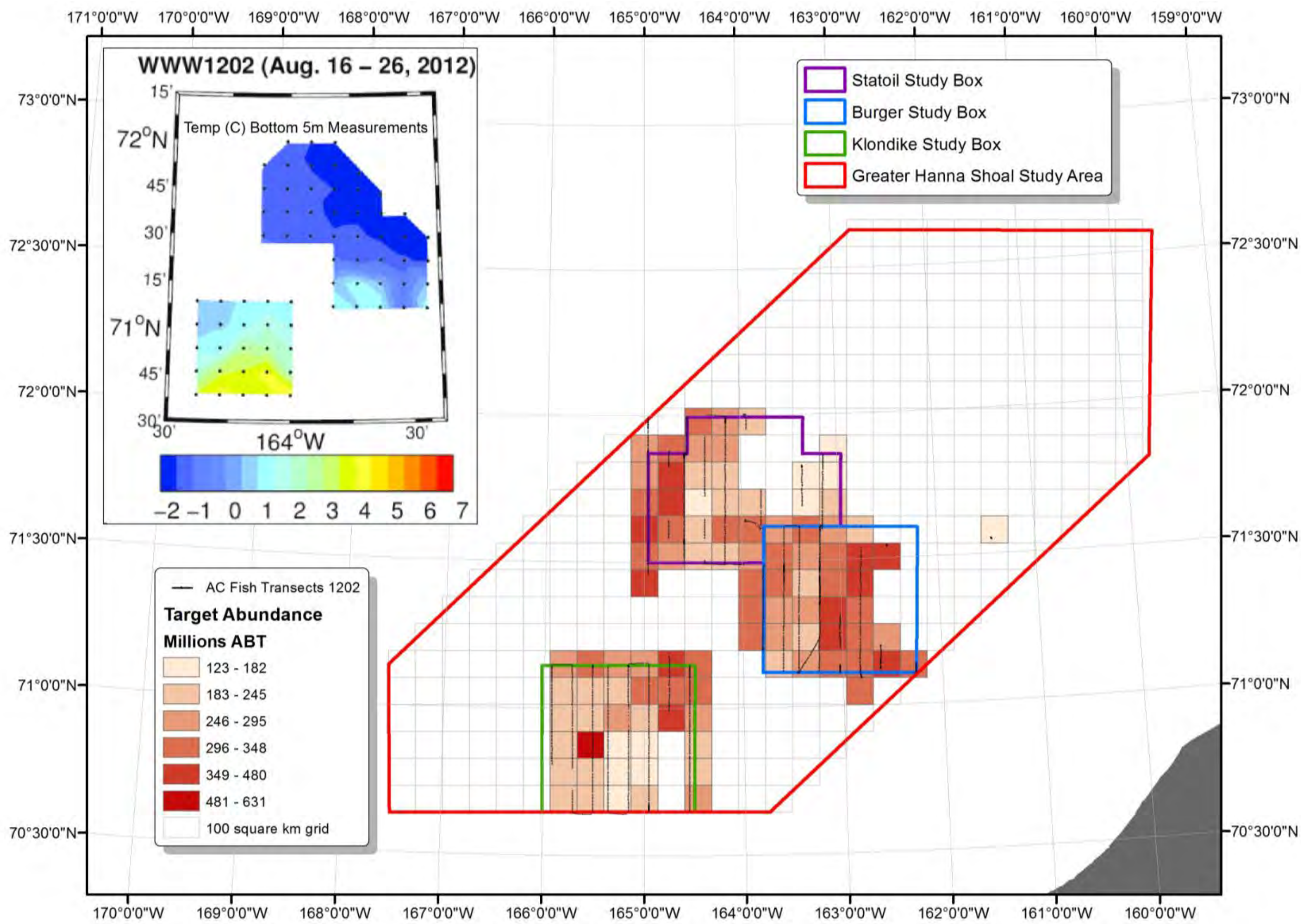


Figure 8. Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1203, CSESP 2012.

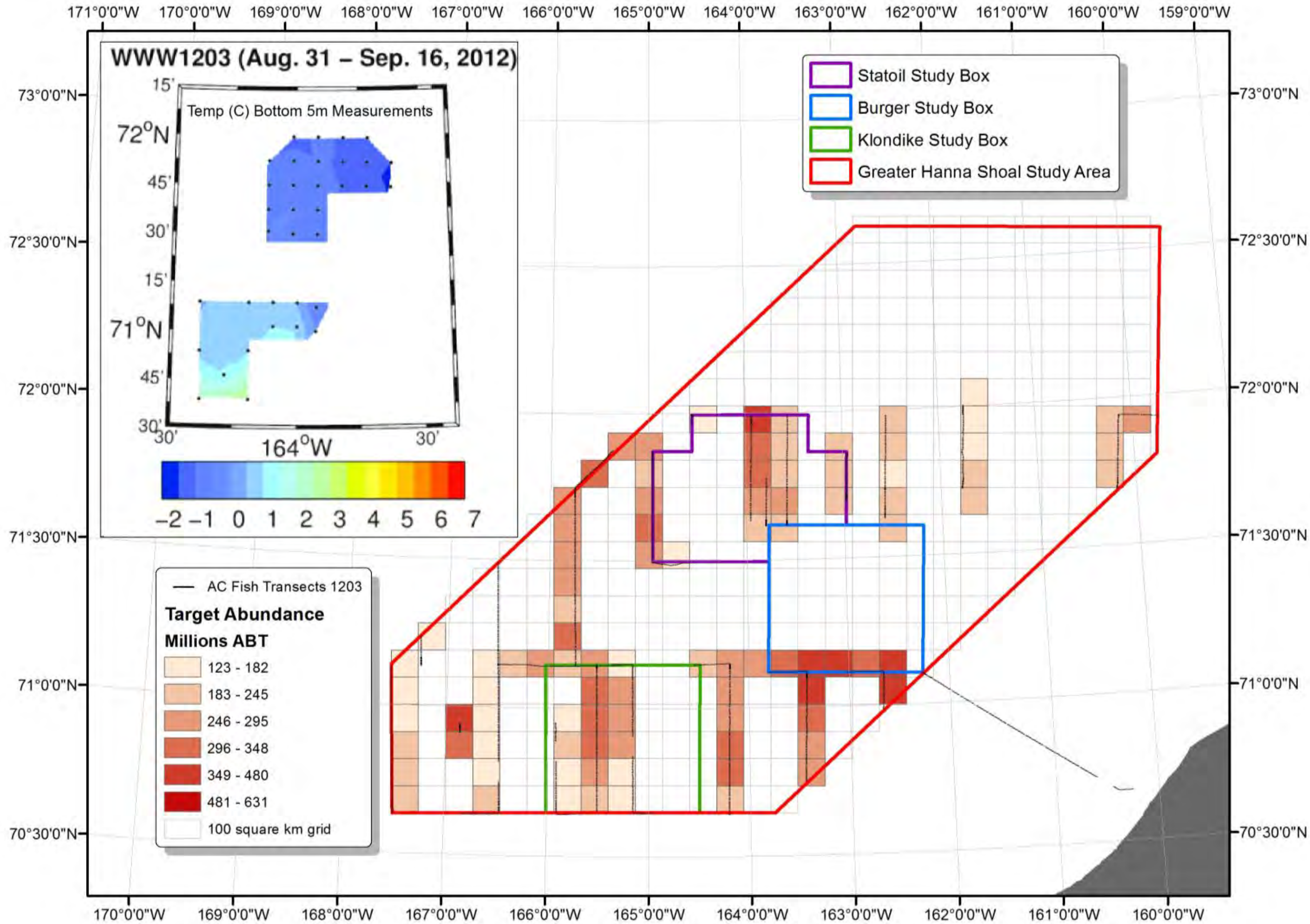


Figure 9. Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1204, CSESP 2012.

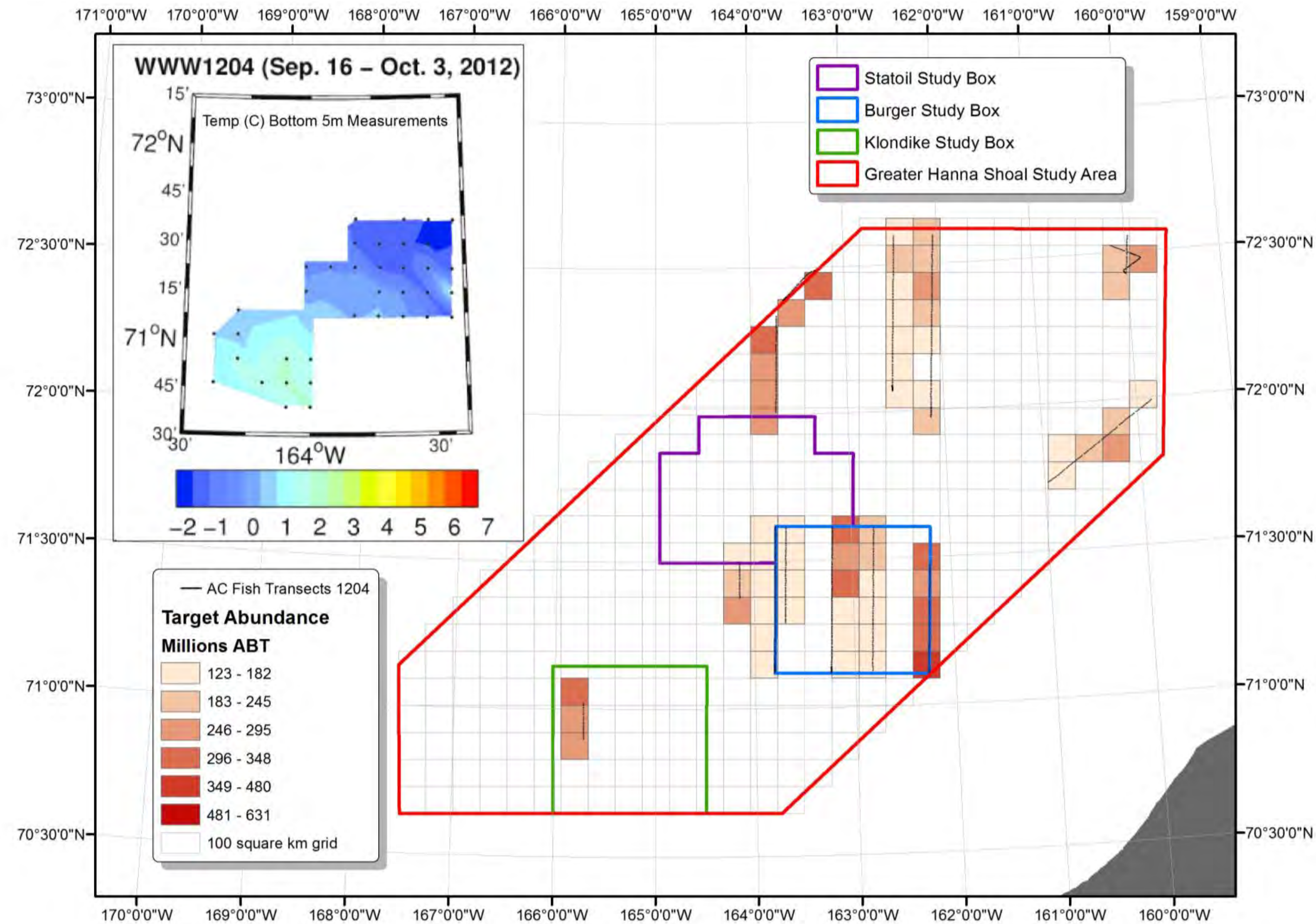


Figure 10. Plot of target strength (TS) for TS values around expected TS for age-0 Arctic cod (~-58dB) by depth strata for summarized acoustic survey data from cruise WWW1202, CSESP 2012.

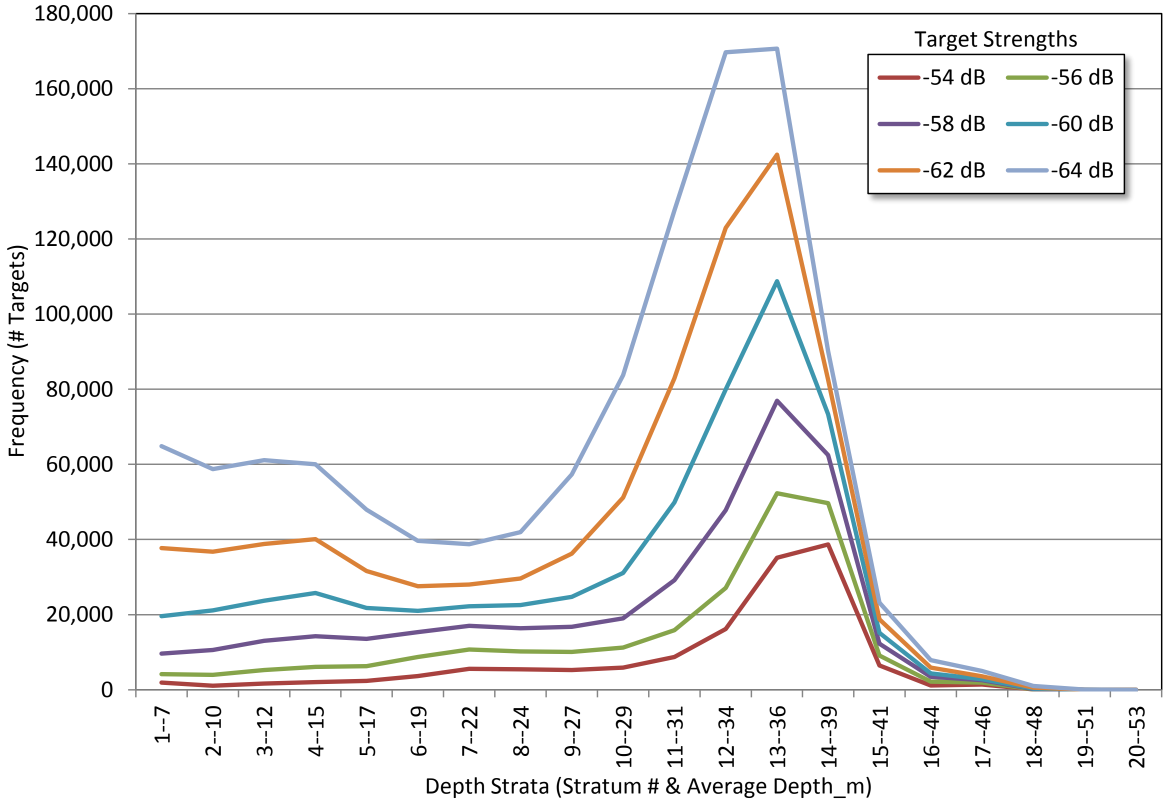
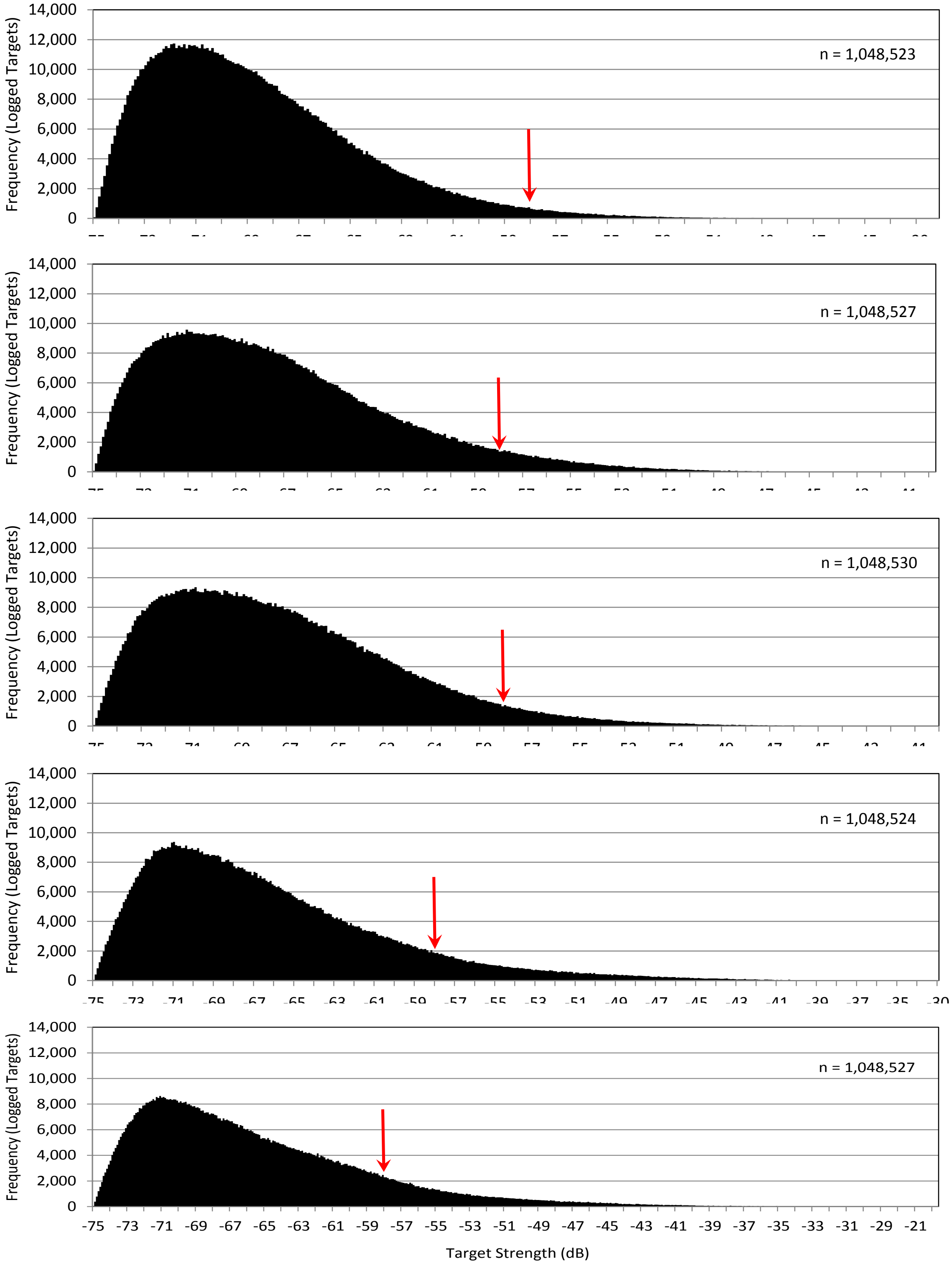


Figure 11. Frequency distribution of target strengths from a subsample (45% of total) of all recorded individual targets logged in echo-integration target logs from processed acoustic survey data from cruise WWW1202, CSESP 2012. The red arrows point to estimated age-0 Arctic cod TS.



Attached Slides

Split Beam Data Processing and Results, CSESP 2012

Natural Resources Consultants and
Aldrich Offshore Services

December 13, 2013

Aldrich Offshore Services LLC
Natural Resources Consultants, Inc.

Equipment and Collection Specifications

- **Equipment**
- A 122 kHz DT-X Biosonics echo-sounder coupled with Biosonics Visual Acquisition software was used to collect data
- Echo-sounder was mounted mid ship on the port side of the vessel near a crane pedestal

- **File Setup**
- Transmission rates typically 15.15 pings per second
- Data were acquired for 30 minute increments to keep the files manageable
- Data threshold: -130 dB (collected every echo from 0 to -130)
- Depth collection range: 1 to ~60 meters
- Sound Velocity: 1461.55 m/s
- Water temperature: 2-4^{o} C
- Salinity: 31 ppt

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Key Concepts

- Acoustic backscatter is the amount of power scattered by a target in the direction of the transmitting transducer.
- Differences in the amount of power scattered can allow for identification of that target
- Acoustic data is measured as negative numbers

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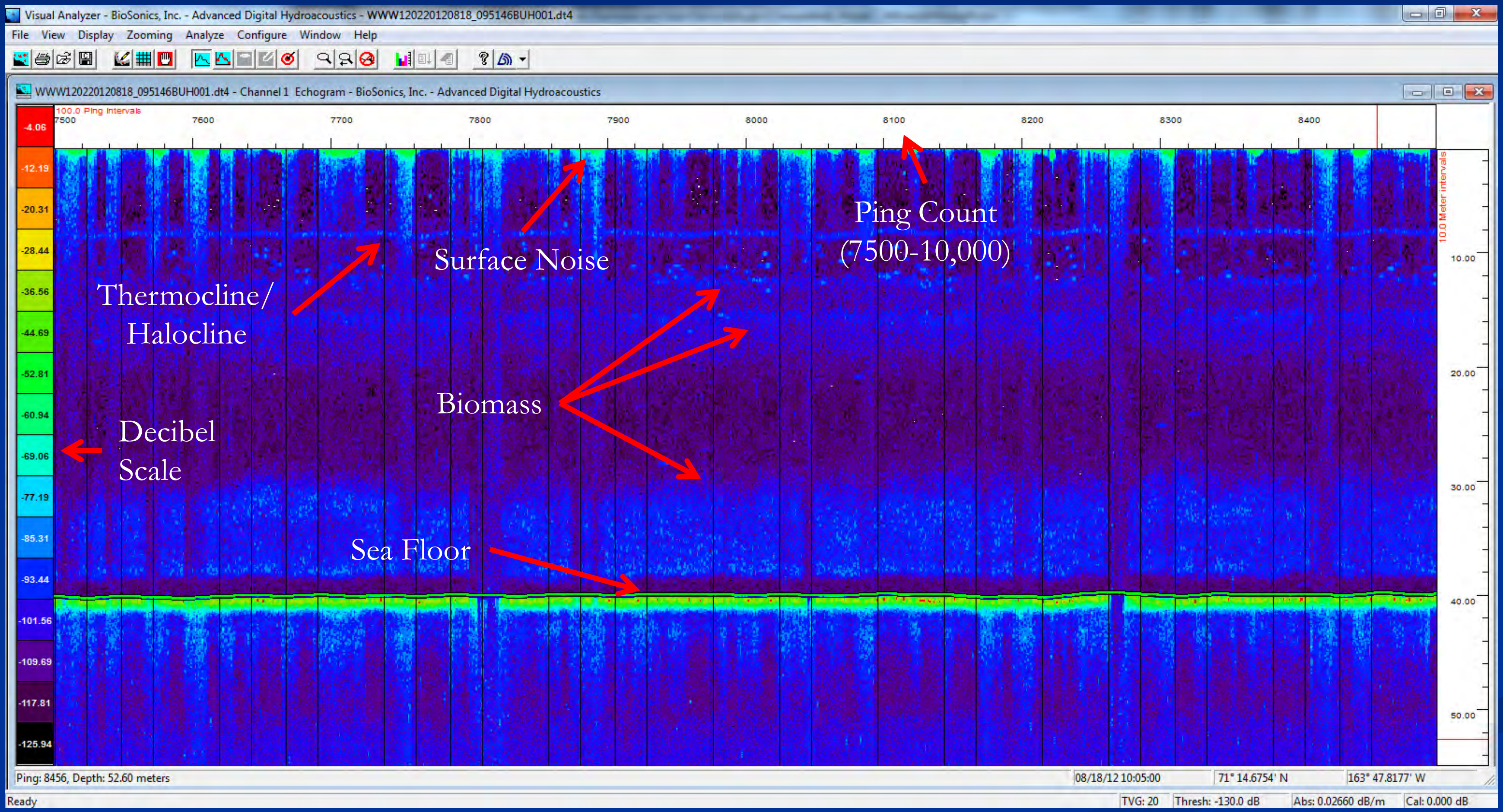
Typical Raw Acoustic File



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View of Acoustic Data

Acoustic Range displayed is 0 to -100 dB for Ease of Viewing

Ping Count (7500-10,000)

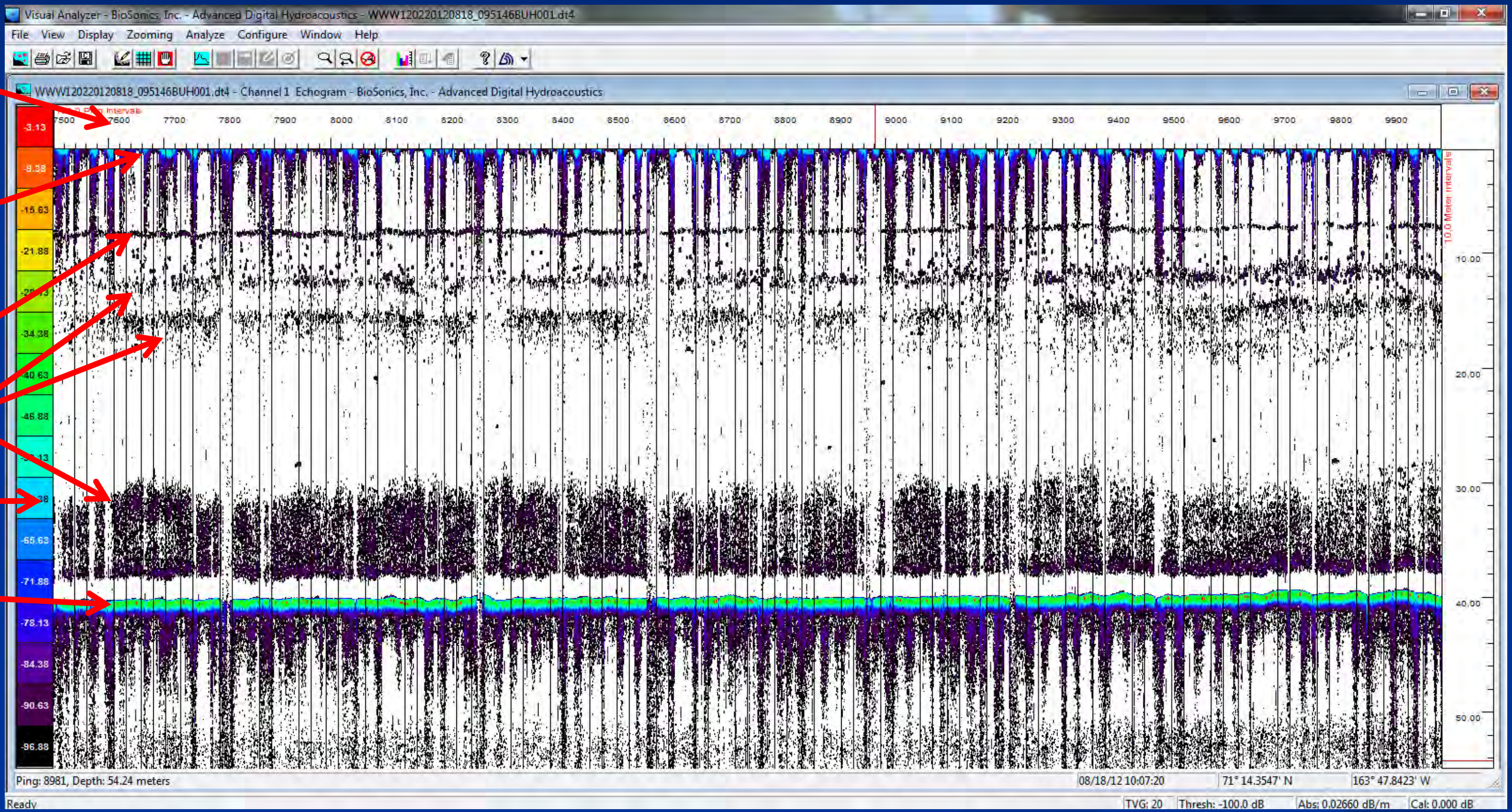
Surface Noise

Thermocline/ Halocline

Biomass

Decibel Scale

Sea Floor



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NRC
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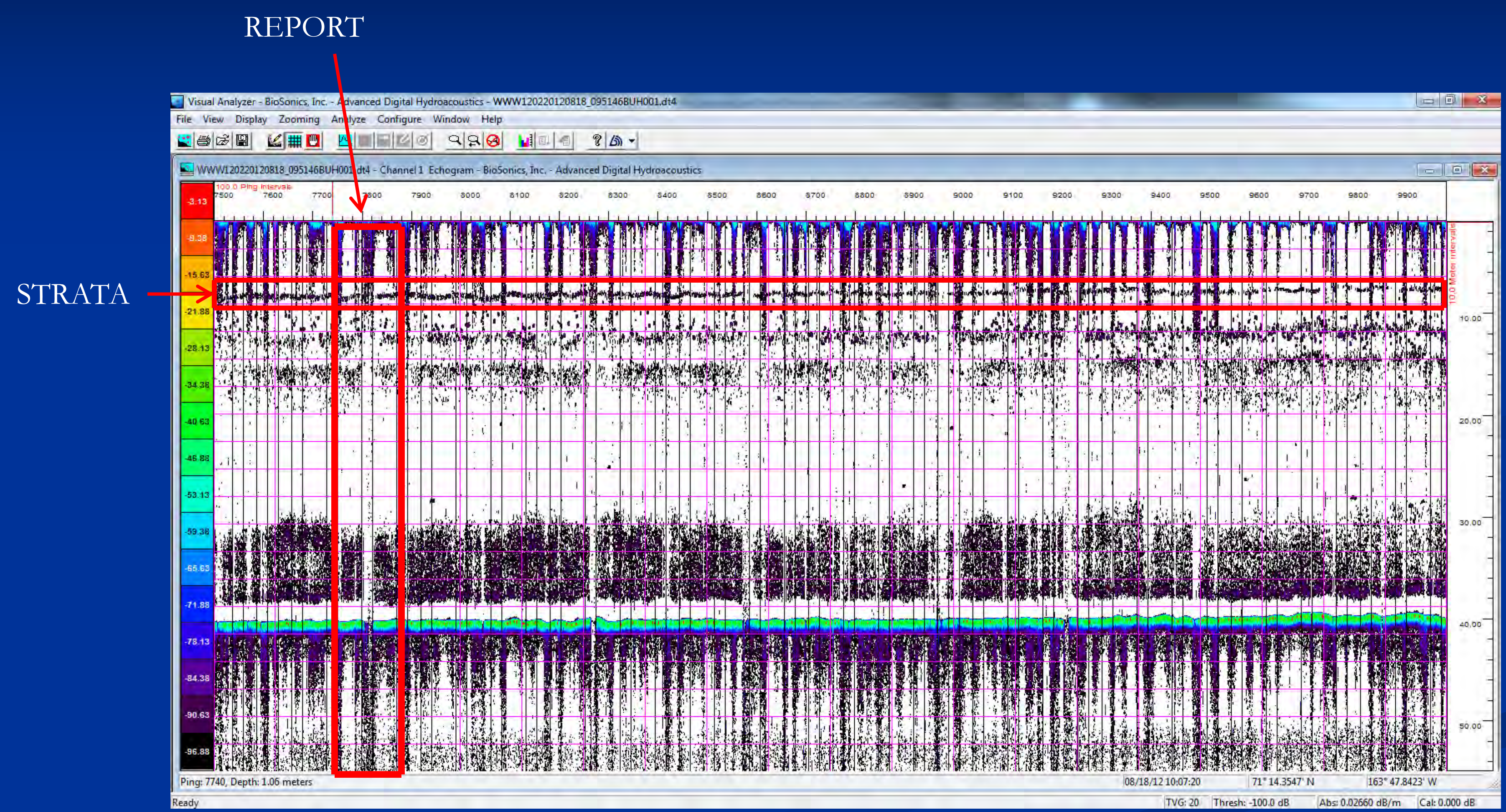
View of Acoustic Data with Grid



View of Echoes with TS>-76 dB

Ping Count
(7500-10,000)

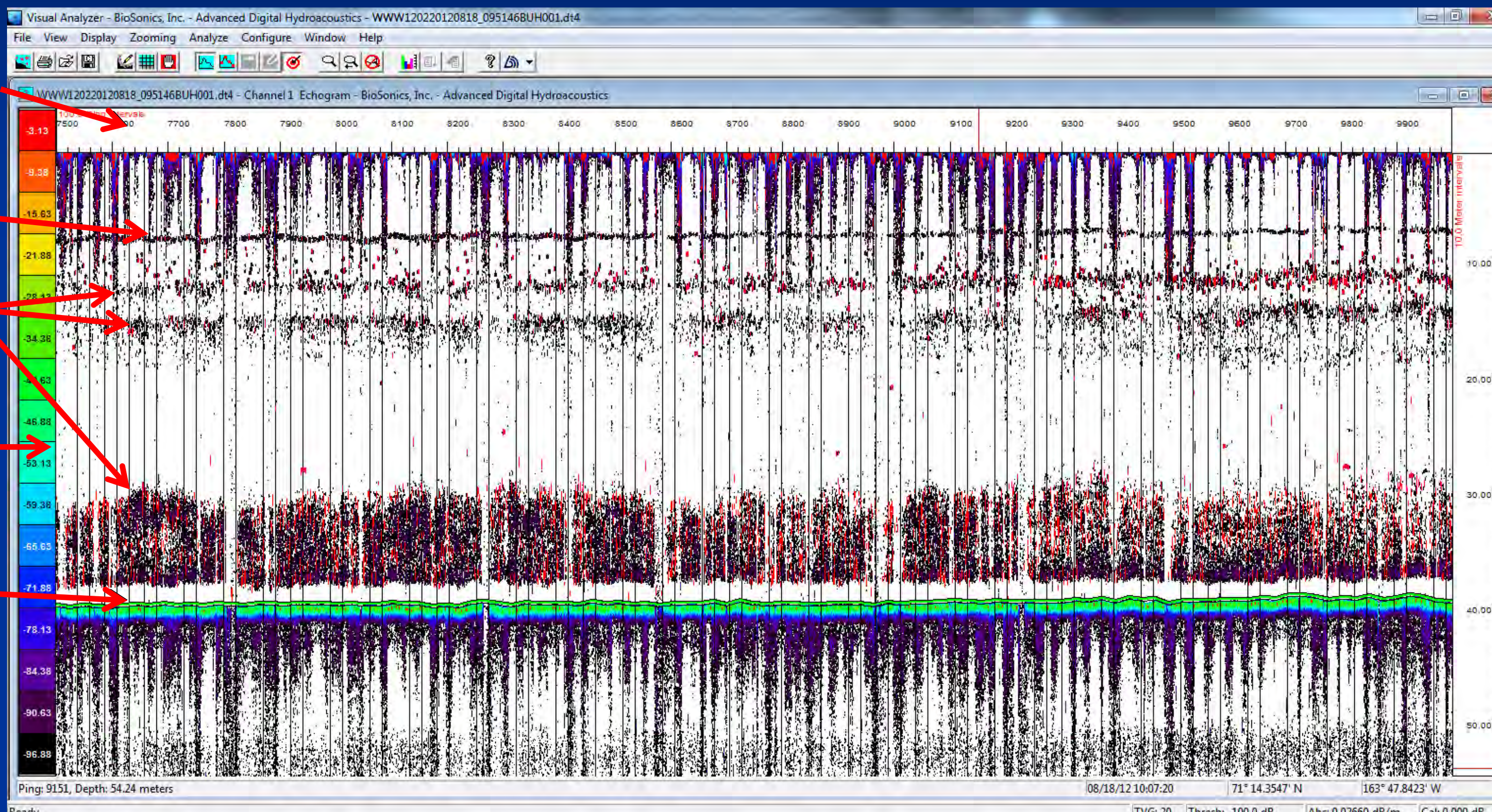
Thermocline/
Halocline

Biomass

Decibel
Scale

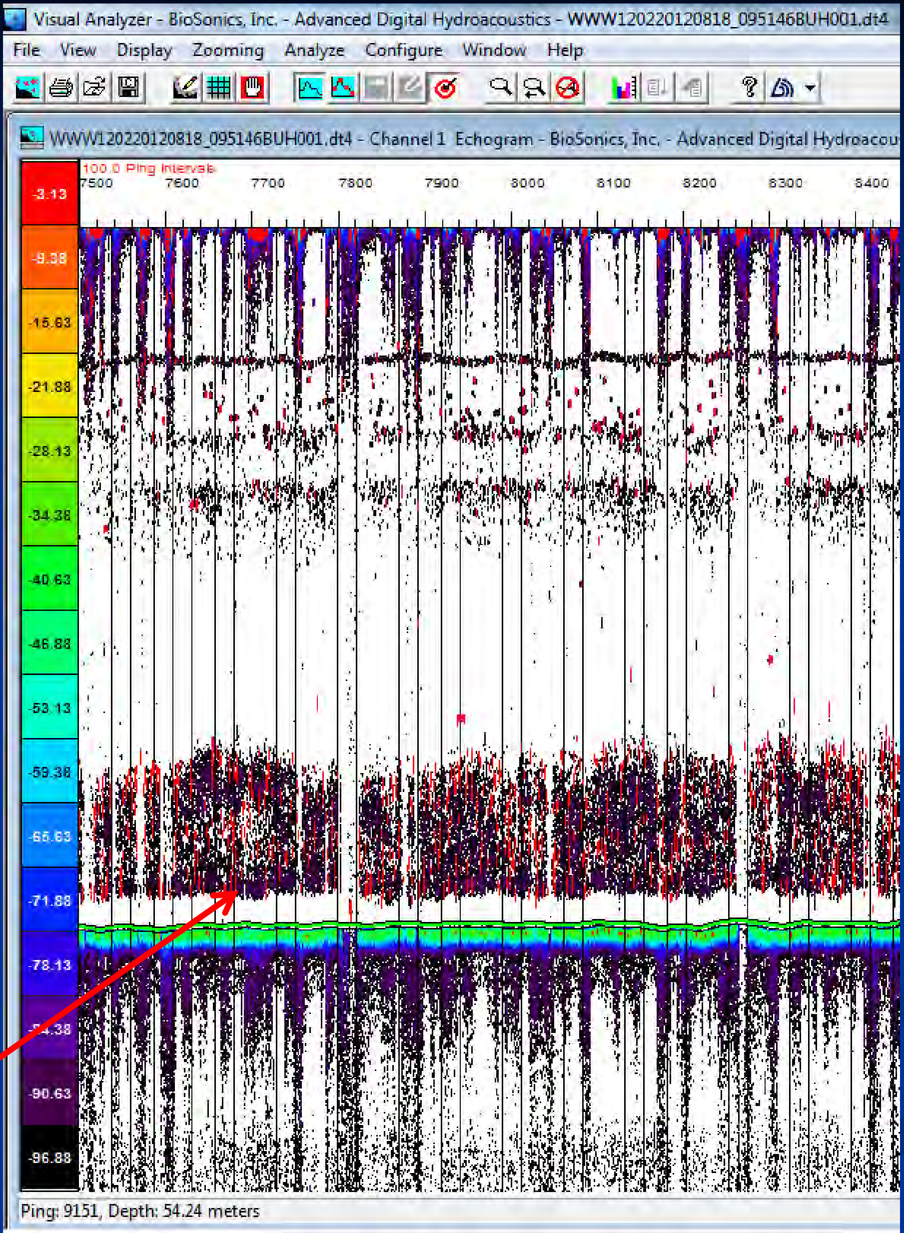
Sea Floor

Valid Echoes
In Red
(0 to -76 dB)



Data Processing

- Background noise and thermocline/halocline presence makes Echo Integration a balancing act
- Echoes with a Target Strength from 0 to -76 dB could be included without biasing the data (determined by trial and error processing)
- Other settings were applied in order to optimize data processing such as:



Example of targets < -76 dB
(were not included in echo integration)

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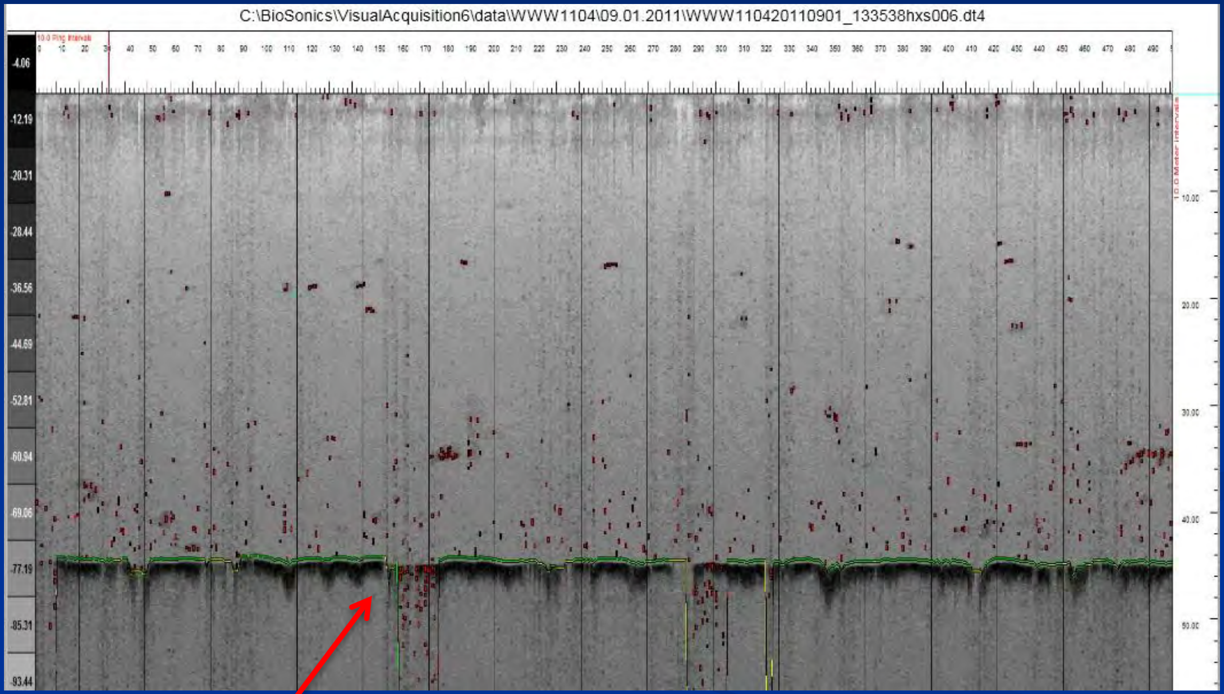
Data Processing Cont.

- Bottom blanking applied to minimize inclusion of bottom in echo recognition
- Bottom blanking: 0.5 meters above sea floor not included in analysis
- Depth range analyzed: > 4 meters typically but some files required up to 10 meters below sea level to be excluded to minimize surface noise and not bias the processed data
- Strata X Report grid = 20 X 20
- Example of gridding:
  - Columns (reports) are ~75 seconds long, rows (strata) are 3.3 meters deep, and collection rate is 15.15 pps; one column = 75 sec x 15.15 = 1136 pings.
  - 30 minutes file = 27,270 pings.



Lost bottom

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Data Summary

Data were summarized for further analysis as follows:

- The data were summarized by stratum and report
  - Stratum summarization = Absolute Density of Fish or Fish Per Cubic Meter (estimate of number of fish in a given volume of water)
  - Report summarization = Fish Per Unit Area (estimate of the number of fish in the water column)
- If the sample is above the strata threshold (user defined);
  - It is squared and added into a running sum for the stratum
  - The sum is divided by the number of samples measured to calculate an estimate of average energy within a volume of water.
  - Average energy is scaled by environmental and calibration parameters to provide an estimate of volume backscattering strength (S^v).
  - a mean backscattering cross section value can be obtained for each individual stratum.
  - Absolute Density of Fish within the stratum is estimated by applying backscattering cross section (FPCM) to the stratum area
- Absolute Density of each Report is multiplied by the interval thickness (stratum) and then multiplied by the interval sampled to get Fish Per Unit Area

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Vertical Integration Examples

- Strata: Stratum number referenced to the surface
- Top: Start depth of the strata in meters
- Bottom: End depth of the strata in meters
- Sv: Volume backscatter strength
- Applied Sigma: Backscattering cross section used to scale the integration
- FPCM: Fish per cubic meter. The estimate of the density of fish in the volume of water referenced
- Notice that after 45.79 meters there is no data because it is below the bottom.

VERTICAL INTEGRATION RESULTS

STRATA	TOP	BOTTOM	Sv (dB)	Applied Sigma	FPCM
1	4	7.79	-7.48E+01	1.53E-05	2.15E-03
2	7.79	11.59	-7.94E+01	6.57E-06	1.73E-03
3	11.59	15.4	-8.00E+01	8.03E-06	1.24E-03
4	15.4	19.19	-8.11E+01	7.84E-06	9.94E-04
5	19.19	22.99	-8.04E+01	6.89E-06	1.31E-03
6	22.99	26.8	-7.99E+01	4.79E-06	2.15E-03
7	26.8	30.59	-7.91E+01	6.97E-06	1.78E-03
8	30.59	34.39	-7.79E+01	7.04E-06	2.32E-03
9	34.39	38.2	-7.56E+01	5.68E-06	4.81E-03
10	38.2	42	-6.61E+01	1.85E-05	1.34E-02
11	42	45.79	-4.81E+01	2.33E-05	6.57E-01
12	45.79	49.6	0.00E+00	1.00E+00	0.00E+00
13	49.6	53.4	0.00E+00	1.00E+00	0.00E+00
14	53.4	57.19	0.00E+00	1.00E+00	0.00E+00
15	57.19	61	0.00E+00	1.00E+00	0.00E+00
16	61	64.8	0.00E+00	1.00E+00	0.00E+00
17	64.8	68.59	0.00E+00	1.00E+00	0.00E+00
18	68.59	72.4	0.00E+00	1.00E+00	0.00E+00
19	72.4	76.2	0.00E+00	1.00E+00	0.00E+00
20	76.2	79.99	0.00E+00	1.00E+00	0.00E+00

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Horizontal Integration Examples

- Report: Numbered from the start of the file or partial file
- Time and Date: Local time from the data file
- Depth: Average depth in meters of current report
- Latitude: Latitude of the start of the report
- Longitude: Longitude of the start of the report
- Sv: Volume backscattering strength
- Applied Sigma: Backscattering cross section used to scale integration
- FPUA: Fish per unit area. An estimate of the number of fish in the water column.

HORIZONTAL INTEGRATION RESULTS

REPORT	TIME AND DATE	Depth	Latitude	Longitude	Sv (dB)	Applied Sigma	FPUA
1	09/02/11 19:22:52	41.37			-6.66E+01	1.01E-05	1.30E-01
2	09/02/11 19:24:11	41.46	70° 40.7970' N	164° 57.0740' W	-6.66E+01	1.01E-05	2.60E-01
3	09/02/11 19:25:31	41.48	70° 40.6240' N	164° 57.0710' W	-6.68E+01	1.01E-05	2.96E-01
4	09/02/11 19:26:50	41.45	70° 40.4480' N	164° 57.0740' W	-7.49E+01	1.01E-05	1.43E-01
5	09/02/11 19:28:09	41.55	70° 40.2740' N	164° 57.0640' W	-7.52E+01	1.01E-05	5.85E-02
6	09/02/11 19:29:29	41.64	70° 40.1000' N	164° 57.0460' W	-5.38E+01	1.01E-05	1.58E-01
7	09/02/11 19:30:48	41.66	70° 39.9210' N	164° 57.0290' W	-5.35E+01	1.01E-05	1.62E-01
8	09/02/11 19:32:07	41.72	70° 39.7420' N	164° 57.0160' W	-6.36E+01	1.01E-05	1.02E-01
9	09/02/11 19:33:27	41.77	70° 39.5650' N	164° 57.0150' W	-7.38E+01	1.01E-05	1.08E-01
10	09/02/11 19:34:46	41.75	70° 39.3860' N	164° 57.0110' W	-6.82E+01	1.01E-05	6.47E-02
11	09/02/11 19:36:05	41.74	70° 39.2090' N	164° 57.0290' W	-5.38E+01	1.01E-05	2.27E-01
12	09/02/11 19:37:25	41.77	70° 39.0330' N	164° 57.0490' W	-6.68E+01	1.01E-05	6.26E-02
13	09/02/11 19:38:44	41.67	70° 38.8540' N	164° 57.0470' W	-7.69E+01	1.01E-05	8.06E-02
14	09/02/11 19:40:03	41.67	70° 38.6820' N	164° 57.1060' W	-6.63E+01	1.01E-05	6.38E-02
15	09/02/11 19:41:23	41.76	70° 38.5340' N	164° 57.3560' W	-6.68E+01	1.01E-05	7.58E-02
16	09/02/11 19:42:42	41.73	70° 38.4500' N	164° 57.7870' W	-7.55E+01	1.01E-05	7.16E-02
17	09/02/11 19:44:01	41.64	70° 38.4420' N	164° 58.2890' W	-6.52E+01	1.01E-05	1.19E-01
18	09/02/11 19:45:21	41.58	70° 38.4250' N	164° 58.8060' W	-6.98E+01	1.01E-05	1.96E-01
19	09/02/11 19:46:40	41.5	70° 38.4190' N	164° 59.3220' W	-7.68E+01	1.01E-05	9.02E-02
20	09/02/11 19:47:59	41.4	70° 38.4160' N	164° 59.8380' W	-6.39E+01	1.01E-05	1.78E-01

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RESULTS AND DISCUSSION

ALDRICH OFFSHORE SERVICES LLC

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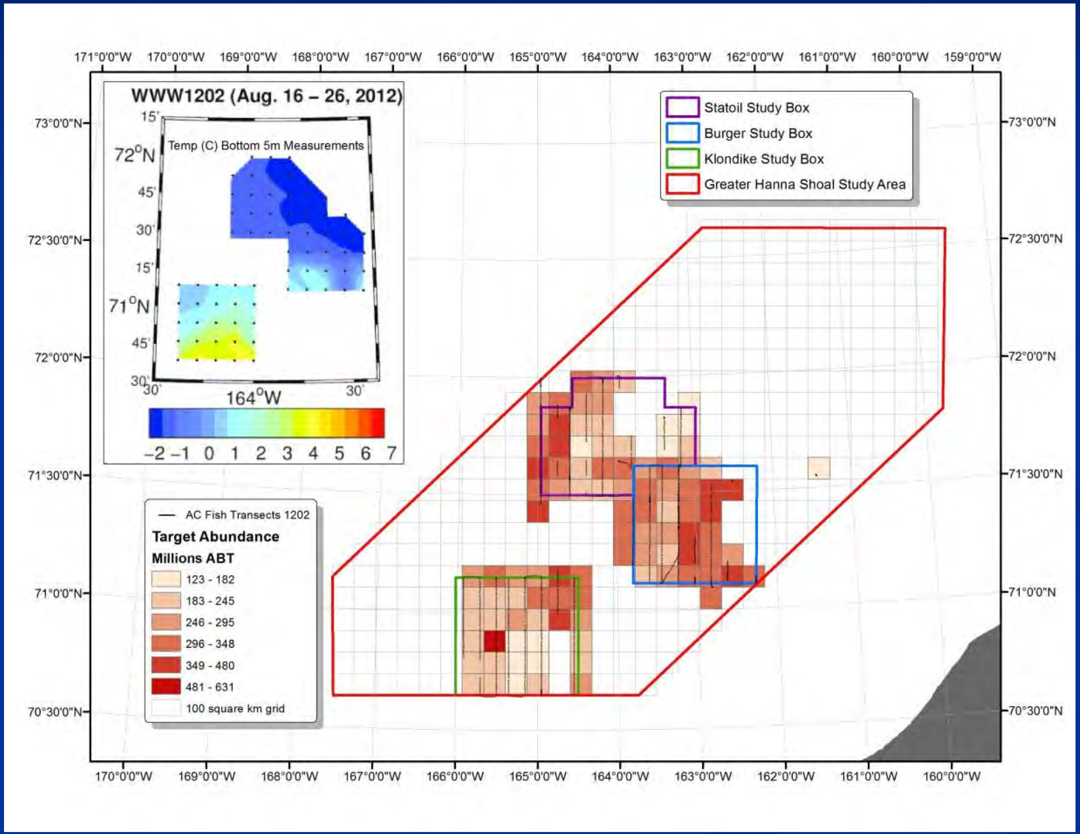
Abundance Estimates

- The relative density (FPUA) at each summary file location was plotted by its recorded positional information within the Greater Hanna Shoal (GHS) study area to provide visual inspection of the data
- Abundance estimation was reviewed for nine area-cruises (Statoil, Burger and Klondike X 3 cruises)
- Sufficient data was collected during cruise WWW1202 to conduct abundance estimation in all three boxes (Klondike, Burger and Statoil), during cruise WWW1204 sufficient data was acquired for abundance estimation for the Burger box, no estimation could be conducted for cruise WWW1203
- Abundance estimation was completed using a standard summary grid
  - FPUA values within a cell grid were averaged and then multiplied by the area of the grid to expand to total targets

Cruise WWW1202 Abundance Estimates

Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1202, CSESP 2012



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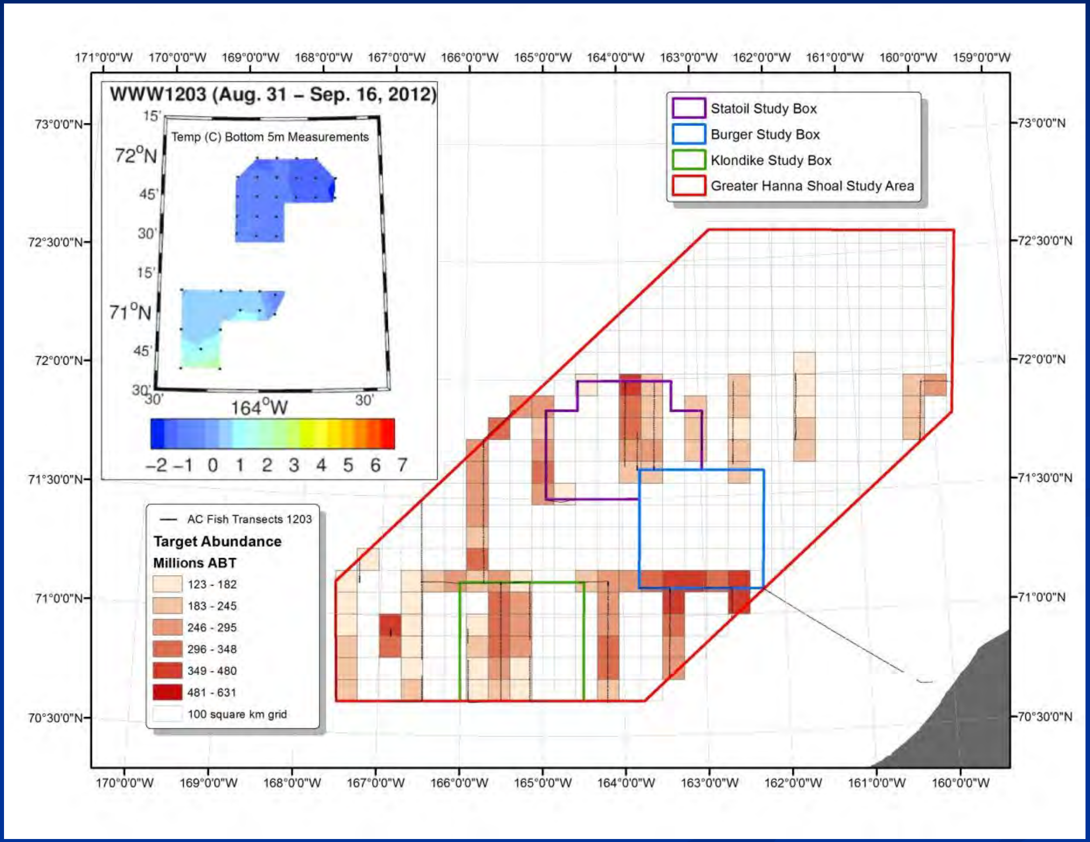
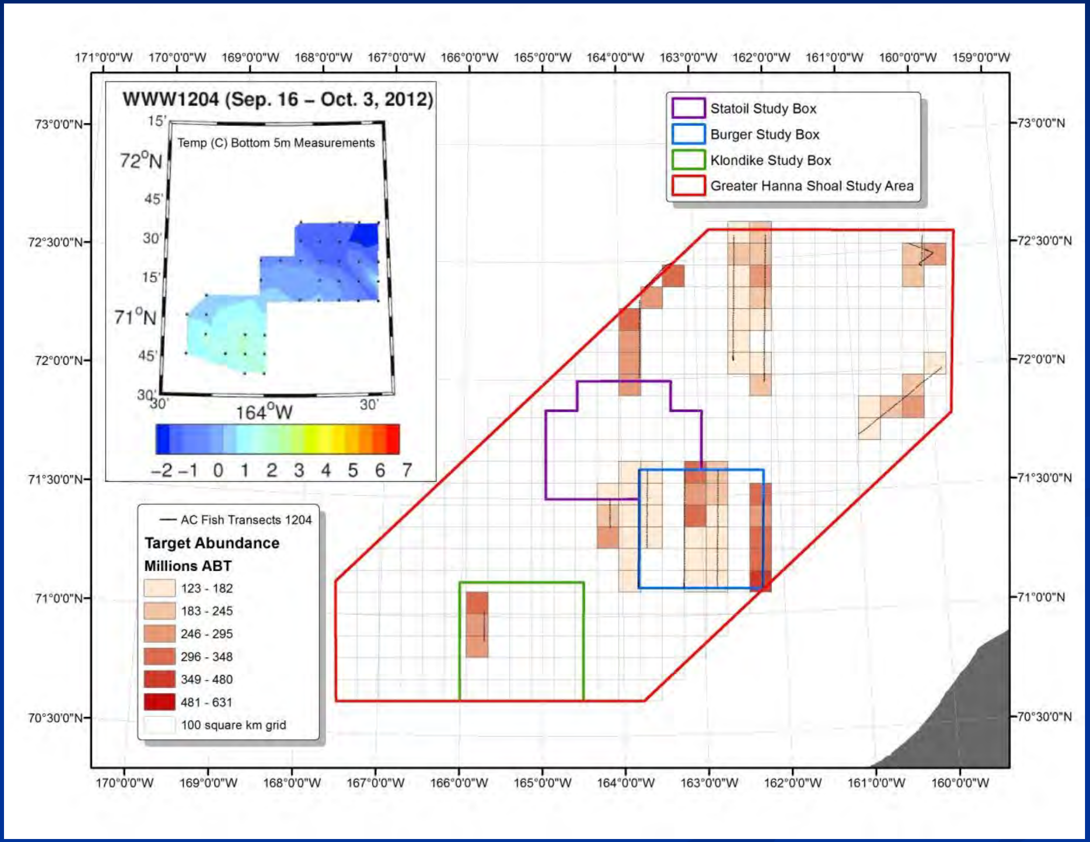
Cruise WWW1203 Abundance Estimates

Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1203, CSESP 2012



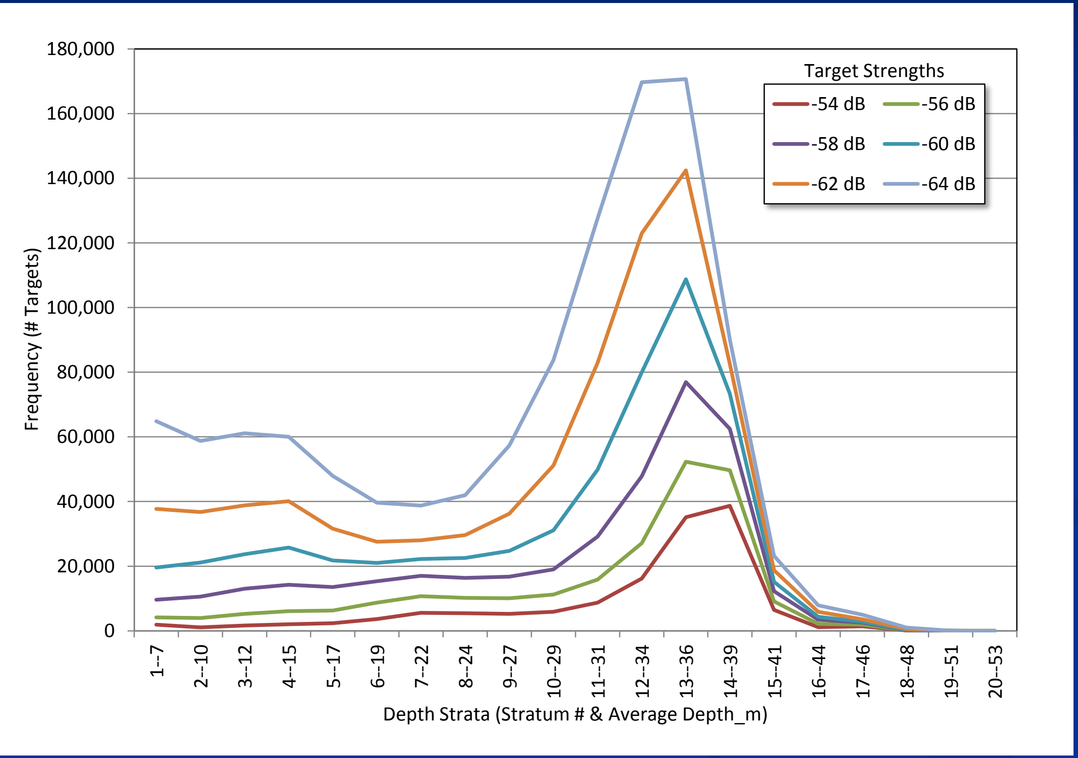
Cruise WWW1204 Abundance Estimates

Plot of abundance estimates of acoustic backscattering targets (ABT) within summary grid cells from processed acoustic survey summary files collected during cruise WWW1204, CSESP 2012



Target Strength Distribution for Expected Age-0 Arctic cod

- Target strength interpretation is limited when no pelagic survey trawl is utilized to verify species in the water-column (McClatchie et al. 2000, Foote 1987)
- The plot shows TS values from the first cruise (WWW1202) across the three boxes by stratum where age-0 Arctic cod would be expected
    - Purple line represents TS = -58 dB
    - Does not show a relative difference from other TS plots by depth. This plot shows at both low frequency (shallower depths) and high frequency (deeper depths)



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Conclusions

- It can be assumed that ABTs are comprised of mostly jellies, some Arctic cod and likely a few capelin
- the TS frequency distributions, normal distributions of FPUA values and the relatively low confidence intervals around the abundance estimates completed suggest that the measured ABT from 2012 CSESP acoustic fish surveys were quantified successfully
- Completing a trawl survey in tandem with the acoustic survey could allow for an improved understanding of what the biomass is composed of in the northeastern Chukchi Sea

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