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Descriptive Report to Accompany NOAA Ship *Oscar Dyson* 2011

Project DY 11-03
Shuman Reef to Mitrofania Islands, Alaska
June 24 to July 11, 2011

1. GENERAL DESCRIPTION AND INTRODUCTION

This survey was conducted as part of an acoustic-trawl stock assessment survey conducted by scientists from the Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division on the NOAA Ship *Oscar Dyson*. This survey was designed to estimate the distribution and abundance of walleye pollock (*Theragra chalcogramma*) and primarily relied on data collected with Simrad EK60 scientific echo sounders in addition to trawl gear. In addition, data were collected using a Simrad ME70 multibeam echosounder (MBES) that was developed specifically for observing targets in the water column, rather than bathymetric mapping. The ME70 data collected during a portion of the MACE survey has been opportunistically repurposed at the University of New Hampshire Center for Coastal and Ocean Mapping / Joint Hydrographic Center and the NOAA Integrated Ocean and Coastal Mapping Center to generate soundings for charting purposes. Despite the non-traditional nature of this survey, this opportunistic use of the data is expected to provide useful information on shoal soundings in under-charted areas and as a reconnaissance tool for planning future hydrographic surveys. Since this data was collected for non-hydrographic purposes, many aspects do not conform to normal hydrographic standards or practices.

This reprocessing largely uses the same work flow described for the year previous, survey W00219 from cruise DY1001. Some improvements have been made for how this survey data was collected and processed, largely as a result of investigations the previous year.

A. AREA SURVEYED

The data described herein, which represent a subset of the data collected during AFSC Mace cruise DY 11-03, were acquired between June 24 and July 11 (DN 175 to DN 192) on two separate trips. These data are generally located between Shuman Reef and Mitrofania Islands, AK (Figure 1). Fisheries MBES (Simrad ME70) data were obtained in the survey area with variable line spacing ranging from 2-20 km and from transit to and from a Kodiak inport. Fish trawls and habitat surveys conducted episodically throughout the survey occasionally results in more complete coverage. A total of 1,872 linear nautical miles of survey are submitted as part of this data set. The survey area is estimated from the number of 8 m grid cells in the submitted CUBE surface, yielding 352 square nautical miles (SNM) of survey area with at least one sounding per 8 m grid cell.

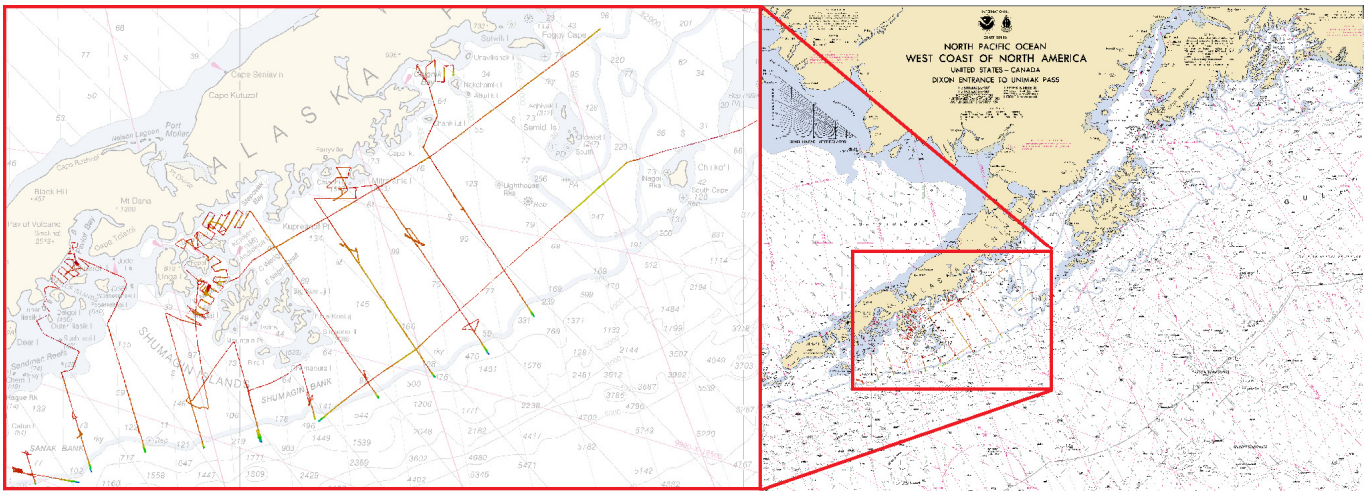


Figure 1. Survey Area

B. DATA ACQUISTION AND PROCESSING

B1. Equipment and Vessels

Specifications for NOAA Ship *Oscar Dyson* and the equipment used for data acquisition and survey operations during this survey are listed below in Table 1.

	Oscar Dyson
Hull Registration Number	R224
Builder	VT Halter Marine, Inc., Moss Point, MS
Length Overall	209 feet (63.8m)
Beam	49.2 feet (15.0m)
Draft, Centerboard extended	29.7' feet (9.05m)
Cruising Speed	12 knots
Max Survey Speed	12 knots
Primary Echosounder	Simrad ME70
Sound Velocity Equipment	SBE 911plus, SBE 45 Micro Thermosalinograph
Attitude & Positioning Equipment	POS/MV V4
Type of operations	MBES

Table 1: Vessel Information

The Simrad ME70 is a fisheries MBES designed for collecting backscatter from midwater targets (i.e., fish) rather than bathymetric mapping. The system is configurable for number of beams, frequencies and steering angles. The ME70 has a different frequency for each beam within a range of 70 kHz to 120 kHz. Specifications for the beam configuration used for the dataset discussed in this report is outlined in Table 2. Beam numbers 0 and 30 are excluded from this data submission.

Beam Number	Frequency (kHz)	Beam Steering Angle (Forward / Athwartship)	Beam Size (Forward / Athwartship)
0	73.2	0 / -65.9	4.5 / 11.0
1	76.1	0 / -56.7	4.3 / 7.9
2	78.9	0 / -49.7	4.2 / 6.4
3	81.8	0 / -43.8	4.0 / 5.6
4	84.7	0 / -38.5	3.9 / 5.0
5	87.5	0 / -33.8	3.8 / 4.5
6	90.4	0 / -29.5	3.6 / 4.2
7	93.2	0 / -25.5	3.5 / 3.9
8	96.1	0 / -21.7	3.4 / 3.7
9	99.0	0 / -18.2	3.3 / 3.5
10	101.8	0 / -14.8	3.2 / 3.3
11	104.7	0 / -11.5	3.2 / 3.2
12	107.5	0 / -8.4	3.1 / 3.1
13	110.4	0 / -5.4	3.0 / 3.0
14	113.2	0 / -2.4	2.9 / 2.9
15	116.8	0 / 0.4	2.8 / 2.8
16	114.7	0 / 3.2	2.9 / 2.9
17	111.8	0 / 6.1	2.9 / 3.0
18	109.0	0 / 9.1	3.0 / 3.1
19	106.1	0 / 12.2	3.1 / 3.2
20	103.2	0 / 15.4	3.2 / 3.2
21	100.4	0 / 18.8	3.3 / 3.5
22	97.5	0/ 22.3	3.4 / 3.6
23	94.7	0 / 26.1	3.5 / 3.9
24	91.8	0 / 30.0	3.6 / 4.1
25	89.0	0 / 34.3	3.7 / 4.5
26	86.1	0 / 39.0	3.8 /4.9
27	83.2	0 / 44.1	4.0 / 5.5
28	80.4	0 / 50.0	4.1 / 6.4
29	77.5	0 / 57.0	4.3 / 7.8
30	74.7	0 / 66.0	4.4 / 10.8

Table 2: ME70 beam configuration used during this survey.

B2. Quality Control

Crosslines

Crosslines were not designed into this survey, but eleven crossings between coverage from different days did occur. The data within these self crossing areas is generally self consistent , with improved performance for near-nadir soundings and diminished accuracy for outer beams that is likely due to an inaccurate sound speed profile model. Data from different survey days were primarily examined visually in the CARIS subset editor as demonstrated in Figure 2. Visual comparison of the nadir soundings of one swath to the entire swath of the crossing line provides an intuitive visualization of nadir different and the variation across the swath. In general these crossings agree within a few decimeters.

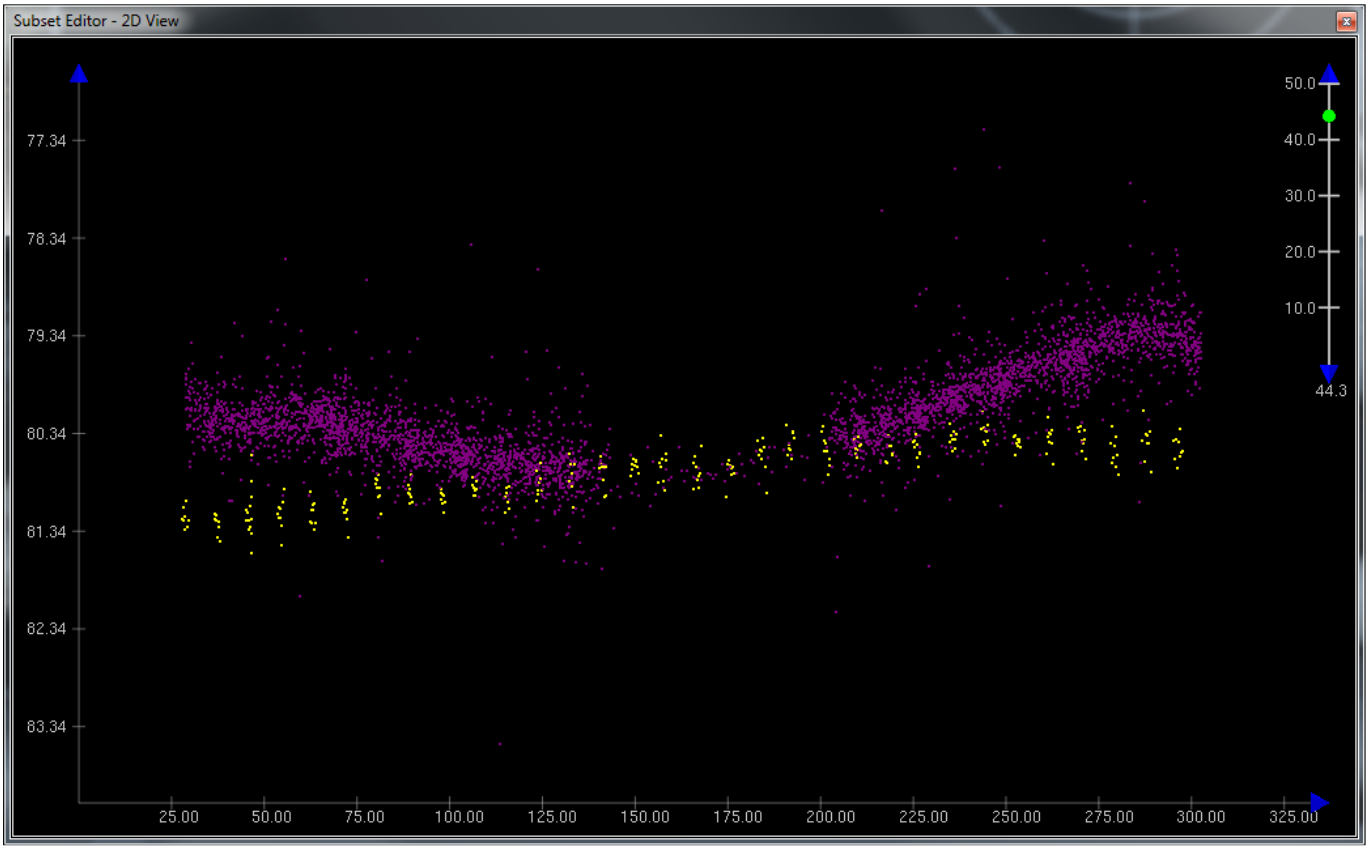


Figure 2. Surface difference for the crossing between day number 179 and 190.

Two exceptions for good inter-day crossline comparison were observed, and these were between day number 179 and 188 and day numbers 179 and 189. An offset at Nadir of two meters is observed in both instances as shown in Figure 3. No clear explanation for these discrepancies is apparent, but it is likely due to an inaccurate realization of the water level and not the echosounder measurements.

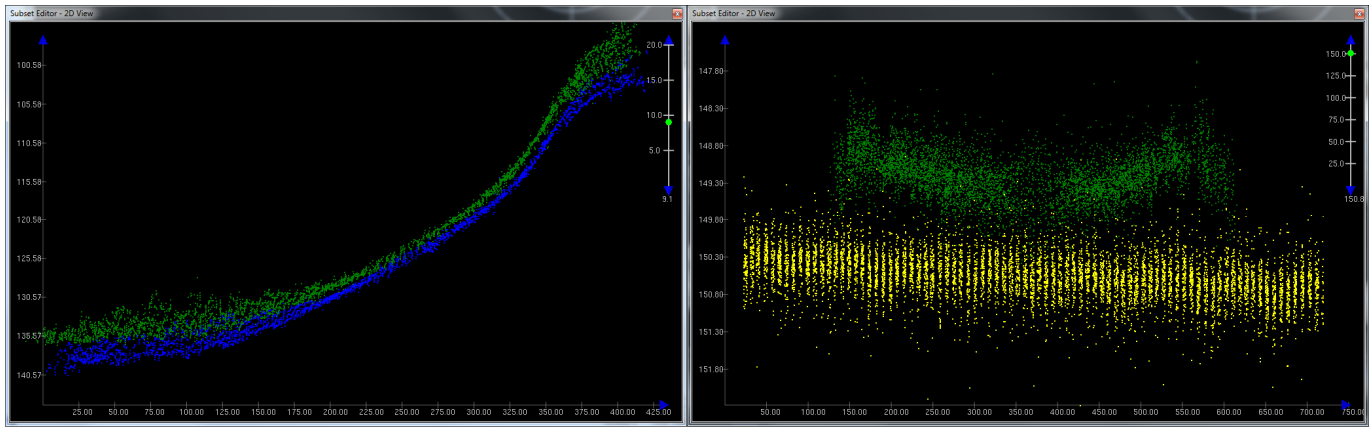


Figure 3. Day number 179 to 188 comparison (left) and day number 179 to 189 comparison (right) as viewed in CARIS HIPS subset editor.

Junctions

Because of the large area covered by these survey lines, multiple archived surveys were available for comparison as shown in Figure 4.

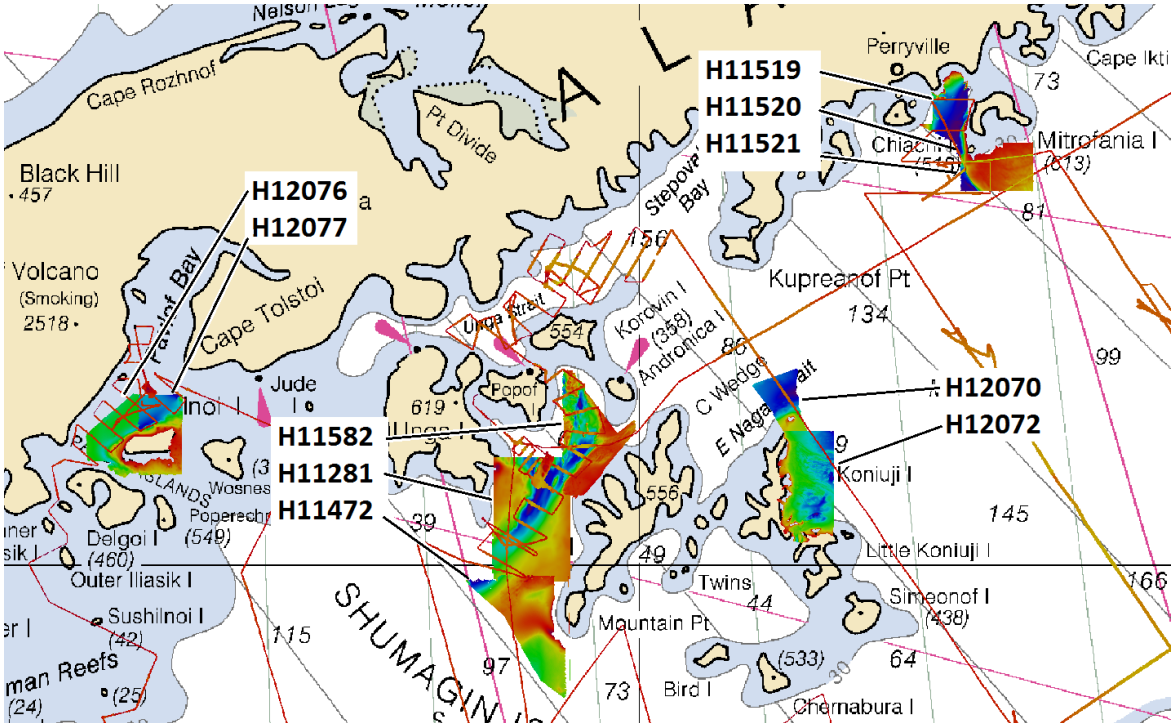


Figure 4. The geographic locations and names of the surveys compared to this dataset.

A comparison between previous surveys and this dataset was conducted through a surface difference in CARIS Bathy Database by subtracting this survey data from the previous surveys. Negative values indicate a deep bias in this survey as depths are positive and larger values in the Dyson dataset would result in negative values. Tables 3 and 4 show the resulting mean difference, standard deviation, and the approximate depth range for the areas compared.

Table 3 Results of comparisons to data from field sheet DY1103_West, day numbers 175, 176 and part of 177.

Surface compared	Mean Difference (m)	Standard Deviation (m)	Approximate Depth Range in Overlap (m)
H12076 combined 8m	-0.49	0.49	40 – 110
H12077 combined 8m	-0.60	0.38	50 – 100

Table 4 Results of comparisons to data from field sheet DY1103_East, day numbers 177 through 192.

Surface compared	Mean Difference (m)	Standard Deviation (m)	Approximate Depth Range in Overlap (m)
H11582 combined 20m	-1.26	1.57	50 – 220
H12072 combined 8m	-0.63	0.21	70 – 80
H12070 combined 8m	-0.91	0.32	70 – 170
H11281 5m	-0.56	4.95	60 – 220
H11519 5m	-0.34	0.39	100 – 130
H11520 5m	-0.29	0.38	50 – 130
H11521 5m	-0.40	0.37	70 – 110
H11472 5m	-0.56	0.31	60 – 90

In general there is a deep bias in the survey data described here, on the order of 0.3m to 0.6m. This bias is likely due to an imperfect understanding between the vessel waterline and the face of the transducer, but is considered small enough for the water depths in question to establish the validity of this particular dataset. It is of interest to note that this is a rare comparison of data from many hydrographic surveys with a single vessel over a short period of time, and it appears to confirm consistency in previous surveys.

Quality Control Checks

Simrad ME70 MBES data from the *Oscar Dyson* was collected over the Shilshole Reference Surface in Puget Sound in the spring of 2011, an area often used by NOAA hydrographic vessels to conduct system quality checks. A comparison between these two data sets was conducted in order to assess the accuracy of waterline and instrumentation lever arm estimates. To minimize refraction errors from the *Dyson* data, only beam angles between +/-20° were used. *Dyson* and *Rainer* base surfaces for this area differ by a mean of 3 cm with a standard deviation of 30 cm.

Data Quality Factors

POSITIONING:

The positioning and attitude sensor aboard *Dyson* was from a survey quality POS M/V version 4 with DGPS from a CNAV satellite signal receiver. In general, and with good satellite coverage, positioning

from such a system would maintain horizontal control within the 5m specification. Since this survey does not contain overlapping lines that include a features it is difficult to check positioning consistency.

One evident error in positioning occurred on day number 189 at 2207, where the vessel appeared to jump 170m. When this positioning error began and why it occurred in not understood, but is assumed to be due to poor satellite coverage and / or a loss in DGPS signal. No real time observation of this problems was noted.

HEAVE and ATTITUDE:

Real time heave from the POS M/V was logged in the raw sonar files during acquisition and applied in post processing. Pitch and Roll are provided to the sonar at a rate of 200 Hz and are applied by the sonar through real-time beam steering. Some heave artifacts are evident in the data, but are not considered problematic for this dataset where generalized bathymetry is the goal. In a few cases heading artifacts are evident due POS M/V GAMS dropouts, as noted in lines D20110625_T214340, D20110626_T115752, D20110705_T220209, and D20110708_T220506.

SOUND SPEED PROFILES:

Sound speed profiles were largely determined through XBTs while underway, with a few CTDs also taken during the survey. Noise was present in the XBT casts, likely due to the conductive wire contacting the vessel hull. These spikes were removed graphically and the profile limited to the water depth in the area. The temperature profile was then extended using the average profile for the month in the world ocean database, and sound speed was calculated using an average salinity profile from the world ocean data base.

SOUNDING COVERAGE

While the ME70 can provide several thousand soundings across track for each ping, the along track ping rate (~1.7 pings/sec) and vessel speed during normal survey operations (~6 m/s) are set by the type of survey operation. This results in a relatively low along track sounding density. For nadir beams, which have the narrowest along-track beamwidth, one hundred percent along track coverage is achieved only for depths greater than 210 m.

PATCH TEST

Although components of a patch test have been performed for the ME70 on the *Dyson*, a full patch test has not yet been completed. In particular, there is relatively high uncertainty in the yaw bias. Because the ME70 compensates for pitch and roll in real-time, a yaw bias in the system creates cross talk between pitch and roll. This is particularly noticeable in high sea states.

B3. Corrections to Echo Soundings

Bottom Detections

The Simrad ME70 MBES is designed to provide water column information in a manner consistent with a split beam Simrad EK60, but at multiple angles and for narrower beam widths. As a result the amplitude

and phase time series from each beam, and within each beam, is of exceptional quality. The system is not designed to provide hydrographic soundings but, because raw water column information has been collected and stored for each beam, soundings can be extracted in post processing. For a typical MBES the number and size of beams can be used as an indicator of sounding density collected by the system. With the ME70 multiple phase detections per beam are possible if the angle of incidence to the sea floor is large enough. One sounding per beam is available where amplitude detection is used, typically in the area within 10-15° of nadir. The bottom detection algorithm that extracts soundings from the raw ME70 data was developed and implemented by Dr. Tom Weber at the Center for Coastal and Ocean Mapping at the University of New Hampshire. These bottom detections are written to a Generic Sensor Format (GSF) for import into CARIS HIPS.

Uncertainty Estimation

Since the ME70 MBES is not typically used in hydrographic survey, no error model exists in CARIS HIPS for proper attribution of uncertainty. To provide sounding uncertainty into the CARIS workflow the Hare Uncertainty Model is implemented during the RAW to GSF conversion process. CARIS HIPS uses these predetermined estimates of uncertainty for the soundings, which includes tidal, sound velocity and vessel offset uncertainty estimates.

Instrumentation and Waterline Offsets

Typical hydrographic processes to convert raw range and angle measurements from the multibeam into georeferenced soundings were observed. As *Dyson* is not usually required to provide hydrographic quality positions of the sea floor, instrumentation offsets and the waterline location have only roughly been accounted for in the past. These offsets were verified where possible and updated where inaccuracies were found.

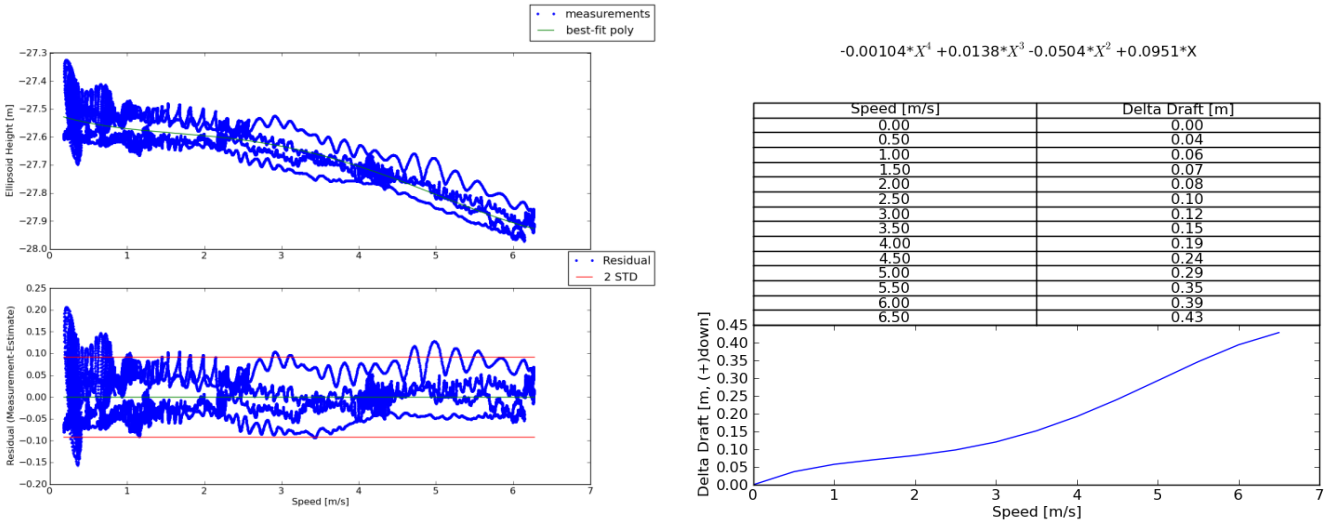
INSTRUMENTATION OFFSETS

In general, a document created by Scott Furnish at the NOAA MACE accurately describes instrumentation offsets with the exception of the vertical reference of the ME70 from the primary reference point (granite block). Another document specific to surveying the ME70 location by Westlake Consultants, Inc better describes the ME70 location but references a different datum within the sonar room. These documents have been combined and included as DysonOffsetDocuments.PDF. Observations aboard *Dyson* in June, 2011 estimate the vertical difference between the granite block and the sonar room datum to be 0.40 meters (up positive). Since the ME70 measurement reference is at the transducer face, the offset between the granite block and the ME70 is -1.46 meters (West Lake Survey) plus the datum difference of 0.40 meters, resulting in an updated offset of -1.06 meters vertically between the granite block and ME70 MBES.

VESSEL WATERLINE

An accurate estimate of the static waterline relative to the vessel reference point was needed to use ME70 measurements for hydrographic purposes. Given the sparse nature of the vessel drawings, the ellipsoid height of the vessel primary reference point was compared with the ellipsoid water level height at a nearby tide gauge over a period of time. Further information on this technique and specific measurement can be found in the attached document DysonStaticWaterline.PDF.

Vessel settlement with changes in speed was estimated using the changes ellipsoid height of the vessel with changes in speed. The table for speed verses change in draft was produced using the Pydro ProcSBETDynamicDraft script macro. The output from Pydro is contained in Figure 5.



Speed [m/s]	Delta Draft [m]
0.00	0.00
0.50	0.04
1.00	0.06
1.50	0.07
2.00	0.08
2.50	0.10
3.00	0.12
3.50	0.15
4.00	0.19
4.50	0.24
5.00	0.29
5.50	0.35
6.00	0.39
6.50	0.43

Figure 5. Pydro output for vessel ellipsoid height and regressed settlement table.

B4. Data Processing

Simrad RAW files are created by the ME70 and are converted into GSF format as previously described. These files are imported into CARIS HIPS 7.1 with Service Pack 2 and Hot Fix 1 to correct for tide, sound velocity and vessel offsets. Only cursory cleaning was conducted to remove obvious fliers effecting the surface. Periodic attitude and heading artifacts remain in the submitted data.

TPU Values

The survey specific total propagated uncertainty values are calculated using the Hare uncertainty model [Hare et al 1995] and are provided on import with soundings into CARIS. No TPU calculation step was required in CARIS HIPS. The uncertainty values used to calculate the TPU can be found in Table 3.

The various contributors to the TPU at a depth of ~70 m is shown in Figure 4. The largest contributors to the depth TPU are the uncertainties due to the sounder, roll, and refraction. The roll uncertainty is dominated by the alignment uncertainty, which has been conservatively estimated at 0.2° due to difficulties associated with a patch test. The refraction error is large (and increases with increasing depth) due to the high uncertainty in the sound speed profiles. Uncertainty for individual soundings is calculated using the similar to the Hare model for amplitude detects and is based on Lurton [2000] for the phase detections. The horizontal TPU is dominated by the horizontal position uncertainty, due to the lack of GPS corrections, and by the alongtrack beamwidth. This survey generally meets IHO order 1 within a swath angle of approximately +/-54° (Figure 6), and generally meets IHO order 2.

Type	Value (1σ)
Heave accuracy	Max(0.05 cm, 5%Heave)
Lever arm offsets	0.2 m
SSP	3 m/s
Surface SS	1 m/s
Roll & Pitch alignment	0.2º
Heading Alignment	0.5º
Dynamic Draft	0.1 m
Static draft	0.04 m
Tide	0.12 m
Time Latency	1 ms
Speed over ground	0.1 m/s

Table 5: Survey Specific TPU Parameters

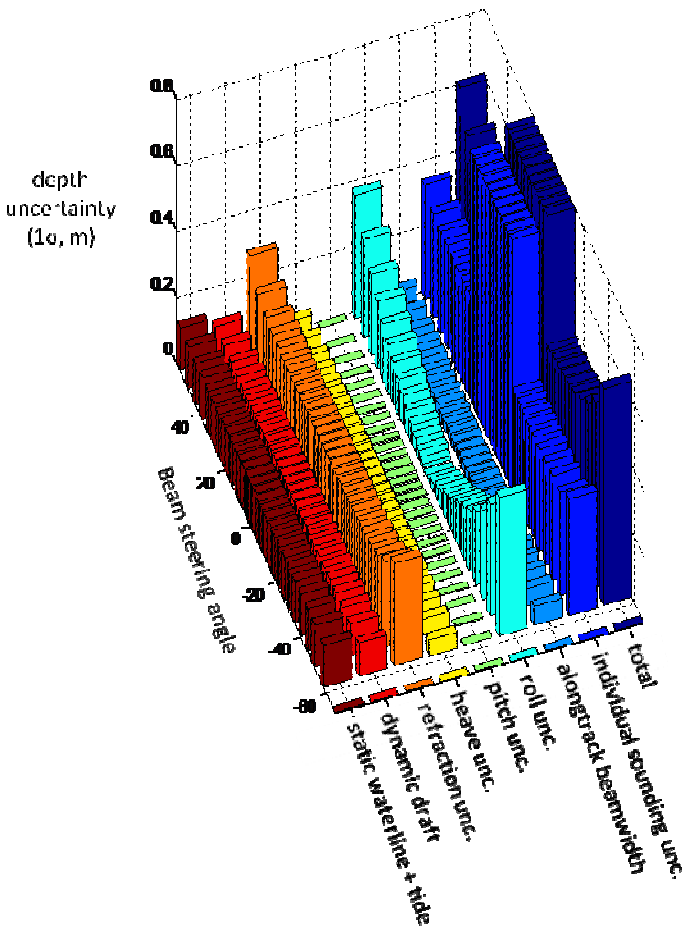


Figure 6. An example of the total propagated uncertainty and contributors for a depth of ~70 m.

CUBE Surfaces

CARIS HIPS BASE (Bathymetry Associated with Statistical Error) surfaces were created using the CUBEParams_NOAA.xml for 2011. An 8m resolution was chosen for the entire survey area because it best matched the along track data coverage. No finalized surfaces were created.

Fieldsheet Name	Surface Name	Depth Ranges (m)	Resolution (m)	CUBE Parameters
DY1103_West	DN175-DN177_8m_Cube	Full survey depth range	8m	NOAA_8m
DY1103_East	DN177-DN192_8m_Cube	Full survey depth range	8m	NOAA_8m

Table 4: Depth Ranges, Resolutions, and CUBE Parameters

C. HORIZONTAL AND VERTICAL CONTROL

A summary of horizontal and vertical control for this survey is as follows. No additional reports for horizontal and vertical control have been formulated.

C1. Horizontal Control

The horizontal datum for this project is the North American Datum of 1983 (NAD83) because DGPS was supplied during survey. The resulting horizontal positioning of the survey vessel is typical for surveys conducted at this latitude.

C2. Vertical Control

The vertical datum for this project is Mean Lower Low Water (MLLW). The operating National Water Level Observation Network (NWLON) primary tide station at Sand Point, AK (945-9450) served as control for datum determination and as the primary source for water level correctors for the surveyed area.

Tides were applied through Pydro using Final Tides and a TCARI surface originally intended for NOAA survey H12072. This TCARI grid, P183FA2009-Final, originally used a temporary water level gauge 945-9163, which was installed by the field party on Herendeen Island. As the temporary gauge data was not available during this survey, TCARI only uses the Final Tides from the Sand Point gauge to model and reduce water levels for this survey.

A few points on the southern side and in the very deepest part of this dataset were outside the TCARI grid and received no tide correction.

No further attempt was made to improve the vertical control for this survey.

D. RESULTS AND RECOMMENDATIONS

D.1 Chart Comparison

A chart comparison was conducted using CARIS HIPS. A least depth sounding layer was extracted from the CUBE surfaces at a 500m spacing. This sounding layer was compared to the charts listed in Table 7 and were found to be generally consistant with these sources.

NOAA Chart Number	Chart Scale	Edition Number	Edition Date	Updated with Notice to Mariners through
500	1:3,500,000	8	June, 2003	April 16, 2011
16011	1:1,023,188	38th Ed.	August, 2012	July 28, 2012
16013	1:969,761	30th Ed.	July, 2006	July 28, 2012
16540	1:300,000	13th Ed.	October, 2010,	July 28, 2012
16547	1:81,326	9th Ed.	March, 2004	July 28, 2012
16549	1:80,000	16th Ed.	March, 2010	June 30, 2012
16551	1:80,000	10th Ed.	April, 2008	June 30, 2012
16553	1:80,000	7th Ed.	March, 2011	June 30, 2012
16556	1:80,000	6th Ed.	July, 2011	June 30, 2012
16561	1:80,000	4th Ed.	October, 2010	July 28, 2012
16566	1:77,477	11th Ed.	August, 2007	July 28, 2012
16587	1:135,000	2nd Ed.	February, 2012	July 28, 2012

Table 5: NOAA charts compared to this survey.

Chart Comparison Recommendations

While the coverage type of this survey does not meet the requirements specified by the *Hydrographic Surveys Specifications and Deliverables Manual* (HSSDM), the age of surveys in some of the areas covered by this data set and currently supporting the charts in these waters is inferior to the data described here. While the charts largely agree with this survey, using these data for significantly shoal soundings or areas of the chart without soundings would still constitute an improvement to the current products.

Dangers to Navigation

One DTON was found and submitted from this dataset to the Marine Chart Division on June 26th, 2011, under the title DysonJune26. The charts have been subsequently updated to include this submission.

D.2 Additional Results

Backscatter

Seafloor backscatter data is not included with this data submission, but does exist within the raw dataset. The backscatter is being extracted for further use in trawlability and fish habitat studies at the University of New Hampshire.

D.3 References

Boyer, T., Stephens, C., Antonov, J., Conkright, M. E., Locarnini, R., O'Brien, T. D., and Garcia, H. E. (2002) World Ocean Atlas 2001, Volume 2: Salinity. NOAA Atlas NESDIS 50. U.S.Government Printing Office. Washington, D.C., USA.

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Lurton, X (2000). "Swath bathymetry using phase difference: theoretical analysis of acoustical measurement precision." *IEEE J. Ocean. Eng. 25(3),* 351-363.

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