



Canadian Hydrographic Service's Backscatter Metadata Requirements and Client Feedback Loop Questionnaire

Prepared under contract for: Fisheries and Oceans Canada - Canadian Hydrographic Service

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Date: 2023-03-27

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Executive Summary

The Canadian Hydrographic Service (CHS) has retained the services of HydroOctave Consulting Inc. for two tasks to support the 2023 pilot project to disseminate CHS backscatter products on NONNA. The outcomes of these two tasks is summarized below for quick reference. The interested reader who wants to understand more off the methods and thought process can refer to the main text of this report.

Task 1 – Metadata Templates

The first task was to develop a set of backscatter metadata templates to capture relevant information from the acquisition, processing and production stages of multibeam backscatter. Input was sought from a wide range of contributors based on global users of multibeam backscatter to ensure that the template captured the needs of many potential producers and consumers of multibeam backscatter. Though the needs were varied and often complex, it was directed to aim for a simple and pragmatic template that (a) allow an end user to assess if products were fit for purpose, and (b) that would not be overly complex or onerous to complete by field and processing personnel in these early stages of backscatter acquisition and processing.

The net result is presented in the three sections below for ease of quick reference. The process through which these were derived is described in the main body of text. Note that it is an exact copy of information shared later in the text.

Acquisition Metadata Template

Item	Entry Type	Comments and Recommendations
Sonar firmware version number	Text entry	This can become important in identifying if a data set from a sonar was acquired with a flawed firmware version that could affect backscatter. Recommend keeping this. For example, a recent version of Norbit firmware has fixed false dB offsets between dual-head systems.
Acquisition software vendor and version	Text entry	This can become important in identifying if a data set acquired with a flawed version of an acquisition system that that could affect backscatter. For example, until recently, Hypack could not log R2Sonic TruePix and Snippets simultaneously.
Were efforts made to maintain sonar settings that affect backscatter constant though the survey?	Yes/No	High value driver in assessing if a product will have artifacts or not. Not all sonar settings can be adequately compensated in post-processing, thus many surveyors opt to lock down the settings.
Sonar frequencies used during acquisition	Numeric entry, multiple entry	Capture different frequencies used throughout the survey. This applies mostly to R2Sonic, Norbit and Kongsberg EM2040 systems, all of which have a high degree of agility in terms of operating frequency. The deeper water Kongsberg systems should report the nominal sonar frequency. For these systems, the frequency changes by depth mode

		and also between sectors. The nominal frequency is sufficient for an end user to assess the suitability of a data set.
Was pulse length held constant through the survey?	Yes/No	Knowing that at least the pulse length was held constant is valuable. This infers that the user can expect the same spatial sampling and thus resolution.
Description of calibration procedures, if any.	Text	Expect that this is “None” for all CHS vessels at the moment but good to have this for future growth. Short explanation of calibration procedures done. Address topics such as mode normalization, normalization between different sonars and/or platforms. If beam pattern corrections were estimated and uploaded to the system (Kongsberg, primarily). If an absolute calibration was attempted. If any attempt was made to normalize echo level between heads in a dual-head setup. Was system calibrated over known area with known backscatter values or was backscatter at the calibration site inferred from sediment properties?
Were there procedures in place to capture oceanographic variability?	Yes/No	For typical hydrographic surveys, one would expect this to be yes. Typically reported in bathymetry metadata. ¹
Was the sonar updated with new absorption coefficients with each oceanographic profile?	Yes/No	Related to the item above, but clarifying if the information that was measured was applied in real-time in the sonar settings.
Were all acoustic instruments synchronized so as not to interfere with each other?	Yes/No	Free running acoustic systems will often interfere with each other. This will cause issues with bathymetric detections so it is of high value to control this for the main CHS mission of bathymetry measurement with the side effect of having clean backscatter.
Were there procedures in place to avoid saturation, if necessary?	Yes/No	Most multibeam systems can be saturated if incorrectly configured. Given the large number of R2Sonic systems in the CHS equipment pool and also Norbit systems, this is an important element to capture since both systems are easily overdriven if not careful with sonar settings.
Were beam echo level time-series recorded?	Yes/No	Important value driver for specifying the imagery resolution, though not many respondents identified it. This is also more of a processing configuration, though it is possible to record neither, only one or both types with sonars.
Were beam average echo levels recorded?	Yes/No	It is possible to configure the hardware and/or acquisition systems to not store this. It should always be recorded as a backup for the time-series data in the event of an error in configuration or recording of beam time-series data.

Were ground validation data collected, if so, what type?	Text entry	This is a simple question to add even though CHS does not routinely do this. If the CHS standard becomes a starting point for other agencies to work on, this field will surely appear. It makes sense to include this even though the answer is “No” for CHS data. Typical answers might include: Type: photos, videos, grab samples.
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Processing Metadata Template

Item	Entry type	Comments and Recommendations
Backscatter processing software vendor and version	Text	High value driver when assessing suitability of a product when trying to align use of a particular vendor or avoiding a known problematic version.
Written summary of processing steps	Text	Recommend text entry to capture a summary of processing steps. Leaving it as text allows for flexibility in describing specific vendor related functionality that may not be common across different vendors. The risk is that some may provide very short descriptions. Suggest some example text for field units to use for this. Even better would be a standard processing procedure that is standard for all CHS data. Such text should be exhaustive for the sake of being complete, but use of a standard description will ease the burden for data processors. Items could include: • Description of standard procedure • Specification of the backscatter correction procedure used, in case the software vendor offers different options (e.g. Caris offers use of their own algorithm but also maintains their implementation of UNH/CCOM Geocoder). • Specification of vendor specific processing parameters, such as TVG/AVG corrections, use of terrain model for slope corrections • Use of a beam pattern correction • Was software configured to correct for the typical sonar setting variations that affect backscatter since it is possible with some packages to disable these types of corrections. • Information about location of processing report/log.
Has bathymetry data been cleaned?	Yes/No	High value driver, uncleaned data can result in a very substandard mosaic.
Written summary of artefacts of note	Text	This is an important value driver in assessing if a product is fit for purpose. Recommend a text summary where the quality of the mosaic is assessed. Notable items to discuss might include: • If data were saturated • If weather had a major impact on data quality, if unexplicable dB shifts result even after correction for sonar setting variations. • Description of any remedial measures taken to address artefacts, such as use of dB shift tools, along with summary of parameters used for such tools.

Backscatter Mosaic Metadata Template

Item	Entry Type	Comments and Recommendations
Mosaic cell size	Numeric	Typical metadata that is always specified in any geospatial grid product.
Coordinate reference system	Text	Typical metadata that is always specified in any geospatial product. Suggest use of standard such as WKT.
Spatial bounds	Numeric	Typical metadata that is always specified in any geospatial product.
Data format	Text	Assume the user meant the file format, e.g. Geotif.
Data representation: unitless greyscale imagery or actual backscatter values	Text	Typical metadata that is always specified in any geospatial product. There may be conventions for this for photography or satellite imagery. Mosaics tend to be either unitless greyscale or a gridded product that reports actual dB values.
Frequency of mosaic, in case of multiple frequencies	Numeric, multiple entry	Incredibly important for knowledgeable backscatter users.
Does this product compile data from several sensors and/or platforms?	Yes/No	Import value driver in assessing quality of the mosaic. It can be very difficult to compile data from multiple sonars/platforms without artifacts.
Data representation: unitless greyscale imagery or actual backscatter values	Text	Typical metadata that is always specified in any geospatial product. There may be conventions for this for photography or satellite imagery. Mosaics tend to be either unitless greyscale or a gridded product that reports actual dB values.
Mosaic algorithm and settings	Text	This item and the item below can be captured in a text description of mosaic processing steps. Could include specifics on how overlapping data were handled.
Was beam time-series data processed or beam average?	Text	Specify if software was configured to process beam average or beam time-series data.
Description of any cosmetic corrections that were applied to the imagery to improve appearance	Text	Describe any types of cosmetic corrections, like smoothing, that may have been applied to products.

Task 2 – Backscatter User Questionnaire

The second task was to develop a questionnaire for end-users of backscatter, to be completed either when they download data from NONNA or in follow up interactions. The method used and the result is documented in the main body of this report. The questionnaire is recreated here for ease of reference.

Starter Questions

- How did you learn about the portal?
- Were you able to find what you were looking for?

Tell us about yourself

- What sector do you belong to: Public, Academic, Private, Other
- Which of the following best describes your most typical interaction with backscatter: Planning, Acquisition, Processing, Analyst, None previous
- How many years of experience do you have with multibeam backscatter?
- How would you rate your proficiency or knowledge level with multibeam backscatter? Novice, Intermediate, Advanced, Expert

Tell us a bit about why you're downloading data today

- What is your intended use for this data, e.g. geology, habitat mapping, industry, method development type research
- What value do you expect to derive from this data?

Tell us a bit about the products you found and what could be done to improve it

- If CHS could do one thing differently about the way backscatter is processed and made available, what would it be and why?
- Would you be interested in for the same product to be available in other delivery formats, why?
Example: Floating point geotiff, greyscale image, NetCDF.
- Is the information in the metadata valuable?
- Is there anything else you'd like to see in the metadata?
- Is there enough supporting information available e.g. uses and limitations of backscatter?

Tell us about other backscatter related products that might be of interest to you

- Would you be interested in data that has not been processed, why? Example: Raw sonar data, processed bathymetric data.
- Would you be interested in other types of products, why? Example: Angular response curves.
- Would you be interested in products or data that has been further processed, why? Example: Seafloor characterization maps.

Open Ended "Catch All" questions

- Is there anything else you'd like to tell us?
- If you are open to follow up questions, please provide an email address.

Problem Statement

Scope, as agreed upon in HDACoE2022_TA03 Statement of Work:

“One of the mandates of the Canadian Hydrographic Service (CHS) is the production and maintenance of nautical navigation charts. CHS produces charts using data collected from a variety of sources. CHS’ data holdings may also serve other non-navigational purposes, such as, scientific research and engineering. A by-product of bathymetric data is backscatter intensity returns from the seafloor, which is the strength of the reflected signal back to the sonar transducer influenced by the roughness of the seafloor, among other in-situ factors . Analysis of the returning signal strength can lead to seafloor classification.

Currently the CHS does not have a good understanding of the client demand nor the value added to the scientific communities based on the current catalogue of backscatter products produced by the CHS or other contributing parties. For this reason, the CHS is moving towards a 1-year pilot project with the purpose of gathering client feedback to gain insight into the use case and usefulness of the CHS’s backscatter products for consumption to the broader scientific communities. The pilot project will see the release all CHS backscatter products to the public via the CHS NONNA Data Portal. Metadata is vital to communicating information about the product so that clients can understand the quality of the backscatter products.”

Objectives, as also specified in HDACoE2022_TA03 Statement of Work:

“The intent of this statement of work is twofold. First to provide recommendations on metadata required specifically related to backscatter data on three frontages, data acquisition, data processing, and the resulting backscatter product. The recommendations will be used to influence and guide all parties involved during the lifecycle of a backscatter product. The second objective is to develop a questionnaire to gain insight into the clients who use backscatter products, what they intend to use the products for, whether or not the current products CHS are creating are useful, how the CHS can improve to better meet client expectations, and if given the chance, would clients be interested in raw data to process on their own, or an on-the-fly processing using well known algorithms / models.”

HydroOctave Consulting Inc. was tasked with providing the following services:

Backscatter Metadata Requirements

Task 1.1 - Recommend metadata requirements, while considering full suite of production sounders, to add value to potential client base.

- a) HydroOctave Consulting will investigate CHS current metadata requirements for bathymetric surveys.
- b) HydroOctave Consulting will review other Hydrographic Office data dissemination platforms to compile a set of metadata attributions associated with backscatter intensity products
- c) HydroOctave Consulting will recommend internal backscatter metadata standards for the CHS to consider for newly acquired data. The recommendations will be divided into three (3) categories
1. Data Acquisition 2. Data Processing 3. Backscatter Intensity Product.

- d) Although it is recognized that HydroOctave Consulting is not an expert metadata software solutions, HydroOctave Consulting will make an effort to recommend a format / structure to aid in ease of metadata accessibility (i.e. ease of metadata extraction into JSON or XML file format).
 - 1. The recommendation may consider other Hydrographic Offices, as they may have a solution deployed that the CHS can leverage, or perhaps there is a commercial off-the-shelf solution, or maybe a simple Microsoft excel template is the recommended solution.
 - 2. The recommendation must consider the method for which survey parties populate the necessary fields and highlight how the recommendations eases the workload on the survey parties as well as downstream accessibility.

Task 1.2 - Deliverable – a report containing the recommendations from requirement 1.1 above.

- a) HydroOctave Consulting will provide a report on the recommendations that fulfill the requirements contained with in 1.1. above.
- b) If possible, HydroOctave Consulting will provide a template for metadata population for field survey parties and downstream units, i.e. those doing post processing and product generation/dissemination.

Backscatter Client Feedback Loop Questionnaire

Task 2.1 - Develop Client Feedback Loop Questionnaire

- a) HydroOctave Consulting will develop a client feedback loop questionnaire with the goal of gathering client input on:
 - 1. the usefulness of CHS' current backscatter products.
 - 2. information on the client themselves
 - 3. the use case of the backscatter products
 - 4. interest in raw data requests
 - 5. preferred processing algorithms
 - 6. any other recommendations
- b) The client feedback loop will be developed in two groupings:
 - 1. Short feedback questionnaire that will be visible to the clients with the CHS NONNA Data Portal upon client download of a product.
 - 2. Long form questionnaire via a web application (eg. Survey Monkey) whereby the client is provided a link and the client voluntarily submits the questionnaire.

Task 2.2 - Client Feedback Loop Questionnaire Deliverable

- a) HydroOctave Consulting will develop both a short, high-level questionnaire and a detailed long form questionnaire. Both questionnaires will be in simple text format (Microsoft Word Document).

- b) Incorporation of the questionnaire on the CHS NONNA Data Portal or other means will not be the responsibility of HydroOctave Consulting.

Methods

HydroOctave Consulting undertook a series of one-on-one outreach interactions, primarily via email, with a number of individuals known to work with backscatter. The intent was to engage with a variety of collectors, processors and users of backscatter. While preparing the list of individuals to contact, efforts focused on ensuring that government, private sector and academic sector experts were engaged. Care was taken as well to ensure that outreach include individuals who participate in the entire lifecycle of collecting, processing and using backscatter. The table below categorizes the outreach participants by sector and by type of work they do with backscatter. Table entries provide a summary count as well as initials of those contacted. See Appendix I for a list of individuals who were contacted as part of the outreach, their full names can be matched up with their initials in the table below.

	Public	Private	Academic
Acquisition	8: GR, KP, SB, MM, AS, SI, MR, MW 5: CHS HSWG - GB, DH, SM, SY, EL	9: GM, BJT, PA, CM, LQ, LG, DN, SS, DM	6: LM, JHC, IC, VF, CB, JS
Processing	11: GR, KP, SB, MM, MD, AS, SI, GF, MR, MW, MG	9: GM, BJT, PA, CM, LQ, LG, DN, SS, DM	6: LM, JHC, IC, VF, CB, JS
End-User	5: KP, MD, AS, SI, MR	3: GM, BJT, PA	5: LM, JHC, VF, CB, JS
Hardware Vendor		9: KJ, CP, JC, EL, SM, PP, MB, CB, PK	
Software Vendor		7: JM, BF, TF, TH, EL, EvdV, DM	

Hardware and software vendors were included within the private sector individuals contacted. The table below summarizes the specific vendors that were contacted and the individuals who provided input.

1. Hardware
 - a. Kongsberg
 - i. Kjetil Jensen (Product Line Manager)
 - ii. Colleen Peters (current SIS Product Manager, Deep water systems Product Manager)
 - iii. Jose Cordero (EM2040 Product Manager)
 - iv. Elizabeth Lobecker
 - v. Samantha Bruce
 - b. Norbit
 - i. Pawel Pocwiardowski (current Product Manager)
 - c. R2Sonic
 - i. Mike Brissette (Technical Sales)
 - ii. Charles Brennan (Customer Support)
 - d. Reson
 - i. Pim Kuus (Product Manager)
2. Software
 - a. QPS

- i. James Muggah (current FMGT Product Owner)
 - ii. Ebelien van der Velde (Customer Service)
- b. Teledyne-Caris
 - i. Burns Foster (former HIPS Product Manager)
 - ii. Tami Francksen (former HIPS Product Manager)
 - iii. Travis Hamilton (current HIPS Product Manager)
 - iv. Eli Leblanc (former HIPS backscatter software developer)
- c. Hypack
 - i. Dave Maddock (former software developed who integrated UNH/CCOM Geocoder)

Typical outreach started with asking if the person had any awareness of any backscatter standards for metadata. As the conversation carried on via email, follow up questions included what they thought should be included in a backscatter metadata standard, if one were to be created. Once a reasonable amount of feedback was given on the question of what should be included, a Google survey was created to allow for capture from a wider audience, allowing this wider audience to comment on the combined thoughts of the one-on-one outreach participants. The questionnaire was distributed via LinkedIn for a very broad outreach. It was shared on the Backscatter Working Group email list to target individuals with high degree of interest in backscatter. It was shared also with individuals who could in turn distribute it on organizational mailing lists or contact points for further outreach. This includes the UNH/CCOM emailing list (Academic), NOAA points of contact (Public sector), CHS HSWG regional leads (Public sector).

As of the time this report is being written, 45 responses have been received. The questionnaire is included in Appendix II.

Backscatter Metadata Requirements - Findings and Synthesis

The one-on-one discussions led to the compilation of two lists of potential items to include in backscatter metadata related to acquisition and processing. Before going much further, it is important to note that nobody was aware of an existing solution for metadata backscatter, though some partial solutions were in the works. A Google survey was prepared to capture wider input beyond the one-on-one discussions with these preliminary lists being presented to respondents, and they were asked to comment.

Before getting to the questions about the lists of metadata items, the survey started by asking a few general questions about the respondent, to help inform interpretation of their perspectives. Figure 1 below shows that respondents were spread evenly between sectors and there was no sector that was underrepresented in the results. There is also a good spread of respondents working with backscatter in all stages: planning, acquisition, processing and analysis, as shown in Fig. 2. Turning to Fig. 3, more than 50% of respondents have worked with backscatter over 5-20 years of their career. Finally, Fig. 4 shows that most respondents self reported their expertise as being “mid-level”, with 68% reporting either mid-level or advanced. In summary, it is felt that a good balance was achieved in getting a diverse sampling of backscatter users across sectors, roles and experience levels.

What sector are you in?

43 responses

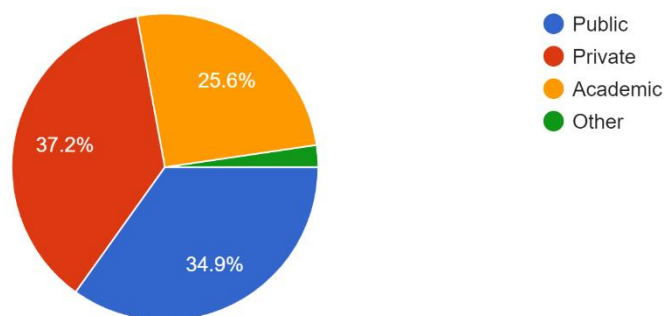


Figure 1. Breakdown of respondents by sector.

How do you work with multibeam backscatter?

44 responses

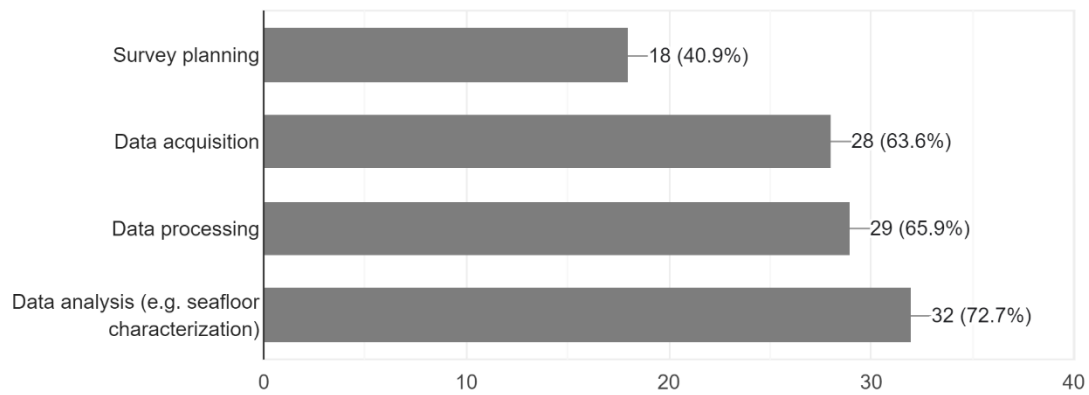


Figure 2. Breakdown of respondents by type of work they do with backscatter.

How many years have you been working with multibeam backscatter?

44 responses

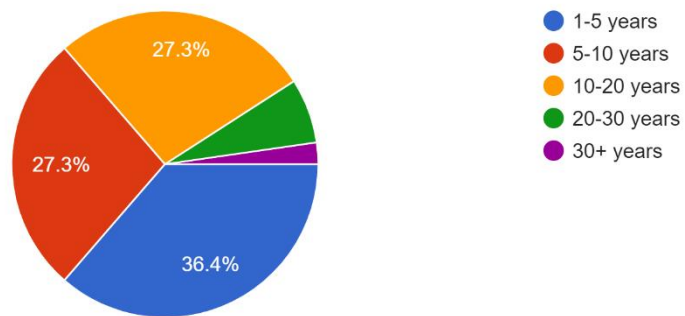


Figure 3. Breakdown of respondents by years of experience working with backscatter.

What would you say is your level of expertise with multibeam backscatter?

44 responses

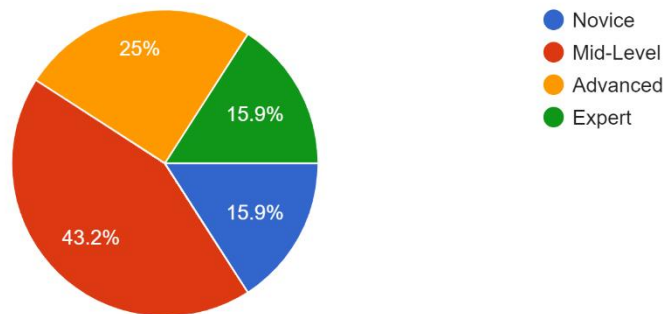


Figure 4. Breakdown of respondents by level of expertise with backscatter.

As mentioned previously, respondents were presented with two lists of potential items to include in backscatter metadata. Respondents were also asked if they could add one more item to each list and to explain why. They were also asked to identify what they thought was the most important item to capture and to explain why. Both of these are summarized separately for Acquisition and Processing in the tables below. The right most column indicates the vote count when respondents were asked to identify the most important item in the list. Several respondents chose more than one item since the question was a long form text entry return field, thus the total votes exceeds the number of respondents. The majority were able to isolate three important items and many acknowledged that choosing a single item was limiting.

Findings – Acquisition

Table 1. Summary of candidate items for backscatter acquisition metadata with respondent votes on priority items.

Item	Vote Count
Dates of acquisition	7
Vessel name	0
Vessel operator	0
Make, model and serial number of sonar(s)	9
Single or dual-head?	1
Sonar firmware version number	0
Acquisition software vendor and version	0
Type of calibration (relative, absolute)	11
Quality of calibration (none, factory, laboratory, field)	7
Were efforts made to maintain sonar settings that affect backscatter constant though the survey?	15
Was the sonar head damaged or replaced during the survey	1
Were there procedures in place to avoid saturation, if necessary?	1

Were there procedures in place to capture oceanographic variability?	3
Were ground truthing seabed samples collected?	0

Below is a list of items that respondents recommended to add to the list when they were challenged to add one more item. Some items were reported multiple times, this is indicated by the count after each item.

- Survey platform (surface vessel, ASV, AUV): 2
- Link to field report: 1
- Quality control: 1
- Sonar settings: Frequency, pulse length, power, gain, mode, absorption, spreading: 14
- Calibration curve (beam pattern): 1
- When settings were changed and why: 2
- Repeatability of instrument: 1
- Type of imagery: snippets, beam average: 1
- Primary purpose of survey: 1
- Whether dual-head systems were calibrated for alignment between heads: 1
- Distribution of casts: 1
- Project name: 1
- Location: coastal, offshore, deep sea: 1
- Geographic location: 1
- Survey log: 2
- Weather conditions (rough sea, wind, waves): 2
- Typical survey overlap coverage between lines, line spacing: 1
- Were sediment properties used for calibration: 1
- Presence of artificial targets in area: 1
- Was patch test completed: 1
- Any known interference from other acoustic instruments running at the same time: 2
- Hull mount or pole mount: 1
- Line start and end times: 1
- Name of survey area: 1
- Positional accuracy: 1
- Who oversaw collection of data: 1
- Sound velocity measurements at transducer: 1
- Information on water column stratification or other water column effects that could affect backscatter: 1

Findings – Processing

Table 2. Summary of candidate items for backscatter processing metadata with respondent votes on priority items.

Item	Vote Count
Bathymetry processing software vendor and version	2
Were any special bathymetric corrections applied, e.g. navigational shifts?	4
Has bathymetry data been cleaned?	5
Backscatter processing software vendor and version	5
Were any special corrections applied, e.g. dB shifts, beam patterns?	12
Written summary of processing steps	10
Written summary of artefacts of note	1
Mosaic cell size	2
Spatial bounds	0
Coordinate reference system	2
Single sonar or compilation of multiple sonars	1
Data representation: unitless greyscale imagery or actual backscatter values	1

Below is a list of items that respondents recommended to add to the list when they were challenged to add one more item. Some items were reported multiple times, this is indicated by the count after each item.

- Raw file list: 1
- All parameters that affect radiometric and geometric backscatter signal: 1
- All information such that processing is reproducible: 1
- Percentage saturation: 1
- Use of slope correction, resolution of terrain model used for this: 2
- Are extra bathymetry layers available: std. dev, density, slope: 1
- Backscatter processing algorithm used: 1
- Written summary of bathymetry processing steps: 1
- Ground validation data collected, type: photos, videos, grab samples: 1
- Mosaic algorithm and settings: 1
- BS processing code level from Lamarche and Lurton (2017): 1
- Description of how overlapping data is handled in mosaics: 1
- Parameters used in configuration files with all processing parameters: 2
- Frequency of mosaic, in case of multiple frequencies: 4
- Was system calibrated over known area with known backscatter values: 1
- Processing standard operating procedures: 2
- Procedures to remove noise or interference from other devices: 1
- Data format: 1
- TVG/AVG parameters: 2
- Backscatter processing log: 2
- Who oversaw processing of data: 1

Synthesis

There seems to be a blurring of lines in demands for backscatter metadata between the normal things that one might find in a metadata record and what one might find in a detailed survey report. A survey

report for a bathymetry and backscatter survey can run several tens of pages, perhaps even hundreds with survey logs included as appendices. Such reports are considered the authoritative and often exhaustive source of information on all aspects of the survey from planning, execution, processing and deliverables. Many respondents in the one-on-one sessions and in the google survey sought out the kind of information that might be included in such a report. Metadata for bathymetric surveys is typically lean and would tend toward indicating that a report exists and where to find it in the event that more information was needed.

Many respondents wanted detailed information on sonar settings, whether they were fixed or not. If they were not held fixed, when were they changed and why. This information is stored in the raw sonar files and can be programmatically queried to form a report. Though many respondents asked for detailed sonar settings, it is important to note that the overwhelming vote for the top value driver in the metadata list was whether settings were controlled or not. The answer to this question alone indicates if they can expect to see problems in the mosaic that may have not been corrected, or correctable, in processing. As a counterpoint, there are some settings that are useful for assessing fitness for purpose: frequency and pulse length. The seafloor response will vary with frequency, thus this particular sonar parameter is important to capture. An end user will not likely want to combine a 100 kHz mosaic with a 400 kHz mosaic, for example. Similarly, pulse length is important since it captures aspects of the imaging resolution of the sensor itself, thus what spatial resolution to expect in any derivative mapping products. Note that this is very often quite different from the mosaic resolution (usually quite smaller).

It is important to focus on the fact that mosaics are going to be generated by CHS and the user will have no ability, at least not at first, to ask for raw data. So, what purpose does the metadata serve? It will help the user understand how the data were collected and processed such that they can assess if the product is fit for their purpose. This type of assessment can be done by simply looking at a mosaic. An average user who is familiar with backscatter can assess the quality of the mosaic by looking at it. Someone interested in a single mosaic would be ill served by assessing the metadata record alone, a visual inspection would almost always be necessary to ensure quality.

Requests for documentation on steps to recreate the processing are not driving value to the end user at this stage simply because they cannot replicate the steps anyway. Even if they did, they are likely a sophisticated user and would choose their own processing approaches anyway. Perhaps of use though would be having the metadata capture if backscatter data were problematic to work with and required special corrections. This is also only of use if a user is going to reprocess their backscatter. Documenting steps to reproduce is helpful for users who collect and process their own data since it helps to retrace their steps or to recover from error. It is of little value to an average user who only has access to the end result. That being said, capturing the processing configuration can provide value for CHS in that feedback can be sought from users on particular settings they might prefer for future processing products.

In addition to the outreach external to CHS, there were a number of short phone/video interviews with CHS Hydrographic Services Working Group (HSWG) team members from each region. The intent of these interviews was to understand current survey acquisition and processing practices as they pertain to backscatter. With an understanding of these, it is envisioned that they can inform a recommendation of what level of detail can practically be captured in any backscatter metadata. It would be unwise to set a very high bar for extreme detail in backscatter metadata that may be incongruent with current practices.

In general, most regions are already collecting backscatter data as a standard practice. Some are already following reasonable procedures such as to support a reasonable expectation of accuracy when processing backscatter. Examples include collection of oceanographic information to enable input of absorption coefficients in the sonar controller interface during acquisition. Another example is monitoring the sonar for saturation when using R2Sonic systems. Most are not processing backscatter at all or are handing it over for processing by others external to CHS such as GSC.

In preparation for this project, discussions highlighted that metadata requirements were needed to support public dissemination in the summer of 2023 to provide the public with an understanding of the quality and/or how data were acquired and processed. This project itself was conducted over a period of seven calendar days and thus was accelerated and needed to focus on high value drivers. It is important also to recognize that the primary mission of CHS is focused on bathymetry and that it is unlikely that major accommodations will be made to achieve backscatter of supreme quality if it comes at the expense of bathymetric data quality or operational efficiency.

Given these factors, it is felt that a pragmatic solution is needed for backscatter metadata requirements. Though it is entirely possible to craft a backscatter metadata template that is exhaustive and highly detailed, the opportunity for something that is “good enough” may be missed, especially when current field and processing practices may not yield backscatter results that would fully utilize the entirety of such a detailed and exhaustive backscatter metadata standard. Put succinctly, and perhaps glibly, there is a difference between “right thing to do” and “good enough”. Focusing on the “good enough” does not need to come at the expense of the “right thing to do”. It can be a subset of steps to take towards the lofty goal of the “right thing to do” as long as one is aware of the general direction to proceed.

To help assess a reasonable first step towards the “right thing to do”, it is important to understand what the purpose of metadata is, especially given the blurred line in understanding from the outreach efforts discussed earlier. The purpose of geospatial metadata is to primarily assist in querying, searching and finding data that is fit for purpose. In depth metadata can be geared towards allowing the user to understand the quality. For example, see the ISO 19115 metadata description on wikipedia:

"The objective of this International Standard is to provide a clear procedure for the description of digital geographic data-sets so that users will be able to determine whether the data in a holding will be of use to them and how to access the data. By establishing a common set of metadata terminology, definitions and extension procedures, this standard promotes the proper use and effective retrieval of geographic data."

The key text in the description above is *"...determine whether the data in a holding will be of use to them..."*.

Next, one must consider who the intended user is of CHS backscatter data. In the key sentence highlighted above, who is “them”? In discussions leading up to this project and in the HSWG interviews, it was clear that the end user, or customer, is not yet known. The CHS has decided that it must start by making backscatter data available first and that this is the quickest way to then discover the level of interest, the end user’s intended use of backscatter mosaics and if the products are fit for that purpose. Until then, it would be wise to assume that the average user would have average knowledge about backscatter and also average capabilities in assessing data. Though there are advanced and expert level users of backscatter, it is a small community. When considering those that may be interested in data in

Canadian waters, it is an even smaller community. It is expected that expert users would be the minority user of any data that CHS makes available.

Previous Work and Existing Standards

To find a balance between “the right thing to do” and “good enough”, it is important to look at previous work, research and existing standards. An example of what might be considered a highly specialized, detailed and thorough set of backscatter metadata for processing is shown in Fig. 5 (Schimel et al., 2018). This particular example gives rich detail but might be a bit too much for assessment of whether a product is fit for purpose. Perhaps this level of detail is best included in a descriptive report as opposed to being included in metadata that is meant for discovery, search and querying.

Detailed metadata for backscatter data products

- General:
 - System used: manufacturer, model, system serial number.
 - Parameters used in acquisition: operating frequency or frequencies (transmit sectors), “mode(s)” of operation (CW or FM pulse, etc.), dual head, transmit power and gain settings, etc.
- Stage 1. Raw data decoding:
 - Backscatter data type and units.
 - Process of calculation of this type and/or relevant datagram version.
- Stage 2. Georeferencing:
 - Information regarding how the XYZ positions of the samples were calculated (ideally, formulas).
 - Information regarding how the incidence angles of the samples were calculated (ideally, formulas).
- Stage 3A. Correction for the Gains applied in Reception (CorGR):
 - Were the built-in static and time-varying gains compensated for? What values/equations were used?
- Stage 3B. Correction for the effects of propagation through the Water-column and interaction with the Seafloor (CorWS):
 - What models of transmission losses were applied?
 - How was sound absorption considered: Constant value, depth-dependent, frequency dependent?
 - What model ofinsonified area was used?
- Stage 3B. Correction for the Mechanical Properties of the transducers (CorMP):
 - Was an absolute value used to correct for gains in the axis (source level, receive sensitivity) in bulk or separately measured? Provide values.
 - Were beam patterns compensated for? Provide values.
- Stage 4. Angle dependence removal:
 - Assuming the standard methodology was followed:
 - What was the data subset used for correction (e.g. one for all dataset, one per file, sliding window size, etc.)?
 - What operation was used to calculate the corrective curve from the subset (mean or median, linear units or dB, etc.)
 - What was the reference angle, or angular interval, used (if any)?
 - Was the standard deviation corrected as well?
 - If not, description of the methodology, or at least name of the proprietary algorithm and version.
- Stage 5. Pre-mosaicking corrections:
 - Any detail on pre-mosaic data filtering.
- Stage 6. Mosaicking:
 - Projection of final mosaic.
 - Step 1a: Grid resolution value.
 - Step 1b: Gridding strategy. How were the values blended in a one cell? What strategy for line overlap?
 - Step 2: Any post-mosaic image enhancement correction?
 - Step 3: Colour-scale mapping information (e.g. “Data in dB units were [all kept / cropped at 5%-95% percentiles / cropped at $\pm 3\sigma$ / cropped at -X to -Y dB], and mapped [linearly / logarithmically] to an [8 / 16]-bit scale”).

Figure 5. Example of suggested processing metadata (after Schimel et al. (2018), Fig. 6).

As an alternate approach that is closer to a pragmatic and “good enough for now” solution, see the decision tree approach promoted in the Backscatter Working Group Guidelines and Recommendations (Lurton and Lamarche, 2015) in Fig. 6 below. These important decisions help to actualize a user’s intent when planning a backscatter survey for a particular purpose. As such, they provide a good framework to assess the fitness towards a particular purpose for a backscatter survey after data are collected and processed.

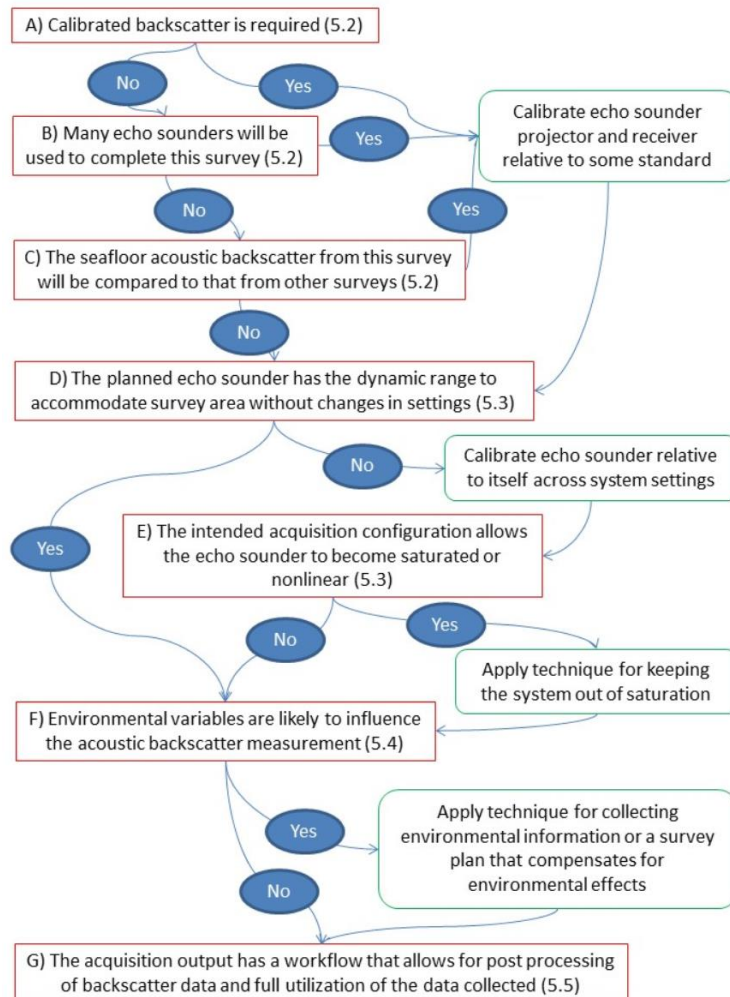


Figure 6. Example of key decisions to make when planning a backscatter survey (after Lurton and Lamarche (2015), Fig. 5-1)

In correspondence with Matt Wilson and Grant Froelich of NOAA, they both gave hints at what is currently being considered within NOAA for attributing backscatter data that they produce themselves and also accept from third parties. The placeholder text in the draft reworking of their mapping specification has the current text, based on the ideas in Fig. 6:

1. Was the backscatter calibrated? If so, was it an absolute or relative calibration?
2. Do the echo sounder(s) have the dynamic range to accommodate the survey area without changes in sonar settings? If no, were the echo sounder(s) calibrated to itself across system settings?
3. Will the intended acquisition configuration allow the echo sounder(s) to become saturated or nonlinear? If yes, was a technique applied to prevent system saturation?
4. Were environmental variables a likely influence to the acoustic backscatter measurement? If so, was a technique applied for collecting environmental information to compensate for environmental effects?

5. Did the acquisition output have a workflow that allows for post processing of backscatter data and full utilization of the data collected?”

Some of these types of questions were included in the Google questionnaire as well. Notably, the first and second questions were highly voted as an important point to capture in metadata by the respondents with these two receiving the top votes of all the items on the list in the questionnaire.

Looking further into Lurton and Lamarche (2015), there is a section devoted to the topic of backscatter metadata (section 3.7.2) as well, but it proposes a general framework only whereas Schimel et al. (2018) is much more expansive and thorough. A notable quote is worth highlighting:

“Currently, there are no accepted standards of how backscatter data are reported. This is due to the fact that the reporting of backscatter results will vary from manufacturer to manufacturer and even for a particular sonar manufacturer several processing options will be available to users.”

Though this was written in 2015, the situation has not improved since that time. This particular quote focuses on the sonar themselves and in particular the way that signal level information is captured and stored and how that differs between manufacturers. The same problem exists in terms of how software handles the signal level data and processes it to arrive at backscatter. Referring to the work of Malik et al. (2019), there are significant discrepancies in the outputs of different software packages. Though this work calls for priority action in defining backscatter processing standards, including metadata, little action has followed largely due to the 2020 COVID-19 pandemic. Activities are just beginning to resume among the interested parties as travel restrictions have loosened and collaboration is facilitated.

We can look to what others that are producing backscatter products, and metadata, are currently doing. In the one-on-one conversations, some examples were provided. Steve Intelmann of NOAA’s Alaska Fisheries Science Center (AFSC) provided an example metadata file that his team uses to capture their own backscatter field procedures and processing information. Notable excerpts are included below with the entire metadata file included in Appendix III.

Purpose: A Kongsberg EM710 multibeam echosounder, mounted to the keel of the NOAA Ship FAIRWEATHER, was used to survey various selected regions in the summer of 2018. The objective of the EM710 backscatter measurements on the Gulf of Alaska trawlability cruise was to obtain as “uniform” (realistic) set of backscatter data, as possible with the EM710, given its particular operational capabilities. At a high level, the operational capabilities of the EM710 include a Single-Swath mode and a Dual-Swath mode. Within each of those swath modes, there are several depth modes, which are designed for optimal bathymetric and backscatter operation in a particular depth range. The several depth modes (Very Shallow, Shallow, Medium, Deep, Very Deep and Extra Deep) employ different pulse lengths (0.2ms to 120ms) and different modulation of the transmit pulse (gated CW and FM). The Extra Deep depth mode is unique in that it is designed specifically for optimal bathymetric operation, which renders the backscatter measurements in that mode incapable of being “calibrated”. An operational plan was developed which involved allowing the EM710 to “Automatically” change between modes deeper than Medium but “Manually” constraining the system from “Automatically” moving from Medium into Shallow or Very Shallow. Selective use of “Manual” and “Automatic” switching between depth modes would have the effect of keeping the range of acoustic frequencies as narrow as

practical and thereby would “remove” the acoustic frequency from serious consideration as being the root cause of any observed spatial variations in backscatter. In general, the acoustic backscatter was extracted from the sonar data, compensated for static gains, time-varying gains and sonar specific manufacturer corrections, along with correction for source level and transmit/receive beam patterns using specialized software (QPS FMGT). The acoustic data are presented as an georeferenced, grey-scale image of seabed reflectivity in which tone and texture are representative of the nature and geomorphology of the seafloor. This 5m mosaic is specifically for Blocks 1 and 9 of the selected cells of the 2018 GOATS project.

Process Description: For this project, backscatter and bathymetry data were of equal importance. Data were filtered beyond +/-65 degrees during raw conversion. Sound-speed profiles were acquired throughout the project according to the standard operating practice of the OCS. The EM710 was operated using the updated Bscorr.txt that file provided to the ship by the scientific party. The EM710 was to be operated with dynamic Dual Swath enabled, FM enabled, and pitch & yaw stabilizations activated. When the water depth was approximately 250 m, or greater, the EM710 was to be in the Auto Depth Mode, which would allow transitions between the Medium, Deep, Very Deep and Extra Deep modes, as required. When the water depth was approximately 250 m, or less, the EM710 was to be in the Manual Depth Mode, with the mode set to Medium.

QPS FMGT version 7.9.2 software was used to normalize and extract the multibeam backscatter imagery. File import involved using the paired file import/conversion routine where backscatter packets within the .all files were timestamp matched by file, beam, pings to the cleaned processed depths inside the Caris HIPS HDGS libraries. This should have the affect of eliminating bad flagged soundings being passed into the backscatter rendering. Within, the Adjust Tab of FMGT, the starting beam angle was set to 15 degrees. A cutoff beam angle was set to 65 degrees. Head1 Bias was set to 5 dB. Under the Filter Tab in FMGT, the AVG algorithm was set to flat with an AVG window size of 300 (defaults). In the Filter Tab in FMGT, Linear space (amplitude) was selected. In the Format Tab of FMGT; EM ping mode corrections were set as follows: Very Shallow: 0.0 Shallow: -2.0 Medium: 0.0 Deep: 0.2 Very Deep: 3.4 Extra Deep: 6.9

Mosaic was exported from FMGT at 5m resolution into tif format. A raster Catalog created in ArcGIS, then mosaic imported into the Raster Catalog.

Of note in the AFSC approach is that text descriptions carry all the pertinent information that is needed. In conversations with Steve, he indicated that he does this so that he can retrace his own work in the event that a rework is necessary. With this style of documentation, it is very human readable but difficult for machine reading to assess and provide some sense of the fitness for purpose by another user. The user would need to read the text descriptions.

An example format with different and more machine-readable style was provided by Alex Schimel of the Geological Survey of Norway (NGU) (Fig. 7). He said that this was a work in progress and arguably he was driven to generate this based on my queries and the sudden interest from CHS and other agencies around the world who are looking to begin addressing the topic of backscatter metadata. This approach is thorough and easy to expand with detail. Some of the fields that are used are quite vendor specific, such as “acquisitionMode”, which is geared heavily towards a Kongsberg Maritime echosounder’s operational profile. Such an entry is potentially meaningless for other vendors. Creating a superset of all

possible entry items for all vendors would be a prohibitively lengthy effort and would require constant vigilance and maintenance to keep it up to date. The template below is included in Appendix IV.

```
{
  "metadata": {
    "authority": "NGU",
    "version": "0.2",
    "author": "Alexandre Schimel, Margaret Dolan",
    "date": "09/03/2023"
  },
  "survey": {
    "project": "MAREANO",
    "year": 2022,
    "client": "Kartverket",
    "surveyor": "Clinton",
    "site": "B34",
    "vessel": "Northern Storm",
    "sonarModel": "EM2040",
    "sonarSerialNumber": "?"
  },
  "data": {
    "frequencyKHz": "300",
    "pulseLengthMicroSec": "?",
    "acquisitionMode": "MediumCW",
    "filesList": ["file_1.all", "file_2.all"]
  },
  "processing": {
    "processingMetadataTemplate": "FMGT_v7.10.2_RevB",
    "softwareName": "FMGT",
    "softwareVersion": "7.10.2",
    "sourceData": "Beam time series",
    "referenceGridFilename": "B34_GRIDNODES.tif",
    "AVG_algorithm": "Flat",
    "AVG_windowSize": 300,
    "AVG_referenceBand": "Adaptive",
    "absorptionCoefficient": "0 (default)",
    "navigationTimeWindow": 5,
    "lineBlending": 20,
    "mosaicStyle": "blend",
    "filteringType": "dB Mean",
    "fillGaps": true
  },
  "mosaic": {
    "author": "Alexandre Schimel",
    "date": "09/03/2023",
    "filename": "Clinton-2022-m-block34_BS_v3.tif",
    "projection": "WGS84-UTM31N",
    "pixelSize": 1,
  }
}
```

```

    "status": "preliminary",
    "comments": "Still a few artefacts to correct"
  },
  "qualityControl": {
    "author": "Margaret Dolan",
    "date": "09/03/2023",
    "grade": "good",
    "comments": "None"
  }
}

```

Figure 7. Early sample of a "work in progress" backscatter metadata template from NGU.

There are examples of metadata being provided via public facing download portals by various agencies around the world. For example, Irish public sector data is provided online at the INFOMAR Marine Data Download Portal (<https://www.infomar.ie/data>). A sample metadata file is included in Appendix V, subsets of it are quoted below. Of note with the INFOMAR approach is the care taken to explain what backscatter is to a general user, perhaps with the intent of encouraging reasonable use of the data. The second quote very tersely describes the overall process with no detail given at all.

"Backscatter is a derived product from bathymetry data collection activity. It is the reflection of sound waves back to the direction they came from. By analysing the amplitude of the returning sound wave it is possible to extract information about bottom structure and hardness, allowing for identification of bottom types. The bottom reflectivity properties depend on the hardness and the roughness of the seafloor surface. In simple terms a strong return signal indicates a hard surface (rocks, gravel), and a weak return signal indicates a soft surface (silt, mud)."

"1. Raw bathymetry data collected by Kongsberg Multibeam echosounder as raw .All files. 2. Raw data processed in Caris HIPS & SIPS hydrographic data processing system. 3. Backscatter Geotiffs produced by Caris. 4. Geotiff to ESRI Grid in ArcMap. 5. Added to Backscatter Mosaic Dataset."

As a final example of backscatter metadata, consider NOAA's use of NCEI for dissemination of their National Ocean Service (NOS) backscatter products. A survey from 2018 was downloaded to examine the metadata file, which was in .xml format and included in Appendix VI In the metadata, the portion that described backscatter is as follows:

"Backscatter was processed in accordance with Hydrographic Technical Directive (HTD) 2018-3."

"H13095 Backscatter Overview gridded at 2m resolution"

The download bundle from NCEI for the selected survey includes a lengthy Descriptive Report (DR), however no additional information is given in the report about the backscatter.

Recommendations

From a quick search, some agencies are providing backscatter data for download but metadata for these data products is very limited in terms of content. It is difficult to be exhaustive in such a short period of

time, but it is likely safe to say that nobody is doing backscatter metadata well, if they are doing anything at all.

From a quick review of scientific and engineering literature, it is clear that there is a desire for backscatter metadata within the research community but a solution is not on the immediate horizon. Given that we have no standard way of processing data between commercial and public software packages, it is too early to have a standard way of describing the unique processes and steps. This will come with time, perhaps, but certainly not in time for the 2023 field season. The Backscatter Working Group is likely to make movement on this topic but, again, outcomes will not materialize in time for the 2023 field season. With nothing to use directly, if the CHS want to have something for the 2023 field season, they will need to craft it.

To this end, the approach taken was to review the user input from one-on-one sessions and questionnaires, prioritize these with an eye towards value delivered to an unknown customer, and then determine efficient ways that such metadata entries can be populated for each survey with a minimum amount of effort. Given the amount of information identified by respondents, it will be a challenge to isolate the key value driver from each reported item. Some imagination is required. As a practical example, one respondent suggested to report what kind of cleaning was done to the bathymetry, by swath or by point cloud. Meanwhile, in the one-on-one outreach people identified that a useful piece of information was:

“Was the bathymetry data cleaned prior to backscatter processing? Yes/No.”

This is generic enough that any provider of backscatter data and metadata does not have to work hard to complete this. It brings tremendous value to the end user. Was it cleaned or not? A clean mosaic is better than one that is not cleaned at all. You could get very descriptive on HOW it was cleaned: Manual, Automated. If Automated, what kind of filter. If using a filter, what were the settings? These types of metadata entries would capture very accurately what was done and is perhaps useful to someone retracing the steps to recreate a product. But they are in the realm of diminishing returns of descriptive data to help an end user of the product assess if the product is fit for purpose. Just knowing it was cleaned delivers MOST of the value. Knowing how it was cleaned is interesting, but it delivers less value to someone simply assessing if a product is fit for their purposes.

This way of thinking can help reduce the level of effort for some of the information that respondents requested to include in the metadata. Switching to an example that is more focused towards backscatter:

“Were any special corrections applied, e.g. dB shifts? Yes/No”.

That delivers MOST of the value compared to the exact parameters of any special corrections tools. All vendors provide many different mechanisms to fix problematic data sets and they all do it differently but they largely achieve the same outcome: a mosaic that is free of a particular type of artifact. The exact settings are also interesting to a few, but they deliver less value and are more difficult to build consensus between vendors on how to describe. The value to an end user of the data is whether this type of correction was necessary, which could hint at quality problems with the data.

There are several key value drivers that the one-on-one and questionnaire respondents directed the CHS to focus on. Seen below are summary tables from earlier in this report but sorted by vote count. The items that respondents added to the list are included as well, with the vote count for these items being

the number of respondents who independently mentioned the same item. These are intermingled with the original list as well, with no distinction between them. Note that the processing section is broken into processing and mosaic related metadata. For each section, there are two tables. The first is as described above whereas the second condenses the information for the final recommended metadata template for use for each stage of acquisition, processing and mosaic.

Acquisition

Table 3. Summary of candidate items for backscatter acquisition metadata with respondent votes on priority items along with comments and recommendations.

Item	Vote Count	Comments and Recommendations
Were efforts made to maintain sonar settings that affect backscatter constant though the survey?	15	High value driver in assessing if a product will have artifacts or not. Not all sonar settings can be adequately compensated in post-processing, thus many surveyors opt to lock down the settings.
Sonar settings: Frequency, pulse length, power, gain, mode, absorption, spreading	14	Frequency is incredibly important and pulse length to assess if data are fit for purpose. All other settings do not drive value in assessing the utility of a generated product. See item above, where respondents would like to know if settings were constant.
Type of calibration (relative, absolute)	11	There are very different use cases for each of these two potential types of survey.
Make, model and serial number of sonar(s)	9	Typically reported in bathymetry metadata. ¹
Quality of calibration (none, factory, laboratory, field)	7	Suggest pairing with Type of calibration (relative, absolute)
Dates of acquisition	7	Typically reported in bathymetry metadata. ¹
Were there procedures in place to capture oceanographic variability?	3	For typical hydrographic surveys, one would expect this to be yes. Typically reported in bathymetry metadata. ¹
When settings were changed and why	2	This could be addressed by providing a link to the survey report or survey log. This provides little value to someone assessing a backscatter product for applicability for their purpose. Recommend ignoring this request.
Survey log	2	Typically reported in bathymetry metadata. ¹
Weather conditions (rough sea, wind, waves)	2	Typically reported in bathymetry metadata. ¹
Any known interference from other acoustic instruments running at the same time	2	Though few respondents identified this, it is an important value driver for quality backscatter products. Could be reframed as a yes/no question: Were all acoustic instruments synchronized so as not to interfere with each other?
Survey platform (surface vessel, ASV, AUV)	2	Typically reported in bathymetry metadata. ¹
Single or dual-head?	1	Typically reported in bathymetry metadata. ¹
Was the sonar head damaged or replaced during the survey?	1	Typically reported in bathymetry metadata. ¹

Were there procedures in place to avoid saturation, if necessary?	1	Few respondents identified this as important, it could be due to lack of knowledge of the importance for this. Most multibeam systems can be saturated if incorrectly configured. Given the large number of R2Sonic systems in the CHS equipment pool and also Norbit systems, this is an important element to capture since both systems are easily overdriven if not careful with sonar settings.
Hull mount or pole mount	1	Typically reported in bathymetry metadata. ¹
Line start and end times	1	Typically reported in bathymetry metadata. ¹
Name of survey area	1	Typically reported in bathymetry metadata. ¹
Positional accuracy	1	Typically reported in bathymetry metadata. ¹
Who oversaw collection of data	1	Typically reported in bathymetry metadata. ¹
Sound velocity measurements at transducer	1	This provides little value to someone assessing a backscatter product for applicability for their purpose. Recommend ignoring this request.
Information on water column stratification or other water column effects that could affect backscatter	1	This is difficult to observe and very subjective to report on. Working in rivers with high suspended sediment load, especially in areas where these water masses intermingle with coastal oceanic water, can affect backscatter. Perhaps this is mentioned in survey report. Recommend ignoring this request for now.
Quality control	1	Typically reported in bathymetry metadata. ¹
Calibration curve (beam pattern)	1	This is more associated with the calibration section. Recommend addressing it within the calibration context.
Repeatability of instrument	1	This is difficult to assess and likely implicit by the sonar make/model. Until well defined metrics are available, suggest ignoring this request for now.
Type of imagery: snippets, beam average	1	Important value driver for specifying the imagery resolution, though not many respondents identified it. This is also more of a processing configuration, though it is possible to record neither, only one or both types with sonars. Suggest leaving this as an acquisition item but also including an equivalent entry in the processing section.
Primary purpose of survey	1	Typically reported in bathymetry metadata. ¹
Whether dual-head systems were calibrated for backscatter alignment between heads	1	Suggest including this as part of the calibration section.
Distribution of casts	1	Typically reported in bathymetry metadata. ¹
Project name	1	Typically reported in bathymetry metadata. ¹
Location: coastal, offshore, deep sea	1	Typically reported in bathymetry metadata. ¹
Geographic location	1	Typically reported in bathymetry metadata. ¹
Typical survey overlap coverage between lines, line spacing	1	Typically reported in bathymetry metadata. ¹
Were sediment properties used for calibration	1	Suggest including this as part of the calibration section.

Presence of artificial targets in area	1	Unclear on what the respondent's intent was with this or under what scenarios it could happen. Suggest ignoring this item.
Was patch test completed	1	Typically reported in bathymetry metadata. ¹
Link to field report	1	Typically reported in bathymetry metadata. ¹
Vessel name	0	Typically reported in bathymetry metadata. ¹
Vessel operator	0	Typically reported in bathymetry metadata. ¹
Sonar firmware version number	0	Though no respondents identified this as a key item, from experience this can become important in identifying if a data set from a sonar was acquired with a flawed firmware version that could affect backscatter. Recommend keeping this. For example, a recent version of Norbit firmware has fixed false dB offsets between dual-head systems.
Acquisition software vendor and version	0	Though no respondents identified this as a key item, from experience this can become important in identifying if a data set acquired with a flawed version of an acquisition system that that could affect backscatter. Recommend keeping this. For example, until recently, Hypack could not log R2Sonic TruePix and Snippets simultaneously.
Were ground truthing seabed samples collected?	0	This is a simple question to add. If the CHS standard becomes a starting point for other agencies to work on, this field will surely appear.

Table footnotes:

1: Suggest to always pair bathymetry and backscatter metadata to avoid double data entry and potential human error leading to inconsistent reporting.

Table 3 is compacted and refined with a final recommended template for backscatter metadata acquisition in Table 4 below. Note that all items in Table 3 that were assumed to be included in bathymetry metadata should be verified to indeed be report there. If not present, CHS should consider adding these to the items in Table 4.

Table 4. Final recommended backscatter metadata template for acquisition.

Item	Entry Type	Comments and Recommendations
Sonar firmware version number	Text entry	This can become important in identifying if a data set from a sonar was acquired with a flawed firmware version that could affect backscatter. Recommend keeping this. For example, a recent version of Norbit firmware has fixed false dB offsets between dual-head systems.
Acquisition software vendor and version	Text entry	This can become important in identifying if a data set acquired with a flawed version of an acquisition system that that could affect backscatter. For example, until

		recently, Hypack could not log R2Sonic TruePix and Snippets simultaneously.
Were efforts made to maintain sonar settings that affect backscatter constant through the survey?	Yes/No	High value driver in assessing if a product will have artifacts or not. Not all sonar settings can be adequately compensated in post-processing, thus many surveyors opt to lock down the settings.
Sonar frequencies used during acquisition	Numeric entry, multiple entry	Capture different frequencies used throughout the survey. This applies mostly to R2Sonic, Norbit and Kongsberg EM2040 systems, all of which have a high degree of agility in terms of operating frequency. The deeper water Kongsberg systems should report the nominal sonar frequency. For these systems, the frequency changes by depth mode and also between sectors. The nominal frequency is sufficient for an end user to assess the suitability of a data set.
Was pulse length held constant through the survey?	Yes/No	Knowing that at least the pulse length was held constant is valuable. This infers that the user can expect the same spatial sampling and thus resolution.
Description of calibration procedures, if any.	Text	Expect that this is “None” for all CHS vessels at the moment but good to have this for future growth. Short explanation of calibration procedures done. Address topics such as mode normalization, normalization between different sonars and/or platforms. If beam pattern corrections were estimated and uploaded to the system (Kongsberg, primarily). If an absolute calibration was attempted. If any attempt was made to normalize echo level between heads in a dual-head setup. Was system calibrated over known area with known backscatter values or was backscatter at the calibration site inferred from sediment properties?
Were there procedures in place to capture oceanographic variability?	Yes/No	For typical hydrographic surveys, one would expect this to be yes. Typically reported in bathymetry metadata. ¹
Was the sonar updated with new absorption coefficients with each oceanographic profile?	Yes/No	Related to the item above, but clarifying if the information that was measured was applied in real-time in the sonar settings.
Were all acoustic instruments synchronized so as not to interfere with each other?	Yes/No	Free running acoustic systems will often interfere with each other. This will cause issues with bathymetric detections so it is of high value to control this for the main CHS mission of bathymetry measurement with the side effect of having clean backscatter.
Were there procedures in place to avoid saturation, if necessary?	Yes/No	Most multibeam systems can be saturated if incorrectly configured. Given the large number of R2Sonic systems in the CHS equipment pool and also Norbit systems, this is an important element to capture since both

		systems are easily overdriven if not careful with sonar settings.
Were beam echo level time-series recorded?	Yes/No	Important value driver for specifying the imagery resolution, though not many respondents identified it. This is also more of a processing configuration, though it is possible to record neither, only one or both types with sonars.
Were beam average echo levels recorded?	Yes/No	It is possible to configure the hardware and/or acquisition systems to not store this. It should always be recorded as a backup for the time-series data in the event of an error in configuration or recording of beam time-series data.
Were ground validation data collected, if so, what type?	Text entry	This is a simple question to add even though CHS does not routinely do this. If the CHS standard becomes a starting point for other agencies to work on, this field will surely appear. It makes sense to include this even though the answer is “No” for CHS data. Typical answers might include: Type: photos, videos, grab samples.

Processing

Table 5. Summary of candidate items for backscatter processing metadata with respondent votes on priority items along with comments and recommendations.

Item	Vote Count	Comments and Recommendations
Were any special corrections applied, e.g. dB shifts, beam patterns?	12	Having to apply unusual correctors is a sign that a data set has problems, which may or may not be surmountable with special tools. Answering “no” does not mean that a data set is high quality since the processor could have chosen to not apply these special tools even though they were needed. Recommend merging this with written summary of processing steps and also the item in which artifacts of note can be documented.
Written summary of processing steps	10	Recommend text entry to capture a summary of processing steps. Leaving it as text allows for flexibility in describing specific vendor related functionality that may not be common across different vendors. The risk is that some may provide very short descriptions. Suggest some example text for field units to use for this.
Has bathymetry data been cleaned?	5	High value driver, as discussed earlier in this report.
Backscatter processing software vendor and version	5	High value driver when assessing suitability of a product when trying to align use of a particular vendor or avoiding a known problematic version.

Were any special bathymetric corrections applied, e.g. navigational shifts?	4	Typically reported in bathymetry metadata. ¹
Use of slope correction, resolution of terrain model used for this	2	This could be included as part of the written summary of processing steps.
Bathymetry processing software vendor and version	2	Typically reported in bathymetry metadata. ¹
Parameters used in configuration files with all processing parameters	2	This could be included as part of the written summary of processing steps.
Processing standard operating procedures	2	This could be included as part of the written summary of processing steps.
TVG/AVG parameters	2	This could be included as part of the written summary of processing steps.
Backscatter processing log	2	This could be included as part of the written summary of processing steps.
Written summary of artefacts of note	1	This is an important value driver in assessing if a product is fit for purpose. Recommend a text summary where the quality of the mosaic is assessed.
All parameters that affect radiometric and geometric backscatter signal	1	This could be included as part of the written summary of processing steps.
All information such that processing is reproducible	1	This could be included as part of the written summary of processing steps.
Percentage saturation	1	This could be included as part of the written summary of artifacts of note.
Are extra bathymetry layers available: std. dev, density, slope	1	Typically reported in bathymetry metadata. ¹
Backscatter processing algorithm used	1	This could be included as part of the written summary of processing steps.
Written summary of bathymetry processing steps	1	Typically reported in bathymetry metadata. ¹
Ground validation data collected, type: photos, videos, grab samples	1	Suggest including this with acquisition.
BS processing code level from Lamarche and Lurton (2017)	1	This is not standard in industry (yet?) and a competing version is offered in Schimel et al. (2018). Suggest leaving this out for now.
Was system calibrated over known area with known backscatter values	1	Suggest including this with acquisition.

Procedures to remove noise or interference from other devices	1	Suggest including this with acquisition. This is typically controlled during acquisition since it is difficult to fix in processing due to lack of tools or inadequate tools.
Who oversaw processing of data	1	Typically reported in bathymetry metadata assuming it is the same person that processes the bathymetry. ¹

Table footnotes:

1: Suggest to always pair bathymetry and backscatter metadata to avoid double data entry and potential human error leading to inconsistent reporting.

Table 5 is compacted and refined with a final recommended template for backscatter metadata processing in Table 6 below. Note that all items in Table 5 that were assumed to be included in bathymetry metadata should be verified to indeed be report there. If not present, CHS should consider adding these to the items in Table 6.

Table 6. Final recommended backscatter metadata template for processing.

Item	Entry type	Comments and Recommendations
Backscatter processing software vendor and version	Text	High value driver when assessing suitability of a product when trying to align use of a particular vendor or avoiding a known problematic version.
Written summary of processing steps	Text	Recommend text entry to capture a summary of processing steps. Leaving it as text allows for flexibility in describing specific vendor related functionality that may not be common across different vendors. The risk is that some may provide very short descriptions. Suggest some example text for field units to use for this. Even better would be a standard processing procedure that is standard for all CHS data. Such text should be exhaustive for the sake of being complete, but use of a standard description will ease the burden for data processors. Items could include: • Description of standard procedure • Specification of the backscatter correction procedure used, in case the software vendor offers different options (e.g. Caris offers use of their own algorithm but also maintains their implementation of UNH/CCOM Geocoder). • Specification of vendor specific processing parameters, such as TVG/AVG corrections, use of terrain model for slope corrections • Use of a beam pattern correction • Was software configured to correct for the typical sonar setting variations that affect backscatter since it is possible with some packages to disable these types of corrections. • Information about location of processing report/log.

Has bathymetry data been cleaned?	Yes/No	High value driver, uncleaned data can result in a very substandard mosaic.
Written summary of artefacts of note	Text	This is an important value driver in assessing if a product is fit for purpose. Recommend a text summary where the quality of the mosaic is assessed. Notable items to discuss might include: • If data were saturated • If weather had a major impact on data quality, if unexplicable dB shifts result even after correction for sonar setting variations. • Description of any remedial measures taken to address artefacts, such as use of dB shift tools, along with summary of parameters used for such tools.

Mosaics

Table 7. Summary of candidate items for backscatter mosaic metadata with respondent votes on priority items along with comments and recommendations.

Item	Vote Count	Comments and Recommendations
Frequency of mosaic, in case of multiple frequencies	4	Incredibly important for knowledgeable backscatter users.
Mosaic cell size	2	Typical metadata that is always specified in any geospatial grid product.
Coordinate reference system	2	Typical metadata that is always specified in any geospatial product.
Single sonar or compilation of multiple sonars	1	Import value driver in assessing quality of the mosaic. It can be very difficult to compile data from multiple sonars/platforms without artifacts.
Data representation: unitless greyscale imagery or actual backscatter values	1	Typical metadata that is always specified in any geospatial product. There may be conventions for this for photography or satellite imagery. Mosaics tend to be either unitless greyscale or a gridded product that reports actual dB values.
Raw file list	1	This is probably overkill and not a value driver for somebody assessing if a product is fit for purpose. Suggest ignoring this item. Regarding file inclusion in a mosaic, it is often preferable to omit cross lines from mosaics.
Mosaic algorithm and settings	1	This item and the item below can be captured in a text description of mosaic processing steps.
Description of how overlapping data is handled in mosaics	1	See above.
Data format	1	Assume the user meant the file format, e.g. Geotif.
Spatial bounds	0	Typical metadata that is always specified in any geospatial product.

Table 7 is compacted and refined with a final recommended template for backscatter metadata processing in Table 8 below.

Table 8. Final recommended backscatter metadata template for [mosaics](#).

Item	Entry Type	Comments and Recommendations
Mosaic cell size	Numeric	Typical metadata that is always specified in any geospatial grid product.
Coordinate reference system	Text	Typical metadata that is always specified in any geospatial product. Suggest use of standard such as WKT.
Spatial bounds	Numeric	Typical metadata that is always specified in any geospatial product.
Data format	Text	Assume the user meant the file format, e.g. Geotif.
Data representation: unitless greyscale imagery or actual backscatter values	Text	Typical metadata that is always specified in any geospatial product. There may be conventions for this for photography or satellite imagery. Mosaics tend to be either unitless greyscale or a gridded product that reports actual dB values.
Frequency of mosaic, in case of multiple frequencies	Numeric, multiple entry	Incredibly important for knowledgeable backscatter users.
Does this product compile data from several sensors and/or platforms?	Yes/No	Import value driver in assessing quality of the mosaic. It can be very difficult to compile data from multiple sonars/platforms without artifacts.
Data representation: unitless greyscale imagery or actual backscatter values	Text	Typical metadata that is always specified in any geospatial product. There may be conventions for this for photography or satellite imagery. Mosaics tend to be either unitless greyscale or a gridded product that reports actual dB values.
Mosaic algorithm and settings	Text	This item and the item below can be captured in a text description of mosaic processing steps. Could include specifics on how overlapping data were handled.
Was beam time-series data processed or beam average?	Text	Specify if software was configured to process beam average or beam time-series data.
Description of any cosmetic corrections that were applied to the imagery to improve appearance	Text	Describe any types of cosmetic corrections, like smoothing, that may have been applied to products.

Recommendations for Field Procedure Improvements

During interviews with HSWG team members, some particular items of note were raised about field procedures that could impact the quality and utility of any backscatter products from CHS. Included here, but beyond the scope of this project, are some simple field procedure changes that will improve backscatter with small operational impact:

1. Use of SV&T probe to calculate salinity and then absorption. Input absorption coefficient into sonar every time a SVP cast is taken. The main benefit of this is that the sonar applies a reasonable estimate of absorption effects in real-time, this need not be corrected further in post-processing. This has two benefits: (a) it saves time and effort, and (b) it reduces post-processing complexity since the SV&T profiles need not be carried into the post-processing, thus removing human error effects due to use of incorrect files, etc. It is recommended to archive the raw sensor measurements as well since the current practice only archives the sound speed and depth measurement files, as used in bathymetric post-processing.
2. Along the same thought process in (1), Kongsberg systems can apply sophisticated oceanographic absorption corrections. Their acquisition software can estimate oceanographic absorption profiles based on upload of SVP, SV+T or CTD profiles. It is recommended to review the various options and isolate the best possible option given that CHS typically always collect SV+T profiles.
3. For Kongsberg systems, disable the “Sector Tracking” option in the filters. This introduces dB offsets into the data as the sonar attempts to self-normalize across sectors in an adaptive manner. The filter is well intentioned, the main problem is that the effect cannot be removed or improved after acquisition since the filter parameters are not stored in the .all format. This was not raised at all during interviews by any of the interviewees, but it is a known trouble spot with a quick win solution for Kongsberg users within CHS.
4. The different operating modes of Kongsberg systems will result in dB shifts whenever the mode is changed. This can be mitigated with some field calibration techniques that are then used to adjust the backscatter calibration file (the so called “BSCorr.txt” file). These effects can be corrected somewhat in post-processing, depending on the software package that is used. Without either a real-time or post-processing correction, the utility of the Kongsberg backscatter data will be compromised, perhaps even severely. It is recommended to schedule a discussion session to explore this further. Note that this problem is isolated to the Kongsberg systems.
5. For R2Sonic systems, ensure the Saturation Monitor is used to direct sonar control adjustments. Educate team members that saturated returns typically lead to higher noise levels due to less effective sidelobe suppression. It was found that Pacific, OP&A, Quebec and Newfoundland regions were observing this practice already, but it is advised to keep on top of this topic as it can greatly reduce the utility of backscatter data if not controlled.
6. For Norbit systems, they also have a built-in saturation monitor in the form of single warning lamp on the controller display. Surveyors using Norbit systems should be made aware of this warning lamp on the controller and be trained on how to avoid saturation. There is no impact on the bathymetry due to the nature of how Norbit systems saturate, however, it is highly impactful on the quality of the backscatter.
7. Operators of all systems should visually confirm that they are collecting echo level datagrams in the acquisition system. In SIS, Qinsy and Hypack, there are display windows that can be easily checked daily to confirm that data is indeed being received and logged. It is realized that screen real estate for displays is scarce, especially on launches, but a simple check once per day is a great best practice that delivers high impact with very little effort. It is recommended to add a step to the typical daily checklist that operators may have already. There should be some additional checklist type items for creating a new Qinsy or Hypack project since it is possible to configure both of these such that they are NOT logging backscatter data.

Backscatter Client Feedback Loop Questionnaire- Recommendations

The following directions, loosely paraphrased, were provided as part of project instruction clarifications.

The intent of the client feedback loop questionnaire is three-pronged.

- 1. To understand the users (who they are and what they are using the products for)*
- 2. To understand the quality / usability of the products that we are creating (minimal viable product to meet client satisfaction)*
- 3. To understand the demand of the backscatter products*

To note, it will be made clear to the clients that CHS will not be accepting raw data requests at this time. CHS needs to understand the demand so it can better prepare the client relations partners with some metrics so that they can build an action plan to handle the expected large increase of raw data requests in the future.

A short set of questions were prepared based on experience and findings from the one-on-one discussions. Given that this deliverable is much less risky if it is misguided, a small sanity check was conducted by sharing the potential questions with two experienced backscatter end-users, Margaret Dolan (NGU) and Dr. Craig Brown (Dalhousie University). They had only small comments and suggestions and felt that the questions would be effective in addressing CHS' aims of better understanding their customers and their needs.

Starter Questions:

- How did you learn about the portal?
- Were you able to find what you were looking for?

Tell us about yourself:

- What sector do you belong to: Public, Academic, Private, Other
- Which of the following best describes your most typical interaction with backscatter: Planning, Acquisition, Processing, Analyst, None previous
- How many years of experience do you have with multibeam backscatter?
- How would you rate your proficiency or knowledge level with multibeam backscatter? Novice, Intermediate, Advanced, Expert

Tell us a bit about why you're downloading data today:

- What is your intended use for this data, e.g. geology, habitat mapping, industry, method development type research
- What value do you expect to derive from this data?

Tell us a bit about the products you found and what could be done to improve it:

- If CHS could do one thing differently about the way backscatter is processed and made available, what would it be and why?
- Would you be interested in for the same product to be available in other delivery formats, why?
Example: Floating point geotiff, greyscale image, NetCDF.
- Is the information in the metadata valuable?
- Is there anything else you'd like to see in the metadata?
- Is there enough supporting information available e.g. uses and limitations of backscatter?

Tell us about other backscatter related products that might be of interest to you:

- Would you be interested in data that has not been processed, why? Example: Raw sonar data, processed bathymetric data.
- Would you be interested in other types of products, why? Example: Angular response curves.
- Would you be interested in products or data that has been further processed, why? Example: Seafloor characterization maps.

Open Ended "Catch All" questions:

- Is there anything else you'd like to tell us?
- If you are open to follow up questions, please provide an email address.

References

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Appendix I – One-on-One Outreach

Individuals with a green check mark replied to the one-on-one. For sake of completeness, the list includes individuals who were contacted but did not reply.

- ✓ Burns Foster (ex-Caris)
- ✓ Tami Beduhn (ex-Caris)
- ✓ Eli Leblanc (ex-Caris)
- ✓ Travis Hamilton (Caris)
- ✓ Glen Rice (NOAA)
- Briana Hillstrom (NOAA)
- ✓ Garrett Mitchell (Fugro)
- ✓ Bart-Jan Tijmes (Fugro)
- ✓ Pete Apostle (Fugro)
- ✓ Kim Picard (GeoScience Australia)
- ✓ Chris McHugh (Sulmara)
- ✓ Simon Bicknese (RWS)
- ✓ Larry Mayer (UNH-CCOM)
- ✓ John Hughes Clarke (UNH-CCOM)
- ✓ Ian Church (UNB)
- ✓ Lauren Quas (S.T. Hudson)
- ✓ Lindsay Gee (former IVS)
- ✓ Vicki Ferrini (LDEO)
- Robert Kung (NRCan)
- ✓ Dave Neff (eTrac)
- Dave Bernstein (Geodynamics)
- ✓ Craig Brown (Dalhousie)
- Paul Johnson (UNH-CCOM)
- ✓ Mashkoor Malik (NOAA)
- Calvin Campbell, Sheila Hynes (NRCan Atlantic)
- ✓ Justy Siwabessy (GA)
- ✓ Margaret Dolan (NGU)
- ✓ Alex Schimel (NGU)
- Tim Battista (NOAA)
- ✓ Steve Intelmann (NOAA)
- ✓ Grant Froelich (NOAA)
- ✓ Marc Roche (Belgian Economie)
- ✓ Kjetil Jensen (Kongsberg Maritime)
- ✓ Pawel Pocwiardowski (Norbit)

- ✓ Pim Kuus (Reson)
- ✓ Elizabeth Lobecker (Kongsberg Maritime)
- ✓ Samantha Bruce (Kongsberg Maritime)
- ✓ James Muggah
- ✓ Mirjam Snellen (TU Delft)
- ✓ Megan Greenaway (NOAA)
- ✓ Colleen Peters (Kongsberg Maritime)
- ✓ Jose Cordero (Kongsberg Maritime)
- ✓ Shep Smith (XOCEAN)
- ✓ Duncan Mallace (XOCEAN)
- ✓ Matt Wilson (NOAA)
- ✓ Ebelien van der Velde (QPS)
- ✓ Dave Maddock (ex-Hypack)

Appendix II – Google Survey Questionnaire

3/26/23, 12:56 PM

Multibeam Backscatter Metadata

Multibeam Backscatter Metadata

I'd like to learn more from you on the topic of backscatter metadata. What kind of information do you think should be stored in metadata for multibeam backscatter? Note that some of the questions below distinguish between metadata related to data acquisition in the field and data processing.

1. What sector are you in?

Mark only one oval.

- ☐ Public
☐ Private
☐ Academic
☐ Other

2. How do you work with multibeam backscatter?

Check all that apply.

- ☐ Survey planning
☐ Data acquisition
☐ Data processing
☐ Data analysis (e.g. seafloor characterization)

3. How many years have you been working with multibeam backscatter?

Mark only one oval.

- ☐ 1-5 years
☐ 5-10 years
☐ 10-20 years
☐ 20-30 years
☐ 30+ years

https://docs.google.com/forms/d/1uuD1Oho5rd9dg_4dO4Gy9K-uAynufOI7y9AyIfQU5qs/edit

1/4

4. What would you say is your level of expertise with multibeam backscatter?

Mark only one oval.

- ☐ Novice
- ☐ Mid-Level
- ☐ Advanced
- ☐ Expert

5. Consider the list below that describes the **ACQUISITION** phase of a backscatter survey in the field. If you could add one more item to the list, what would it be and why?

- Dates of acquisition
- Vessel name
- Vessel operator
- Make, model and serial number of sonar(s)
- Single or dual head
- Sonar firmware version number
- Acquisition Software vendor and version
- Type of calibration (relative, absolute)
- Quality of calibration (none, factory, laboratory, field)
- Were efforts made to maintain sonar settings that affect backscatter constant through the survey?
- Was the sonar head damaged or replaced during the survey?
- Were there procedures in place to avoid saturation, if necessary
- Were there procedures in place to capture oceanographic variability.
- Were ground truthing seabed samples collected?

6. From the list above, what do you feel is the most important information to capture and why?

7. Consider the list below that describes the **PROCESSING** phase of a backscatter survey. If you could add one more item to the list, what would it be and why?

- Bathymetry processing software vendor and version
- Were any special bathymetric corrections applied, e.g. navigational shifts
- Has bathymetry data been cleaned?
- Backscatter processing software vendor and version
- Were any special corrections applied, e.g. dB shifts, beam patterns
- Written summary of processing steps
- Written summary of any artifacts of note
- Mosaic cell size
- Spatial bounds
- Coordinate reference system
- Single sonar or compilation of multiple sonars
- Data representation: unitless greyscale imagery or actual backscatter values

8. From the list above, what do you feel is the most important information to capture and why?

9. Is there anything else you'd like to tell me about backscatter metadata?

10. If you're open to follow up questions, please provide your email address.

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Google Forms

Appendix III – Example NOAA Alaska Fisheries Science Center Metadata

Refer to digital file included with final report.

File name: "Appendix III - NOAA AFSC metadata example - blk1n9_mos5m.xml"

Appendix IV – NGU sample metadata

Refer to digital file included with final report.

File name: “Appendix IV - NGU metadata_example - Work In Progress example from Alex Schimel.json”

Appendix V – INFOMAR sample metadata

Refer to digital file included with final report.

File name: "Appendix V - INFOMAR metadata example - BS_CE19_01_5m_CelticSea_U29N.tif.xml"

Appendix VI – Example NOAA NOS Metadata

Refer to digital file included with final report.

File name: “Appendix VI - NOAA NOS metadata example - H13095_DR.xml”