Report of the Workshop on Recommendations Related to Passive Ocean Acoustic Data Standards

Washington, D.C.
August 6-7, 2018

Executive Summary

On August 6-7, 2018 the Consortium for Ocean Leadership (COL) hosted a workshop in Washington, D.C. aimed to move the underwater passive acoustic community forward by recommending common approaches and methodologies for passive acoustic data collection and processing of ocean ambient sound to support data comparability in present and future studies. Workshop participants represented academia, industry, government, nonprofit organizations, international institutions, and ongoing science and monitoring projects in underwater passive acoustics. As the U.S. underwater passive acoustic community is not unified in its approach to data collection methodologies, the intent of the workshop was to facilitate cross-sector discussion toward recommendations of common methods and standards that participants agreed to follow. Adoption of these recommendations by the broader U.S. community will also be encouraged. In addition to enabling comparison across present and future studies, a benefit of common standards and approaches would be a unified U.S. community voice that allows for effective engagement in international standards discussions.

Participants discussed established standards and the importance of clarity and transparency in the application of standards to data collection (L0 data), applying calibration information (L1 data), and data processing (L2 data).[1] The group encouraged the use of standards and common methodologies that are broad enough to allow for multiple-purpose data processing while enabling data comparability, supporting regulatory requirements, and avoiding unintended consequences due to lack of clarity in the data collection. Resulting from the workshop discussion was a set of agreed upon methods for L0, L1, and L2 data based on a "minimum-optimum strategy"; recommendations for a minimum standard that should be followed, accompanied by an optimum standard or best practice to be followed when possible. The resulting recommendations for sampling and processing parameters are based on—and further expand or clarify—the soundscape measurement recommendations from the joint workshop on "Predicting Sound Fields—Global Soundscape Modelling to Inform Management of Cetaceans and Anthropogenic Noise[2]." The recommendations from this COL workshop are detailed under the recommendations section of this report.

Workshop participants also explored actions needed to support broader adoption of the acoustic data-related recommendations, formalization of these recommendations as standards, and data sharing. Overall, discussion concluded in short- and long-term goals.

In the short term, COL workshop participants will:

1. Identify a subgroup of the workshop attendees to publish a journal paper on the workshop recommendations.

[1] L0 = uncalibrated raw data, as stored on hard drive before any processing; L1 = calibrated but otherwise unprocessed data (e.g., sound pressure time series); L2 = processed data (e.g., rms sound pressure).
[2] IWC draft report SC/65b/Rep03

2. Present the recommendations to the broader community at future conferences, meetings, workshops, and other events.
3. Develop a programming code for data processing following the recommendations for L2 data (as itemized below). Specific workshop participants were identified to write and test the code using datasets from NOAA's noise reference stations and the Atlantic Deepwater Ecosystem Observatory Network (ADEON).

In the long term, COL workshop participants will:

1. Encourage the establishment of an Acoustical Society of America (ASA) working group and produce a U.S. best practices paper or guide.
2. Work toward an International Organization for Standardization (ISO) standard for L0, L1, and L2 data by convening a working group.

The two resulting working groups should run in parallel as well as include participation overlap to inform one another.

Background

There is an increasing number of national and international efforts to track and compare the underwater acoustic environment (especially ambient sound levels) over time, which may produce data that are difficult to compare because of conflicting or inconsistent data collection approaches and/or methodologies. Specifically, the U.S. community, composed of members from different sectors, is not unified in its approach to underwater passive acoustic data collection and processing, which can lead to the misinterpretation of analyses and promote challenges for collaboration across current and future projects or studies. A set of common data collection methodologies or standards would enable comparison and collaboration across sectors, is of interest to multiple agencies, would better support decision making, would increase the value of and understanding from past, present, and future data, and would allow for effective engagement in international standards discussions.

To address these data inconsistency related concerns, the Consortium for Ocean Leadership (COL) organized and hosted a workshop on August 6-7, 2018 in Washington, D.C. Workshop participants represented academia, industry, government, nonprofit organizations, international institutions, and ongoing science and monitoring projects in underwater passive acoustics and came together to move the underwater passive acoustics community toward a set of common and transparent approaches or standards for data collection and processing to support data comparability in past, present, and future studies.

Workshop Overview

Opening remarks from Rear Admiral Jon White (ret.), COL President and CEO, centered on a need for collaborative efforts to establish common standards and methodologies for ambient sound levels to unify the efforts of the U.S. underwater Passive Acoustic Monitoring (PAM) community. These remarks were followed by two introductory talks by ocean acoustic data experts, which set the workshop tone. The first presentation encompassed the context of the workshop: defined common terminology, including the preference of "acoustic environment" over "underwater soundscape;" highlighted the value of standardizing passive acoustic data collection methodologies across different sectors; described disjoint data collection methodologies; and identified agreements on common approaches that would enable comparison between studies and datasets. The same presentation also posed the issue of how to compare data across time and space, highlighted that data comparisons increase the value of understanding acoustic impacts within the oceans, and emphasized the importance of unified reporting.

Ultimately, ADEON was cited as an example of an ongoing project that utilizes a minimum and optimum standardization approach as an umbrella over the whole project design to help reduce variability in data collection methodologies.

The second presentation focused on standardization including: identification of stakeholders in industry, academia and government; established standards such as those from ISO and the International Electrotechnical Commission (IEC); international initiatives, such as the Galway Statement on Atlantic Ocean Cooperation, and an inventory of standards by the Standardization Working Group of the International Quiet Ocean Experiment (IQOE). The same presentation highlighted how standardization would benefit the identified stakeholders by reducing the risk of misinterpretation, and unnecessary expense, while increasing the traceability and accuracy of data reporting. Additionally, the presentation emphasized that there are established standards for acoustical terminology and calibration of hydrophones and recommended their adoption and use. However, it was noted that documented standards are still needed for ambient sound monitoring, specifically for data collection methodologies, data processing, and reporting, which need to include averaging times and frequency bands; and that traceability (i.e., providing an audit trail from the acoustic measurement to fundamental quantities and units) is relatively weak at low frequency because there are few accredited standards laboratories working on calibration below 1 kHz, and there is a lack of standard procedures for calibration of the entire measurement system (which includes digital hydrophones and autonomous recorders) and mitigation of low frequency artefacts such as flow noise. Lastly, ADEON was again highlighted as a useful model that could provide a foundation for L0, L1, and L2 data standards.

The workshop continued with a series of panels comprising a range of passive acoustic experts (e.g., data collectors, instrumentation engineers, data users) from multiple sectors. The professional panels offered perspectives on the specific challenges related to conflicting methodologies for data collection and standardization, followed by identification of current and successful products, approaches, and recommendations. Portability and traceability (metadata records) were identified as key points to ensure data comparability in future and ongoing studies while allowing for flexibility in future technological innovations and capabilities. Flexibility was recognized as an important factor when considering and/or implementing standards. Participants agreed that having a U.S. centric institution that is structurally and financially capable to act as a repository to store and archive U.S. PAM data for decades is necessary. A data repository will provide required stewardship to help ensure that data are compliant across all sectors. Some examples of databases and programs were mentioned that already host data or serve as data sharing platforms, which could be used as models. A demonstration was provided of an open source database that is hosted at San Diego State University called Tethys (https://tethys.sdsu.edu/). Tethys is a desktop application that facilitates sharing of metadata from marine mammal detection and localization studies that allows for analyses and comparisons between different experimental efforts. Tethys is a community tool that follows the ISO 8601:2004 standard for recording dates and times and could provide a foundation when considering data sharing strategies.

Moderated group discussions followed the panels and a consensus that standards are needed but should not overburden the research was reached. Therefore, minimum recommendations should be accompanied by best practice guidelines. Participants described ways in which standards would benefit their specific sectors. From an industry perspective, standards would provide certainty and consistency for activities, such as permitting and decision-making, and support regulations. Within industry, there are currently no standards on how to make acoustic data available or how to engage in data sharing. Thus, industry should consider turning to other communities for standards to obtain consistency and guidance within their research, monitoring programs, and opportunistic data collections, as well as for

comparability across sectors and/or regions in future studies. Already established models and standards for metadata and ambient sound that is available for use to focus on gaps where standards could be useful was identified by the group. Strategies were discussed that describe which levels of data would benefit most from standardization before the data are too modified for specific applications thus limiting the ability to follow common standards. The strategy details are presented in the recommendations sections below.

There was agreement on recommendations for data comparability in future studies, but the participants noted the recommendations should be regularly revised or revisited to provide flexibility for innovation as technology matures. There was further consensus that the standards and recommendations should not limit data analysis but make it easier for others to understand and utilize the data, compare data between projects, and support the long-term use and value of data. The group then reviewed the report from the joint workshop on "Predicting Sound Fields—Global Soundscape Modelling to Inform Management of Cetaceans and Anthropogenic Noise[3]." The report's soundscape measurement recommendations were used as a foundation to revise and establish new recommendations utilizing a "minimum-optimum strategy," recommendations for a minimum standard that should be followed, accompanied by an optimum standard or best practice to be followed when possible.

These COL workshop recommendations are outlined below and include suggestions for next steps that can be undertaken in the short term to develop data sharing tools and circulate workshop outcomes to the U.S. underwater passive acoustic community. Furthermore, goals that can be implemented in the long term to establish working groups focused on implementing recommendations and standards.

Recommendations

The COL workshop participants agreed to adopt the following recommendations and best practices when working with passive acoustic environment measurements and data processing for ambient sound levels. The recommendations account for a multitude of sound sources, comprised of natural and anthropogenic sound, and would allow for meaningful comparison of the collected data. The broader U.S. underwater passive acoustic community is encouraged to adopt the COL workshop recommendations as well. Furthermore, it was advised that the recommendations be revised regularly to adapt to the rapid technological advancements and tools available for these activities.

For a fixed (moored) recording system the following minimum parameters were recommended:

When measuring underwater sound (L0)

1. Record for a minimum of 2 minutes per hour based on minimum 30-s continuous recordings[4].

When sampling and processing (L1) underwater acoustic data

1. Time stamp data in UTC following time standard in ISO 8601 for easier archiving.
2. Process the data using the arithmetic mean of the squared sound pressure:

$$[L_p = 10 \log_{10} \frac{(1/N) \sum_{i=1}^{N} p_i^2}{1\ \mu\text{Pa}^2}\ \text{dB}].$$

[3] IWC draft report SC/65b/Rep03

[4] The 30-second minimum is to support inclusion of and consistency with historical datasets.

3. Process data in decidecade (i.e., 1/10 decade) bands[5].

For calculation of L2 products

1. Calculate the spectral level (power spectral density level) for long-term ambient sound sources
    - Minimum = 1 Hz bands at 1 s resolution

   Spectral-level options for short, transient sources, and high intensity sources where appropriate
    - Optional = 10 Hz bands at 0.1 s resolution, generate and keep all individual power spectral density spectra
    - Optional = 100 Hz at 0.01 s resolution, generate and keep all individual power spectral density spectra
2. Process data in decidecade bands over the bandwidth of the recordings on hourly and 24-h UTC intervals. Center frequency selection should follow the International Standard IEC 61260-1:2014[6].
3. Compute 10th, 25th, 50th, 75th, and 90th percentile sound pressure levels in each decidecade band with 30-s windows, for every 24 h period[7].

The group identified additional gaps within the topics discussed during the workshop that would benefit from standards; the following observations, recommendations, and best practices were suggested for addressing the gaps in future forums:

- There is a lack of data and understanding about particle motion, including terminology, background levels, organismal biological response, and sediment response, thus this topic remains a research and experimental issue.
    - **Recommendation:** A workshop or working group that engages an international audience should be organized to:
        - Discuss best practices on both the use of instrumentation and when to measure particle motion,
        - Define and standardize metrics for reporting particle motion, particularly those related to organismal use and impact, and
        - Establish guidelines for specific project applications as related to sediment.

- Integration time is important for specific projects, especially studies on mammalian responses, as the optimal frequency band depends on the species of interest but does not support the goal of broad data comparability and producing best practices for ambient sound measurement.
    - **Recommendation:** Document and specify the frequency band better than is currently being done.
    - **Best Practice:** To address mammalian integration time, at a minimum use an averaging time of 100 ms for comparability across studies**.**

[5] The decidecade (1/10 decade) is close to one-third of an octave (1/3 oct) and for this reason is sometimes referred to as a “one-third octave” or “one-third octave (base 10).

[6] This recommendation allows for determining long-term trends in the acoustic environment.

[7] Sampling limitations would lead to possible uncertainly because there can be too few samples to compute the percentile levels. These selected percentiles took this into account.

- Between projects, acoustic data often has a wide variety of outputs that are based on the applied filters, frequency weighting, or frequency band of interest, making datasets incomparable.
    - **Recommendation:** Design of the raw data collection and archiving processes for any project (L0 design) needs to ensure that the data collection system characteristics are compatible with the sources or receptors of interest to the study. These include: sufficient recording bandwidth, appropriate system (e.g., hydrophone) sensitivity, appropriate sampling rates, linear response of the system through the recording amplitude range (i.e., dynamic range), and a known frequency and phase responses for the system.

- Fixed and mobile platforms collect different data and frequently use different data collection parameters. To achieve data comparison between platforms:
    - **Recommendation:** Use the same metrics for comparison when there is overlap between fixed and mobile platforms, and apply the same metrics where appropriate, while considering flow noise, platform, and instrument specific issues can be factors hindering comparison.
    - **Best Practice:** When working with sensors, such as hydrophones, capture and record the data streams associated with the depth and sensor location.

- A U.S. centric institution is needed that is structurally and financially set up to act as a repository to store and archive data in the long term.
    - **Recommendation:** Explore federally funded options and engage in private industry partnerships to establish a network of data repositories for PAM data using the National Centers for Environmental Information (NCEI) repository architecture as a model.
    - **Recommendation**: Employ the National Oceanographic Partnership Program to help move the community forward and utilize large companies, such as Amazon or Google, with existing infrastructure for storage solutions.

Next Steps

Workshop participants also explored actions needed to support broader adoption of the acoustic data-related recommendations, formalization of these recommendations as standards, and data sharing. Overall, discussion concluded in short- and long-term goals.

In the short term, COL workshop participants will:

1. Identify a subgroup of workshop .
2. Present the recommendations to the broader community at future conferences, meetings, workshops, and other events.
3. Develop program-code for data processing following the recommendations for L2 data (as itemized below). Specific workshop participants were identified to write and test the code using datasets from NOAA's noise reference stations and the Atlantic Deepwater Ecosystem Observatory Network (ADEON).

In the long term, COL workshop participants will:

1. Encourage the establishment of an Acoustical Society of America (ASA) working group and produce a U.S. best practices paper or guide.

2. Work toward an International Organization for Standardization (ISO) standard for L0, L1, and L2 data by convening a working group.

The two resulting working groups should run in parallel as well include participation overlap to inform one another.

Many additional passive acoustic topics surfaced during the workshop that were deemed outside of this workshop's scope but were recommended for further exploration at future workshops or working groups.

1. Spatial distribution and spatial averaging of acoustic measurement as related to modeling; along a spectrum from a research level need to a standards need to a regulatory need.
2. Develop a minimum measurement standard for sound source directional resolution (bearing), after a literature review and analysis of historical datasets, to address optimal ranges.
3. Define the metric(s) for the duration of effective quiet to inform a future ISO standard. Animal-centric data would be required.
4. There is a tradeoff when discussing the establishment of standards for data collection. Complex standards with copious amounts of data collection requirements would place a large burden on a project for data comparability. Whereas, placing heavy requirements on a data archive would be costly and depend on funding. These concepts need to be addressed.

The best practices and recommendations from this workshop represent a consensus view across multiple sectors and will be communicated for feedback and adoption to the broader community, including to U.S. federal funding and regulatory agencies.

Special thanks to the Richard Lounsbery Foundation for sponsoring the workshop. This workshop and report is a contribution to the International Quiet Ocean Experiment.

Appendix A

Participant List

1. Michael Ainslie, JASCO Applied Sciences
2. Kyle Becker, Office of Naval Research
3. Bill Burgess, Greeneridge Sciences Inc.
4. Michele Halvorsen, CSA Ocean Sciences Inc.
5. CT Harry, International Fund for Animal Welfare
6. Holger Klinck, Cornell University
7. Anurag Kumar, US Navy Living Marine Resources Program
8. Stan Labak, Bureau of Ocean Energy Management
9. Marc Lammers, National Oceanic and Atmospheric Administration, NOAA's Hawaiian Islands Humpback Whale National Marine Sanctuary
10. Jill Lewandowski, Bureau of Ocean Energy Management
11. David Mann, Loggerhead Instruments
12. David Mellinger, Oregon State University
13. Jennifer Miksis-Olds, University of New Hampshire
14. Kim Olsen, CSA Ocean Sciences Inc.
15. Susan Parks, Syracuse University
16. Ruth Mullins-Perry, Shell Exploration and Production Company
17. Stephen Robinson, National Physical Laboratory
18. Marie Roch, San Diego State University & Tethys
19. Natalia Sidorovskaia, University of Louisiana at Lafayette
20. Peter Tyack, University of St Andrews
21. John Young, DHI Water and Environment, Inc
22. David Zeddies, JASCO Applied Sciences

Appendix B

Ocean Sound Workshop Agenda
August 6-7, 2018
Washington, DC

Vision

The workshop aims to move the acoustic community forward by recommending common approaches and methodologies for passive acoustic data collection and processing to support data comparability in future studies.

Monday, August 6th

8:00 AM Coffee and pastries

8:30 AM Welcome and Opening Remarks
- RADM Jon White, Ocean Leadership President and CEO

8:45 AM Introductory Presentations
- Jennifer Miksis-Olds, University of New Hampshire
- Michael Ainslie, JASCO Applied Sciences

9:30 AM Panel 1: Multi-sectoral perspectives on the specific challenges related to conflicting methodologies to data collection and standardization
Moderator: Kyle Becker, Office of Naval Research
- William C. Burgess, Greeneridge Sciences Inc.
- Stan Labak, Bureau of Ocean Energy Management
- Peter Tyack, University of St Andrews
- CT Harry, International Fund for Animal Welfare

11:00 AM Break

11:15 AM Panel 2: Identify current products, approaches, and recommendations from other efforts that are successful
Moderator: Marc Lammers, Hawaiian Islands Humpback Whale National Marine Sanctuary, NOAA
- Anurag Kumar, US Navy Living Marine Resources Program
- Marie Roch, San Diego State University & Tethys
- Ruth Mullins-Perry, Shell Exploration and Production Company

12:30 PM Lunch

2:00 PM Group Discussion
Moderator: Jill Lewandowski, Bureau of Ocean Energy Management

Topics
1. Highlight current projects that can be compared to one another from different ocean sectors

2. Discuss how data management feeds into the importance of having common standards and is an efficient way to advance acoustic sound

3:30 PM Break

3:45 PM Continued Group Discussion
Moderator: David Mellinger, Oregon State University

5:00 PM Adjourn

6:00 PM Dinner

Tuesday, August 7th

8:30 AM Coffee and pastries

9:00 AM Opening Remarks

9:15 AM Group Discussion
Topics
1. Integration time
2. Particle motion
3. Audiograms
4. Frequency weighting
5. Data repositories
6. Fixed v mobile

Moderator: Stephen Robinson, National Physical Laboratory

12:00 PM Lunch

1:00 PM Group Discussion
Topics
1. Ongoing projects
2. Ocean Sound L2 products
3. Next steps: Establish shortlist of recommendations

Moderator: Jennifer Miksis-Olds, University of New Hampshire

2:25 PM Summary Discussion
Moderator: David Mann, Loggerhead Instruments

3:00 PM Closing Remarks

3:15 PM Adjourn

Appendix C

Underwater Acoustics References and Resources

1. Predicting Sound Fields—Global Soundscape Modelling to Inform Management of Cetaceans and Anthropogenic Noise Report
2. Atlantic Deepwater Ecosystem Observatory Network (ADEON)
3. Galway Statement on Atlantic Ocean Cooperation
4. International Quiet Ocean Experiment (IQOE) inventory of existing standards
    a. Working group on standardization
5. International Organization for Standardization (ISO)
6. The E&P Sound and Marine Life Joint Industry Programme
7. NOAA/NPS Ocean Noise Reference Station Network
    a. Noise Recording Stations
8. EU-Marine Strategy Framework Directive (MSFD)