Soundscape Metrics to Support Marine Protected Area Management

Workshop Sponsored by
US NOAA Office of National Marine Sanctuaries &
US Navy Energy and Environmental Readiness Division
May 22-23 2018
Woods Hole Oceanographic Institution, Massachusetts USA

Acknowledgment: The group would like to thank Sarah Weiss, Sofie Van Parijs, Jenni Stanley and Michelle Hophan from NOAA NEFSC for their support in hosting this meeting, and Marie Roch for photos.

Background

In 2018, as the result of a legal settlement[1], the US Navy and NOAA initiated a program to characterize soundscapes within NOAA-managed US National Marine Sanctuaries. This program aims to measure and describe both comparable and site-specific underwater soundscape[2] qualities within the US National Marine Sanctuary System, in order to support developing the capacity to understand and protect "acoustic habitats[3]". This program is funded for three years, but work will likely be conducted over a period of up to five years. The settlement is subject to the following terms of reference:

- Deployment of calibrated passive acoustic recording devices in National Marine Sanctuaries and high-risk areas in the U.S. territorial sea and U.S. EEZ for NMFS-managed protected species. Sites will be chosen to provide meaningful coverage in both the Atlantic and Pacific Oceans;
- Holistic sampling of the soundscape to reflect the specific sampling needs (in space, time, and frequency) of each monitored sanctuary or high-risk area, including anthropogenic sound sources, natural abiotic sound sources, and biological sound sources relevant to each site;
- Further development of metrics to characterize and compare soundscape components among measured sites;
- Archiving of data within federal, publicly accessible, passive acoustic data archives at the National Centers for Environmental Information;
- Integration of acoustic metrics with other data used to characterize habitat condition and species presence, as well as human activity levels, in proximity to recording locations;
- Supporting NOAA's integration of acoustic habitat characterization information within federal management and constituent fora.

NOAA and Navy began discussing agencies priorities for implementing this program in January 2017, including identifying sanctuaries with overlapping ecological and compliance drivers for improved understanding of acoustic conditions and noise impacts. This process focused attention on eight sites, divided into three regional components: the east coast region (Stellwagen Bank, Gray's Reef and Florida Keys National Marine Sanctuaries), the west coast region (Olympic Coast, Monterey Bay and Channel Islands National Marine Sanctuaries) and the Pacific region (Hawaiian Islands Humpback Whale National Marine Sanctuary and Papahānaumokuākea Marine National Monument) (Figure 1).

[1] National Resources Defense Council, et al., v. Pritzker, et al., No. 12-cv-05380-EDL (N.D. Calif.)

[2] Defined by the International Standards Organization (ISO 2014), soundscapes are a "perceptual construct" inclusive of sounds perceived in a place, with a focus on human perceivers; for underwater acoustics, ISO (2017) defined soundscapes as perception-free, inclusive of ambient sound and all source contributions

[3] Distinguishable acoustic environments inhabited by individual animals or assemblages of species, inclusive of both the sounds they create and those they hear (see Chapter 2 NOAA Ocean Noise Strategy; Clark et al. 2009, Moore et al. 2012a, Merchant et al. 2015).

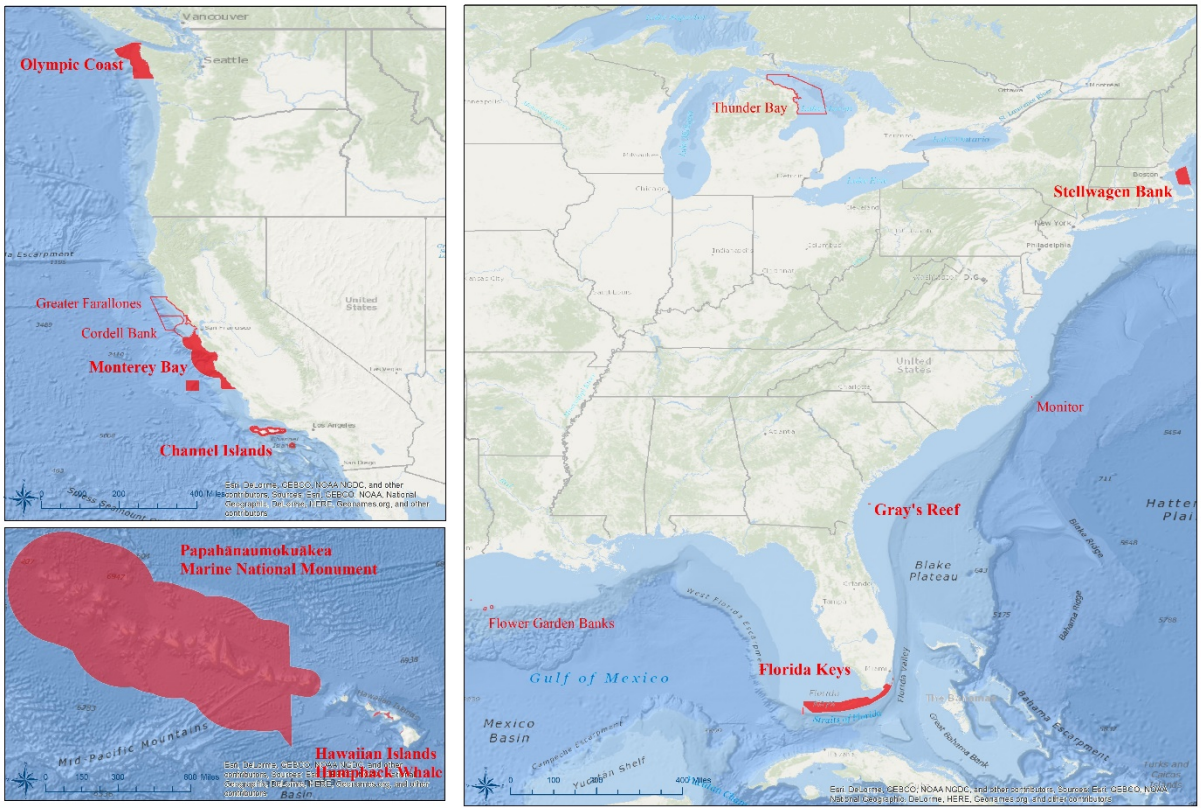

Figure 1. US National Marine Sanctuary System, highlighting (bold and filled) the seven sanctuaries and one Marine National Monument where monitoring will occur.

These discussions also resulted in the identification of central objectives that shaped the development of draft field designs. First, priority was placed on standardized, cross-calibrated instrumentation. Towards facilitating that objective, common instrumentation among sites was preferred, with preference for lower-cost, high performance technology (e.g., SoundTraps, http://www.oceaninstruments.co.nz/) well suited to long-term maintenance via small boats, such as vessels operated by National Marine Sanctuaries. Also contributing towards this objective of uniformity, the majority of effort will be focused on stationary, continuous to near-continuous sampling. Mobile technologies (e.g., gliders) will be used in a few locations to increase spatial coverage or provide higher resolution sampling during specific time periods. The program will leverage the use of past passive acoustic monitoring efforts. New sampling will take place at historical monitoring locations where trends through time are of heightened interest, and cross-calibration of instrumentation will occur. However, new sampling will predominantly focus on ensuring coverage of acoustic conditions of management interest that have received little to no previous recording effort.

Locations were selected using a variety of information available within these protected areas to represent places likely or known to be of importance to sanctuary resources (e.g. marine mammals, soniferous fish, etc.) and when possible, different habitat types supporting these species/ecological communities. Additionally, sites were selected to represent likely/known

different human use levels, predicted to have differing noise contributions. This planning resulted in identification of 37 monitoring locations, 3-5 per sanctuary/monument, ranging in depth from 12-180 meters, and one deeper location (890 meters). Acoustic data from additional locations in the west coast (3-4 locations) and Pacific (1 location) regions with ongoing/historic acoustic data collection will also be analyzed, which largely sample deeper waters (890 to 1000 meters). Gliders will be operated during specific time periods at three sites (Stellwagen Bank, Gray's Reef, and Papahānaumokuākea) during time periods and in areas of heightened interest. Finally, integration of information from telemetry networks regarding the presence of tagged species (e.g. sea turtles, ESA-listed fish, soniferous fish) with recording data was identified as having high value at several sites (Stellwagen Bank, Gray's Reef, Florida Keys, Olympic Coast and Channel Islands National Marine Sanctuaries) (e.g., Figure 2). The incorporation of species presence-absence data will provide additional support for biological signal classification at these sites and a more focused interpretation of ambient noise conditions in relation to species of interest.

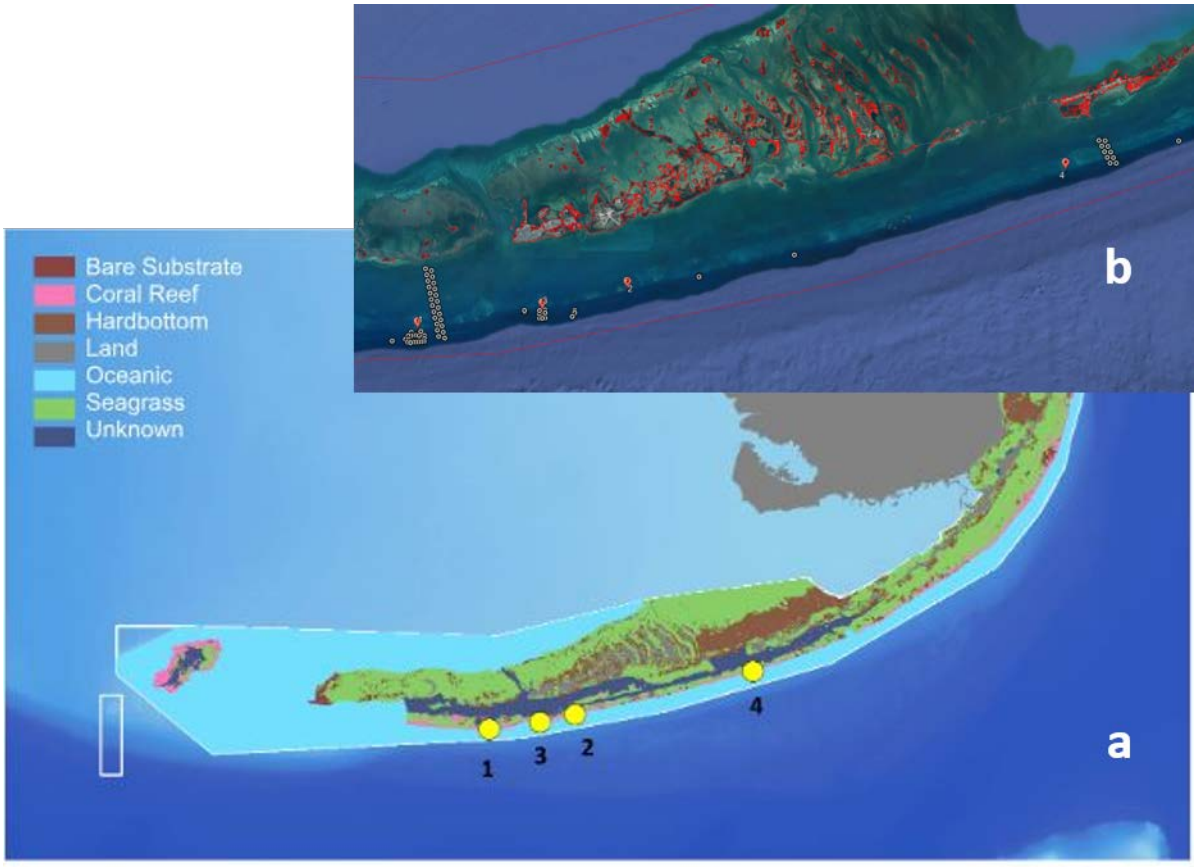

Figure 2. Maps of four acoustic monitoring locations within Florida Keys National Marine Sanctuary off the US southeast coast, showing placement relative to habitat types (a, color zones) and existing telemetry effort (b, white dots).

Workshop

To inform the development of this program, the agencies sponsored a workshop in May 2018 in Woods Hole, Massachusetts to discuss and compare analytical approaches and support dialog among colleagues working internationally (see Agenda, Appendix 1; List of Participants Appendix 2). The meeting sought to match existing or in-development soundscape description and interpretation methodologies with the highest priority information needs identified by NOAA and Navy within US National Marine Sanctuaries. Such information needs stem from the mandates of the National Marine Sanctuary Act, which stipulates that sanctuaries will serve to:

- Improve the conservation, understanding, management and wise and sustainable use of marine resources
- Enhance public appreciation, awareness and understanding of the marine environment, and;
- Maintain for future generations the habitat and ecological services of the natural assemblage of living resources that inhabit these areas.

The Navy participates in several processes that support NOAA's fulfillment of these mandates, including but not limited to engagement in management planning as representatives on Sanctuary Advisory Councils and consulting with NOAA regarding the impacts of specific military readiness activities on sanctuary resources. These processes benefit from improved information regarding species presence and seasonality and contributions of different sound sources to sanctuary soundscapes. Based on agency needs, proximate questions that could be addressed by output from the planned soundscape monitoring program were compiled (List of Questions, Appendix 3). This list was circulated within NOAA's Office of National Marine Sanctuaries to both program and site leadership, including representation from divisions with policy and planning, conservation science, and communication jurisdictions. Recipients were asked to identify their ten highest priority information needs from the list, and input was collated across all surveyed and as well as among those with primarily managerial vs. primarily communication needs. The results indicated that both managers and communication specialists prioritized description and interpretation of soundscapes to better understand biological and human activity within the sanctuary, and to determine risk in areas/during times of higher overlap. These priorities broadly echo the Navy's compliance-driven needs. Sanctuary managers indicated interest in the relevance of existing spatial delineations within sites, such as reserves, to noise conditions. Managers also highlighted interest in acoustic features that can describe cross-taxonomic patterns of biological use or ecological importance in the sanctuary. In contrast, sanctuary communication specialists prioritized products to support experiential materials, such as sound samples and straightforward visual presentation.

The importance and challenge of applying or developing easily interpreted, more layperson-oriented techniques for visualizing multi-dimensional data products was highlighted as a priority for the planned sanctuary program. To further support this need, all participants were asked to select examples of techniques they considered particularly effective for communicating information derived from soundscapes. These examples were used to focus attention throughout the meeting on the central role that broad audience communication will play for this program,

beyond the management utility of quantitative data products by the agencies and other users. Collated response to this request is considered a living document, and will provide ongoing inspiration for this effort.

Workshop participants were also provided with the list of questions, and asked to summarize approaches they have used/are using within their soundscape research to address these needs. This input was collated, and methods were highlighted during the meeting and will continue to serve as a reference for potential collaborations. Input was also coarsely assessed as an indication of the level of existing effort towards each type of need. One objective of the meeting was to gauge the degree of correlation between identified agency information needs and effort level among soundscape measurement experts. Generally, these were found to correlate well, with high emphasis on understanding the contributions of specific source types to soundscapes, and evaluating impacts in higher risk time, area or bandwidth conditions. Addressing a priority for sanctuary managers, soundscape experts showed additional emphasis on efforts to represent soundscape features less signal-specifically and in relation to cross-taxonomic biological use patterns or habitat features. Researchers also emphasized understanding propagation conditions in order to accurately represent the spatial sampling of the soundscape.

Invited presentations reviewed the status of methods for addressing questions of ecological interest at various scales, ranging from multi-regional deep-water surveys, to system-level monitoring of US National Parks, to site-level monitoring within US sanctuaries. The role of these presentations was to further define the niche of the proposed work in relation to other synergistic programs. For example, standardization of soundscape measurements for the ADEON project (http://www.nopp.org/projects/adeon/) was considered useful for identifying cross-sanctuary system and inter-project comparable baseline attributes for soundscapes. Like larger-scale European projects undertaken and underway, ADEON's concerted focus on data delivery and process transparency will support international collaborations. However, ADEON's focus on extrapolating from deeper water measured data through use of remote sensing data and predictive soundscape modeling represents a different emphasis from the planned sanctuary-based program, which will highlight shallower waters, higher resolution data, and ancillary sources of available data from the protected areas.

Lessons from passive acoustic monitoring data gathered across over 850 locations in over 120 US National Parks (https://www.nps.gov/subjects/sound/index.htm) and used to inform directed soundscape management objectives were considered particularly relevant to the initiation of more system-level capacity within marine sanctuaries. After over a decade of effort, the Park Service program's success in supporting long-term management decision-making, as well as challenges it continues to face, were highlighted relative to interests for the planned sanctuary program. Despite a large total number of sampling locations, park monitoring effort to date was noted as sparse relative to complete system-wide coverage (in time, area or frequency) of park soundscapes. Similar to the planned marine sanctuary program, park monitoring locations were chosen to represent management conditions of interest, and sampling is conducted with common instrumentation in a systematic manner, focusing on continuous recording. Post-

hoc evaluation of propagation coverage for the park system has shown sampling to be adequate to represent soundscape features of importance to site management. Park monitoring lead investigators suggested that automation and standardization of analysis and reporting should be important considerations in bounding measurement capacity. Emphasis on a phased approach to identifying which measurements, among many possible and among those with varying degrees of automation, are successful in reporting patterns of interest was central to the presentation of preliminary results from a pilot effort to monitor four east coast and Gulf of Mexico US sanctuaries. This project provided both operational and communication lessons for the planned research in terms of integrating soundscape work within site research and management priorities and determining the availability and utility of ancillary data sources that, when integrated with soundscape data appropriately, can return information of value.

Additional invited presentations highlighted innovation in soundscape data interpretation, through case-specific examples from around the world. Two presentations highlighted work to support assessing the status of noise as a marine pollutant in regional EU seas. Examples from the Baltic Sea highlighted the BIAS program's (https://biasproject.wordpress.com/) decision-support tool, which remains groundbreaking in allowing users to manipulate pre-calculated model and measurement data products to determine levels of exceedance for target intensity levels within specified time periods or areas. This emphasis on data delivery and exploration again underscored the importance of focused attention to these priorities early and throughout the planned NOAA-Navy program. Lessons and progress in developing noise indicators to support implementation of the EU Marine Strategy Framework Directive were provided, including methods under development to calculate "exposure curves" that will allow decision-makers to evaluate both how prevalent (how much of the area/population) and how chronic (how much of the time) noise exposure is, supporting evaluation of risk. This interpretive methodology is valuable for aligning data (either measured or modeled) with multiple objectives for noise management, including in a delineated area of interest.

Final presentations examined interests in extracting soundscape measurements that predict higher-level patterns of variability in the marine environment, such as species richness or diversity. To examine the predictive capabilities of acoustic data relative to more traditional habitat variables, a study was conducted in Stellwagen Bank National Marine Sanctuary and surrounding waters of the Gulf of Maine. This study was innovative both in extracting novel acoustic features and in highlighting the potential for passive acoustics, as a relatively low cost and autonomous marine monitoring tool, to augment our ability to predict areas of ecological value, supplementing fixed oceanographic features such as latitude, longitude, depth and bottom composition. A case study in New Zealand, within the Hauraki Gulf Marine Park, again highlighted the importance of displaying soundscape information in a manner that is readily understood and contextualized by protected area managers. This study found circle plots to be useful for displaying diurnal, monthly, seasonal or annual time variance in acoustic features, with multiple circles providing a visually appealing way to show patterns in multiple features across the same duration (e.g., Figure 3). These plots were identified as particularly of interest for the planned sanctuary effort, which will emphasize high resolution, longer term time-series data at consistent locations.

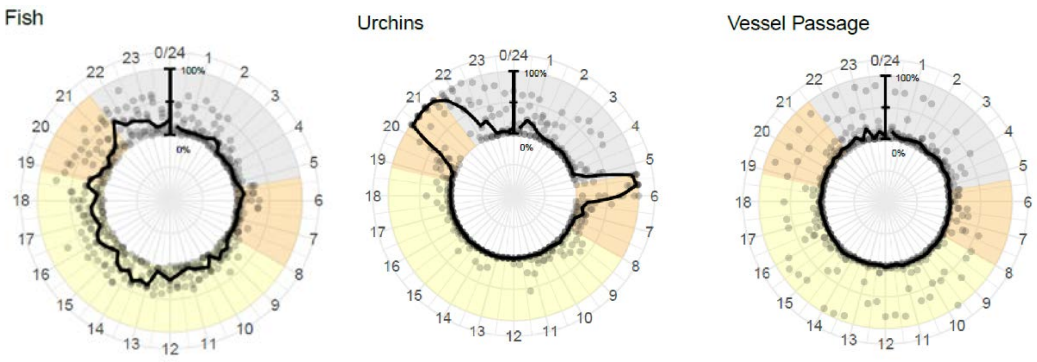

Figure 3. Detections of fish, urchins and vessels during the same 24 hour period in Hauraki Gulf, New Zealand (from Putland R. 2017. Soundscape ecology of the Hauraki Gulf. PhD Thesis, Auckland University).

Discussions within small groups built upon themes surrounding the program's priority information needs and the draft plans for data collection. The four topics of small group discussion were:

- Baseline sanctuary ambient noise status and trends within sanctuaries (including standardization, inside/outside sanctuary comparisons of value)
- Priority biological and human activity occurrence within sanctuaries (detection to coarse classification)
- Priority communication/listening signal to noise and exposure assessment within sanctuaries
- Priority opportunities for integration of soundscape data with other data types within sanctuaries

Discussion surrounding these themes identified several guiding principles that will be of use as the agencies continue to work with partners to mold the sanctuary soundscape program:

1. A high premium should be placed on uniformity and ensuring standardized results, and preference was articulated for ensuring compatibility with a subset of ADEON's identified products. It was noted that the agencies are prioritizing measurement and analysis effort for this project within sanctuaries vs. outside sanctuaries; however, standardization will facilitate comparisons of interest to be made through additional collaborations.

2. The emphasis of the sanctuary monitoring program is on deriving high quality information regarding local conditions of direct ecological or management interest and not solely on maximizing monitoring coverage (spatially). Despite this emphasis, acoustic propagation analysis should be conducted early on for each planned monitoring site so that resulting data can be interpreted properly and their extrapolative value can be communicated clearly. Examining many of the draft locations selected, the group recognized that propagation fields surrounding many locations will be quite small, and thus noise field modeling throughout sanctuaries will not be an analytical or visualization/communication objective for much of this program.

3. The program should have a tier of standardized sound processing tools that are applied at all sites, followed by a tier of variable tools that are more site/signal specific. It was recommended

that the group identify the tools and analytical platforms that will either be used by the regional analysts or identify one lead for each analysis approach across all sites. The current project structure has three regional leads responsible for multiple sites per region, necessitating further coordination between these three teams. Methods for code sharing were discussed, and appreciation was noted for both the BIAS and ADEON projects and their focus on articulation of methodology, which provides both a useful basis for collaboration and a template for similar project-specific documentation.

4. The program should support innovation and application of tools to summarize coarser, more automated and higher level or multiple taxonomic patterns, both to circumvent issues with signal-specific automatic detector development and to address the more holistic management objectives of projected areas. The paucity of methods to do this that perform well in marine environments was noted, as was the potential disconnect in communicating results with stakeholders interested in specific species or noise sources as we move towards more integrative feature extraction. Addressing the latter weakness, it was noted that we can bridge the gap between our desire to use and further develop techniques that more coarsely classify acoustic features (e.g., those that are “more transient” vs. “more chronic” in nature) and the interests of specific stakeholders during the communication stage. For example, features that have contributions from several source types but are dominated by vessels can be presented and discussed based on these principle components. Automated tools for quantifying a proportion of vessel presence were discussed, as well as more time-intensive methods that can identify more variable vessel events but can only feasibly be applied to subsets of data. These discussions underscored the group’s interest in promoting and supporting innovation in common coarse classification/feature extraction approaches, as well as the necessary site-specific application of in-hand detection tools trained on signals of interest.

5. Noise exposure risk assessment in this program should not focus on behavioral response of individuals to specific exposure events. Instead, the group identified the importance of focusing on exceedance metrics in frequency bands of interest (species guilds, groups of sources), much as the National Parks Service has done, including low order statistics to document chronic effects in bands of attentional or informational masking. It was noted that each site has been selected to highlight acoustically active or sensitive species of interest as well as specific noise producing human activities. Thus, measurements should also focus site-specifically on priority biotic signals (levels, periodicity, etc.) and priority noise sources (levels, periodicity, etc.) to examine communication masking. These assessments will draw from existing knowledge regarding hearing threshold information and will consider lost listening area more broadly.

6. Integration of other data types with soundscape measurements could address, broadly, three purposes: interpolation, extrapolation and model transferability. Given the planned research focus on high temporal resolution at spatially dispersed sites, many of which will be propagation limited, it was noted that initial focus should be collating available ancillary data that can support exploratory analysis at both multi-site and single site/location scales. Planned soundscape sampling is unlikely to provide the basis for large-scale extrapolations in many instances, but specific correlations with other geospatial attributes can provide greater spatial context for

interpretation of location-specific results. Propagation modeling will also support smaller scale interpolation and prediction of variables to match finer-resolution geospatial datasets within sanctuaries, such as vessel presence (AIS, VMS) or animal presence (telemetry).

7. The program should focus early and throughout on identifying the audience for results, and meeting the needs and proclivities of these users in selecting and serving data products. Agency dialog surrounding the list of information needs (Appendix 3) had clearly identified need for less complex, more visually appealing presentations that will allow users with specific interests to see those interests easily in the data (e.g., specific species or noise sources), even if the acoustic feature extracted is more multi-faceted. This discussion further categorized data delivery interests for the planned program as ranging from data management to data exploration to decision-support. It was acknowledged that management of both raw data and data products were essential tasks. Raw, security-cleared data will be archived at the National Center for Environmental Information (NCEI). It was noted that further tools could be developed at NCEI through the existing map-based data locator to highlight links to other archived datasets for co-analysis and/or to present first-order acoustic data summaries. Exploration or decision support relying on pre-calculated data products was noted as the likely end-point for user tool development due to resource limitations, vis capabilities for users to select new parameters for analysis in a server-supported web interface.

Significant existing web architecture for NOAA's sanctuaries, both at the system level and for each of the sites to be monitored, can be leveraged to introduce soundscape information within current research and management presentations, and can link to further infrastructure where users can visualize soundscape products, as well as acoustic features in relation to other data types. Web materials would benefit from organization around "stories", either those for individual monitoring locations (based on featured species/noise sources/zoning), individual sites (key questions of management interest) or multi-site (stories around variability in soundscapes among all monitoring sanctuaries or among sanctuaries in a region). NOAA, BOEM and USGS, among other US federal agencies, have considerable equity in "Story Mapping" (e.g. https://marinecadastre.gov/uses/, https://www.usgs.gov/products/data-and-tools/apis) that could be leveraged. Considerable expertise exists in both the commercial and academic sectors (e.g., https://itunes.apple.com/us/app/microsoft-soundscape/id1240320677?mt=8, https://mgel.env.duke.edu/tools-for-marine-gis/). A near-term objective will be to further delineate the data management and data exploration capabilities of interest for this program, as well as the resources available to support these tasks.

Both NOAA and Navy thank the participants for their input as the agencies initiate this new program, which suggests many opportunities for collaboration surrounding the priority needs identified. Subsequent to the meeting, program leads are working on planning or guidance documents for data collection, data management, data analysis, data visualization & exploration, and external communications in order to coordinate and standardize approaches across regional teams. Continuing communication and collaboration with the EU projects and the ADEON project (noted above) will be pursued. Collaboration with subgroups organized by the International Quiet Ocean Experiment and addressing synergistic interests (in particular,

Standardization and Biodiversity Hot Spots) was highlighted, and this interest will be pursued both by project co-managers and by regional team leads. The iterative ranking process to determine focus for the planned work, first among the agencies and now with input from international experts, has also resulted in the identification of ideas for projects that, while not meeting the priorities for the planned program, are of strong interest and viability to pursue with additional resources from NOAA, Navy or other partners. In particular, discussions have identified a need for improved communication and sharing of data assets among soundscape researchers who have worked and/or are working within sanctuaries, in order to encourage coordination as well as participation by researchers in sanctuary stakeholder and public engagement forums.

Appendix 1: Workshop Agenda

Goal:
To support the development of soundscape measurements that can inform management of marine protected areas, including US National Marine Sanctuaries.

Objectives:

1. Review analysis priorities identified by US national marine sanctuary managers
2. Review status of efforts to address similar priorities in scientific community
3. Identify challenges to addressing priorities in new research program
4. Identify opportunities for addressing priorities in new research program and through collaboration with other initiatives
5. Identify next steps for furthering overall goal

Outcome:
Evaluation of methods for addressing sanctuary management priorities using measurements derived from the planned NOAA-Navy effort, including identification of challenges and opportunities for broader collaboration between this effort and others to further the overall goal.

May 22	**DAY 1 AGENDA**
9:00 Hatch, Van Parijs	**Welcome and Logistics**
9:15 Hatch	**Review Workshop Objectives & Agenda**
9:30 All	**Introductions** ● Use pre-work figure to briefly introduce yourself
10:00 Kitchen, Hatch	**NOAA-Navy project in US National Marine Sanctuaries** ● NOAA Ocean Noise Strategy, acoustic habitat and US National Marine Sanctuaries ● Terms of Reference for NOAA-Navy project ● Overview of draft field designs and soundscape features
10:45	**Break**
11:00 Tartt, Kitchen	**What does NOAA need to know about sanctuary soundscapes?** ● Information needs and priorities for supporting 1) planning, permitting, consultation and other management actions, and 2) education, outreach and communication with stakeholders **What does Navy need to know about sanctuary soundscapes?** ● Species presence and seasonality, contributions of different sound sources, and other information that can support assessment of the impact of military readiness activities on sanctuary resources
11:30 Facilitator: Hatch Note Taker: Weiss	**Overview of soundscape measurement progress at various scales that can inform questions of value to sanctuaries, including:** ● Large scale (regional-global), longer-duration baseline ambient noise characterization, standardization and comparison o Jennifer Miskis-Olds, University of New Hampshire ● Multi-site protected area baseline assessment, status/trend evaluation and impact determination o Kurt Fristrup, US National Parks Service ● High-resolution understanding of localized soundscapes, specifically US protected areas, and impact potential associated with specific species and human activities o Jenni Stanley, US NOAA/Woods Hole Oceanographic Institution
12:30	**LUNCH**
1:30 Facilitator: Hatch Note Taker:	**Review of pre-work response provided by all workshop participants** ● Group discussion: status of participant and greater science community effort towards the priorities identified by NOAA and Navy

Weiss	
2:00 Facilitator: Hatch Note Taker: Weiss	**"Beta testing": innovation in delivering soundscape information to protected area managers:** ● Using soundscape measurement and modeling to determine whether noise conditions in a cod spawning ground in the Baltic Sea represent "good environmental status" o Peter Sigray, FOI/Stockholm University ● Including acoustic features in marine ecological prediction: a case study in Stellwagen Bank NMS and Gulf of Maine o Megan McKenna, US National Parks Service ● Developing scalable indicators of noise exposure: from protected areas to international regions o Nathan Merchant, UK Center for Environment Fisheries and Aquaculture Science ● Lessons from the Hauraki Gulf soundscape: metrics for highlighting spatiotemporal trends and species specific impacts o Craig Radford, University of Auckland
330	**Break**
3:45 Facilitator: Hatch Note Taker: Weiss	**Full group discussion: challenges and opportunities for matching questions of sanctuary management interest through the upcoming NOAA-Navy program**
4:45 Hatch	**Summarizing day 1, logistics for dinner, prep for day 2**
5:00	**Adjourn**
7:00	**Group Dinner** Casa Vallarta, 70 Davis Straits, Falmouth MA

May 23	**DAY 2 AGENDA**
9:00 Hatch	**Review day 2 agenda and purpose of small group activities**
9:30 All (each group designate note taker and presenter)	**Small Group Themes:** 1. Baseline sanctuary ambient noise status and trends (including standardization, inside/outside sanctuary comparisons of value) 2. Key biological and human activity occurrence within these sanctuaries (detection to coarse classification), 3. Key communication/listening signal to noise and exposure assessment within these sanctuaries 4. Key opportunities for integration of soundscape data with other data types within these sanctuaries
10:30	**Break**
10:45 All	**Small Groups continued**
11:30 Presenters: From each group Note Taker: From each group	**Begin report out on small groups**
12:30	**LUNCH**
1:30 Presenters: From each group Note Taker: From each group	**Finish report out on small groups**
2:15 Facilitator: Hatch Note Taker: Weiss	**Full group discussion on cross-cutting themes and next steps**
330	**Break**
3:45 Facilitator: Hatch Note Taker: Weiss	**Full group discussion on international opportunities to advance the meeting goal's beyond the NOAA-Navy project**
4:30 Hatch, Kitchen	**Discuss next steps and close meeting**
5:00	**Adjourn Workshop**

Appendix 2: Workshop Participants

Hatch	Leila	US NOAA (NOS SBNMS)	Chair, Program Co-Manager
Kitchen	Danielle	US Navy OPNAV N45	Program Co-Manager
Kumar	Anu	US Navy NAVFAC	Program Co-Manager
Shoemaker	Mandy	US Navy NAVFAC	Program Co-Manager
Baumann-Pickering	Simone	Scripps Institution of Oceanography	
Becker	*Kyle*	*US Navy ONR Ocean Acoustics*	
Eggleston	David	North Carolina State	
Fogarty	Michael	US NOAA (NMFS NEFSC)	
Freeman	*Simon*	*US Navy NUWC NPT*	
Fristrup	Kurt	US National Parks Service	
Gedamke	Jason	US NOAA (NMFS S&T)	
Halpin	Pat	Duke University	
Helble	Tyler	US Navy SPAWAR	
Joseph	John	US Navy Naval Postgraduate School	
Kuegler	Anke	University of Hawaii	
Lammers	Marc	US NOAA (NOS HIHWNMS)	
Margolina	Tetyana	US Navy Naval Postgraduate School	
McKenna	Megan	US National Parks Service	
Merchant	Nathan	UK Center for Environment Fisheries and Aquaculture Science	
Merkens	Karlina	US NOAA (NMFS PIFSC)	
Miskis-Olds	Jennifer	University of New Hampshire	
Mooney	Aran	Woods Hole Oceanographic Institution	
Parsons	Miles	Australian Institute of Marine Services	
Peavey Reeves	Lindsey	US NOAA (NOS CINMS)	
Pijanowski	*Bryan*	*Purdue University*	
Radford	Craig	University of Auckland	
Roch	Marie	San Diego State	
Rowell	Timothy	Scripps Institution of Oceanography	
Sigray	Peter	Stockholm University	
Southall	*Brandon*	*SEA, Inc*	
Staaterman	Erica	US Bureau of Energy Management	
Stanley	Jenni	US NOAA and Woods Hole Oceanographic Institution	
Sutherland	Chris	University of Massachusetts Amherst	
Tartt	Mitchell	US NOAA (NOS ONMS)	
Van Parijs	Sofie	US NOAA (NMFS NEFSC)	

**Unable to attend but participated in meeting preparation*

Appendix 3: Priority Questions (Bold) to Support Sanctuary Management, Education and Communication Needs

Describing Sanctuary Soundscapes

1. **What are the sounds made by human activities in my sanctuary?** *(Management & Education/Communication Priority)*
    - Describe them.
    - Let me hear examples.
    - Can we identify the types of human activities that are producing these sounds?
    - ***Are there patterns in time or space that inform our understanding of how people are using the sanctuary (e.g., occurrence, detection/coarse classification)?***

2. **What are the sounds made by animals in my sanctuary?** *(Management & Education/Communication Priority)*
    - Describe them.
    - Let me hear examples.
    - Can we identify which taxonomic groups/species are making these sounds?
    - ***Are there patterns in time or space in this sound production that inform our understanding of how animals use the sanctuary (e.g., occurrence, detection/coarse classification, biologically important activity, signals of opportunistic importance)?***

3. **How loud/quiet is my sanctuary, based on proportion monitored?** *(Management & Education/Communication Priority)*
    - On average? During loudest times? During quietest times?
    - Can you make that visual?
    - ***Are there data to support comparison with past measurements in my sanctuary and/or estimate trends?***

4. **What proportion of the sound in my sanctuary is slowly varying (often of interest for understanding background levels produced by the physical environment and some chronic sources of noise) versus fast varying/transient sounds (often of interest when identifying sounds made by animals and produced by some human activities)?** *(Management Priority Only)*
    - What is the acoustic complexity or acoustic diversity of my sanctuary's soundscape?

5. **Do different jurisdictions/use areas within my sanctuary (e.g., reserve/non-reserve, shipping lane/non shipping lane) sound different?** *(Management Priority Only)*

6. Do different habitats within my sanctuary (described by their fixed oceanographic features) sound different?

7. How much of my sanctuary's soundscape was monitored, based on where, for how long, and over what bandwidth we listened, and accounting for seasonal changes in sound propagation?
    - How representative are my measurements for describing sanctuary areas that were not monitored?

8. How loud/quiet is my sanctuary compared with other sanctuaries?
    - On average? During loudest times? During quietest times?
    - Can you make that visual?
    - How do soundscape components compare among widely dispersed sanctuaries (e.g., common contributions from physical environment, vessel presence, coarsely classified biological occurrence)?

9. How loud/quiet is my sanctuary compared with a comparable non-sanctuary area?

Interpreting Sanctuary Soundscapes

1. **How loud/quiet is my sanctuary within frequencies used by animals here for listening: food, predators, or navigation?** *(Management & Education/Communication Priority)*
    - On average? During the loudest times? During the quietest times?
    - ***Can you make that visual?*** *(Communication Priority)*
    - What human activities are generating this noise?
    - On average? During the loudest times?

2. **How loud/quiet is my sanctuary within frequencies used by animals here to communicate with each other?** *(Management & Education/Communication Priority)*
    - On average? During the loudest times? During the quietest times?
    - Can you make that visual?
    - What human activities are generating this noise?
    - On average? During the loudest times?

3. **Is there a location within my sanctuary that is particularly important for specific animals to hear each other, and how loud/quiet is it in key frequencies at that location?** *(Management & Education/Communication)*
    - How do these acoustics conditions within the sanctuary compare to a non-sanctuary location that is important to the same animal population/species or a closely related species?

4. **How often do noise levels in my sanctuary exceed NOAA's acoustic guidance for injury to the marine mammals that are present here (implies frequency weighting)?** *(Management & Education/Communication)*

5. **Are the transient sound properties in my sanctuary different in areas with heightened protection (e.g. reserves) vs. outside such jurisdictions?** *(Management Priority Only)*
    - Do they differ in areas with vs. without other active management treatments (e.g., artificial reefs, time/area closures etc.)?

6. **Is there a location within my sanctuary that is particularly important for specific animals to be able to listen, and how loud/quiet is it in key frequencies at that location?** *(Management Priority Only)*
    - How do these acoustics conditions within the sanctuary compare to a non-sanctuary location that is important to the same animal population/species or a closely related species?

7. What is the proportion of noise-free intervals in my sanctuary relative to intervals with a noise intrusion?
    - On average? During a time period of heightened risk? At a location of heightened risk?

8. How often do noise levels in my sanctuary exceed acoustic criteria in use for injury to fishes that are present here (implies frequency weighting)?

9. How often do noise levels in my sanctuary exceed 120 and 160 dB re 1uPa at 1m, often applied to behavioral response and slow-varying/chronic noise impact assessment?

10. What percentage of measured noise levels in my sanctuary are 10dB or more above average ambient levels? 20dB?

11. What percentage of measured noise levels in my sanctuary are 10dB or more above an estimate of historical average ambient levels? 20dB?

12. How often do noise levels in my sanctuary exceed a human-informed benchmark for attention disruption/classroom learning (implies marine interpretation, including frequency weighting)?

13. How often do noise levels in my sanctuary exceed a human-informed benchmark for sleep disturbance (implies marine interpretation, including frequency weighting)?