Science, Service, Stewardship

MAPPING CETACEANS AND SOUND: MODERN TOOLS FOR OCEAN MANAGEMENT

SYMPOSIUM FINAL REPORT

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EXECUTIVE SUMMARY

Sound is the most effective means for marine species to communicate and sense their environment underwater and is critical to multiple life functions for all marine vertebrates and even some invertebrates. With increased understanding of how anthropogenic noise can limit the ability of marine species to hear and communicate, the US National Oceanic and Atmospheric Administration (NOAA), charged with managing the impacts of noise on marine life, has recognized the need to undergo a fundamental shift towards a more integrated and comprehensive strategy for measuring, managing, and reducing chronic noise impacts.

In a January 19, 2010 letter to the President's Council on Environmental Quality, NOAA Administrator Jane Lubchenco committed to improving the tools used by the agency to evaluate the impacts of human-induced noise on cetacean species. As a result, two data and product-driven working groups were convened in January 2011: the Underwater Sound-field Mapping Working Group (SoundMap) and the Cetacean Density and Distribution Mapping Working Group (CetMap). The overarching effort of both Working Groups is referred to as CetSound.

On May 23rd-24th 2012 in Washington D.C., near-final CetMap and SoundMap products were presented at a Symposium entitled *Mapping Cetaceans and Sound: Modern Tools for Ocean Management*. Approximately 170 attendees were present, including participants from government agencies, regulated industries, independent scientists, environmental consultancies, media, and conservation advocacy groups. SoundMap presented new methodologies and mapping products that depict the temporal, spatial, and spectral characteristics of underwater noise. CetMap presented a hierarchal organization of both new and existing time and species specific regional cetacean density and distribution maps. Additional products that identify known areas of specific importance for cetaceans were also presented.

Throughout the meeting, a range of outstanding questions and development opportunities for these tools were discussed. The clear emphasis was on the need for maintenance and growth of the products to ensure maximized utility for supporting the planning, management, and incorporation of new science into decisions of both regulators and noise-producing entities within the context of the multi-use ocean environment. Towards that goal, five main recommendations emerged for continuing and enhancing the multi-agency engagement in this initiative, both financially and through shared expertise, and for formalizing a role for NOAA in leading the effort. The recommendations were the following:

- Institutionalization of the CetSound Effort within NOAA
- Integration of CetSound Effort with NOAA-wide Goals and Programs
- Creation of Forums and Mechanisms to Receive External Input
- Identification of Mechanisms for External Funding
- Focus on Outreach and Education

DAY 1: OVERVIEW

Sally Yozell, NOAA Director of Policy provided opening remarks that highlighted the importance of multi-agency commitments to managing the impacts of human activities on wide-ranging species such as whales, and the role that NOAA seeks to play through efforts like CetSound in leading advancements in management tool development. The NOAA co-leads of the CetSound effort (Jolie Harrison, National Marine Fisheries Service and Leila Hatch, National Ocean Service) then introduced the meeting's agenda, followed by presentations on the CetSound products by analysis team members and chairs of each of the working groups. To ensure shared background for subsequent discussions, a series of presentations regarding prominent management contexts applicable to the CetSound effort were then provided. In the afternoon, a two-hour session was conducted in which symposium participants were invited to learn more about the CetSound products through hands-on exploration of the website and one-on-one discussions with members of each of the working groups. Day 1 concluded with a 90-minute session in which four panelists were invited to provide comments addressing technical aspects of the projects, and engage with the symposium participants in an extended group discussion regarding their current status and future development.

CETSOUND EFFORT: OVERVIEW

In 2011, NOAA convened two independent working groups to develop new tools for visualizing human contributions to ocean noise and updated maps on cetacean distribution and density patterns throughout the U.S. EEZ. The goal of the Underwater Sound Field Mapping Working Group (SoundMap) was to develop tools to map the contribution of human sound sources to underwater ocean noise in U.S. waters. The goal of the Cetacean Distribution and Density Mapping Working Group (CetMap) was to create regional time- and species-specific cetacean density and distribution maps in U.S. waters. Both groups were chaired by NOAA and included technical experts from NOAA, Navy, BOEM, National Parks Service, academia and environmental consultancies (see Appendix B). They met in person for multi-day working sessions in 2011 and again just prior to the Symposium in May 2012. Analysis teams from Heat, Light and Sound Research, Inc. and Duke Marine Laboratory were contracted to assist tool-building efforts for SoundMap and CetMap, respectively. This one year analytical effort was financially supported by NOAA, Navy, and the BOEM. The initial CetSound products and associated metadata are available via the project's website: http://cetsound.noaa.gov.

SOUNDMAP WORKING GROUP: OVERVIEW

Presenters: Leila Hatch, NOAA-NOS & Mike Porter, HLS Research, Inc.

The specific objective of the NOAA Underwater Sound Field Mapping Working Group (SoundMap) was to apply mapping methods to depict temporal, spatial, and spectral characteristics of underwater noise resulting from human activity. The tools developed use environmental descriptors and the distribution, density, and acoustic characteristics of human activities within U.S. waters to depict first-order estimates of their contribution to background noise levels at multiple frequencies, depths and spatial/temporal scales.

Spectral resolution:

The emphasis of SoundMap modeling on broad spatial-scale and long term (seasonal to annual) noise exposure resulted in a focus on low frequencies, ranging from 50 to 1000 Hz (with several specific exceptions), since higher frequencies are subject to strong absorption effects and are more local in effect. Broader band levels (1/3rd–octave) were estimated based on modeled frequencies to assist interpretation relative to mammalian hearing systems.

Spatial resolution:

SoundMap modeling focused on coastal waters at least 5 m in depth out to the 200 nm U.S. EEZ boundary at a 0.1° x 0.1° (~100 km^2 at the equator) grid size. Additionally, due to the emphasis on low frequencies and the lack of a hard boundary for noise at 200 nm, some sources of chronic noise at greater ranges were modeled for larger portions of ocean basins at 1° x 1° (~10,000 km^2 at the equator). To capture differences in sound propagation and how this can influence interactions with marine wildlife that spend time at different depths, modeling was conducted at discrete depths between 5 m and (up to) 1000 m.

Temporal resolution:

The central SoundMap products are predicted noise level maps for U.S. EEZ waters of the continental U.S., Hawai'i and Alaska. These maps depict predictions of wide-ranging contributions from "chronic" anthropogenic sources of underwater noise, including vessels (merchant shipping, ocean-going passenger vessels and mid-sized service, fishing and passenger vessels in regions where data was available) and sustained areas of offshore energy exploration (seismic surveys). Predicted received levels are expressed as equivalent, unweighted sound pressure levels (L_{eq}), which are averages of aggregated sound levels. Averaging time varies according to the appropriate timescales for the activities of interest, with a focus on annual averages from year-round activities (e.g., merchant shipping in most regions), and shorter temporal scales for activities or events which are seasonal (e.g., in sometimes ice-covered areas).

Additionally, mapping efforts were conducted for four localized and transient events that are more episodic or seasonal; these were selected to reflect major acute sources of human-induced noise in areas of biological importance to marine mammals, including: 1) a military active sonar training exercise in Hawai'i; 2) a period of seismic exploration in the Beaufort Sea; 3) the installation of an alternative energy platform off New England; and 4) the decommissioning of an oil platform in the Gulf of Mexico.

Key discussions of the working group focused on each of the transient event scenarios, in particular methods for summing energy from chronic and intermittent sources during the events, and presenting cumulative energy averages over days to months when some sources were intermittent during those time periods. The group wanted to avoid averaging over "quiet periods" between noisy events (especially those with lengthy intervals between events) and losing the short duration but high intensity characteristics of the sound sources, given the ultimate goal of integrating this meaningfully with biologics.

Thus, events were divided into an appropriate number of acoustic "states" characterized by combinations of sources that are coincident over discrete time periods (i.e. staging prior to driving a pile, then driving a pile, then a break, then driving a pile etc.). Duration information associated with these "states" can be retained and exemplary output maps can be created for each.

Methodology and metadata:

SoundMap focused on developing feasible methods that could be implemented within a one year analytical effort. A variety of informed approximations were necessarily applied to enhance computational feasibility and to bridge data gaps. All extrapolations and assumptions made in producing these products have been explicitly documented in methodology summaries and will eventually be available on the website with each dataset. These summaries are intended to assist users in understanding the current status of the data used here, methodologies applied and requirements for producing different or higher resolution products in the future.

CETMAP WORKING GROUP: OVERVIEW

Presenters: Sofie Van Parijs, NMFS & Pat Halpin, Duke Marine Laboratory

The specific objective of CetMap was to create comprehensive and easily accessible regional cetacean density and distribution maps that are time- and species-specific, ideally using survey data and models that estimate density using predictive environmental factors. In order to depict the most comprehensive cetacean density and distribution maps, the CetMap group:

1. Identified a hierarchy of preferred density and distribution model or information types;
2. Conducted a cetacean data availability assessment that included making previously less accessible data available through this effort;
3. Modeled or re-modeled density using first-tier habitat-based density models in some critical areas, based upon updated methods and/or new data;
4. Created standardized GIS files from the new modeling results and other existing modeling results, and;
5. Developed a NOAA website interface that: organizes these datasets and maps to highlight the best available information type; makes them searchable by region, species, and month; and provides many of the GIS files for download.

The Tier 1 (i.e. highest quality) species-specific CetMap products presented (i.e., the habitat-based density models) are predominantly at a spatial resolution of 10 km^2, with a few at 25 km^2, based on the manner in which the data were initially collected or modeled. Products are organized by month, but depicted in a manner that reflects when model results are predicting only seasonal resolution.

Separately, to augment the more quantitative density and distribution mapping described above and provide additional context for marine mammal impact analyses, the CetMap also identified 'biologically important areas (BIA)' (through literature searches, current science compilation, and expert consultation), known areas of importance for cetaceans, such as reproductive areas, feeding areas, migratory corridors, and areas in which small or resident populations are concentrated. These BIA's will eventually be presented as a peer reviewed published paper. The sections below describe the CetMap efforts outlined above and provide links to the products or other information, where appropriate.

Information hierarchy:

The CetMap working group identified and broadly evaluated the information-types and modeling methods available for estimating marine mammal density and distribution and ranked them in Tiers based on their expected ability to accurately predict presence, distribution, or density in a spatially and temporally explicit manner. The ranked Tiers are:

1. *Habitat-based density models*, which allow fine-scale predictions of density (individuals

per km2 throughout a survey region using regression-based models that relate habitat variables to species encounter rates and group sizes;
2. *Stratified density models*, which assume uniform animal density within each stratum (area), for which boundaries are determined based on survey coverage, the number of sightings, and prior knowledge of cetacean distribution and habitats;
3. *Probability of occurrence models*, which indicate areas where a species is likely to occur based on statistical models that relate habitat variables to the presence/absence of a species, but do not provide absolute density estimates;
4. *Records of presence*, which include visual observations, acoustic detections, or satellite tagging indicators;
5. *Expert knowledge*, reflects a lack of spatio-temporally explicit data for a species, but indicates if a species is believed to be present or likely absent by regional experts.

Cetacean data availability assessment:

1. Identified and compiled existing cetacean density models, some of which were not previously available to the public
2. Identified and compiled existing indicators of cetacean presence, including visual observations, acoustic detections, and satellite tagging data, some of which were not previously available to the public, and several of which expand the known range of certain species.
3. Organized the available modeling results and data in a manner that allows the user to quickly identify what type of data is available for a species/region/month and where data gaps exist.

Density modeling:

Following the development of the information hierarchy and an early assessment of cetacean data availability, the CetMap identified and undertook two key modeling efforts to meaningfully improve the understanding of cetacean density and distribution in the U.S. EEZ:

- *Beaufort and Chukchi Seas* – The CetMap used two long-term survey datasets and preferred modeling methods to produce comprehensive habitat-based density models for the species commonly found in the Beaufort and Chukchi Seas. Habitat-based density models were not previously available for this region.
- *Atlantic Coast and Gulf of Mexico* – Using newer survey data provided by NMFS Science Center staff from both the Northeast and the Southeast, as well as habitat-based density modeling methods reflecting those utilized by the Southwest Fisheries Science Center, the CetMap created new comprehensive regional density estimates for all of the Atlantic Coast and Gulf of Mexico species.

In addition, the CetMap is working with NOAA's Southwest Regional Office to showcase an effort that uses shore-based visual sighting data for grey whales along the U.S. West Coast, combined with their swim speed, to model the estimated location and density of the majority of migrating gray whales on any date within the migration period.

Mapping and product accessibility:
CetMap members with Duke University's Marine Geospatial Ecology Lab were responsible for creating standardized GIS files for the new modeling results produced by the CetMap, as well as for several existing model results compiled for this effort, but for which GIS maps had not previously been generated.

Further, CetMap worked with NOAA's Office of Science and Technology to develop the http://cetsound.noaa.gov website through which to access both the CetMap GIS products as well as the SoundMap products.

INTERACTIVE SESSIONS: OVERVIEW

Following the introduction of the CetSound products, the symposium attendees and working group members divided into two rooms hosting interactive sessions, one for CetMap and one for SoundMap. Workshop participants attended either of these interactive sessions and then rotated at a break, giving them access to members of each working groups. Each room was equipped with laptop computer stations to allow attendees to see the methods and products demonstrated and to ask questions directly.

SOUNDMAP WORKING GROUP: SUMMARY

The SoundMap interactive session was introduced by co-chair Brandon Southall who gave an overview of the session and described the individual stations where working group members were located to demonstrate products and answer questions. In his opening remarks, Southall explained the overall approaches taken including key distinctions in spatial and temporal depiction of anthropogenic noise using novel advances and applications of tools and information. Specifically, he explained that the primary emphasis was to depict average noise conditions over relatively long scales (e.g., seasonally or annually) from chronic noise sources, such as vessel activity, but also model shorter term, intense, acute sound sources (e.g., active sonar operations). He explained the overall intent was to reflect average conditions with relatively simple metrics to characterize variance in real conditions and the resulting tradeoffs and logic behind sound metrics, frequency resolution, and 3-D spatial resolution used. Data limitations and needs for subsequent progress with integrative analysis tools were acknowledged and discussed. Most questions within the full group related to the depiction of spatial and temporal resolution and the potential for even more sophisticated integration of information and the use of these tools in a predictive capacity in the future. The interactive session then focused on direct interactions between workshop participants and SoundMap working group members over specific elements of the SoundMap effort including:

Overall SoundMap Structure:
Overall explanation of the GIS mapping configuration approach and integrated dataset demonstrating organization of information by large geographical areas (e.g., Alaska, East Coast) within which chronic noise layers are depicted and (in some areas) discrete sound event scenarios are shown. Working group members showed the approach to using different map layers for both different sound frequencies and discrete ocean depths.

Sound Propagation:
Consideration and explanation of the sound propagation models used specifically in the Sound Mapping working group, including assumptions and advances made in extending these models over large spatial scales.

Average Noise Fields from Chronic Human Sources:
Three different stations were devoted to demonstrating and explaining the databases used and resulting sound field maps for chronic noise (predominately shipping but in some areas also including seismic air gun operations). These were focused largely in different geographical regions of the U.S. EEZ (Alaska, West Coast + Hawaii, and East Coast + Gulf of Mexico).

Transient Noise Field from Acute Human Sources:
Three different stations were devoted to demonstrating and explaining the underlying data sources used and resulting sound field maps for different discrete activities (a Navy active sonar training exercise in Hawaii, geological and geophysical air gun surveys, and wind farm construction and oil platform removal impulsive noise sources).

Empirical Data:
Discussion of existing datasets where empirical measurements of noise in comparable frequency and temporal resolution exist with which to compare modeled results.

CETMAP WORKING GROUP: SUMMARY

In the CetMap interactive session, co-chair Megan Ferguson provided an overview of the CetMap working group effort and products and described the individual stations where working group members were located to demonstrate products and answer questions. Tim Haverland then gave a quick walk-through of the products and the web-site interface. Participants were encouraged to navigate freely through the website, ask questions, and provide comments on website design and ease of use, functionality of the tools, relevance of the products, and recommendations for additional products or capabilities. Discussion during the Session was wide-ranging, including the following topics:

Data Integration:
Two stations were devoted to discussions of regionally-specific data; the East Coast and Gulf of Mexico regions comprised one station, and the West Coast and Hawaii regions comprised the

other. Participants engaged in a self-guided tour of the website, viewing the data products and associated metadata that were available for each region. Participants were interested in discussing the long-term process for ensuring inclusion of most recent cetacean density and distribution data, and in some cases recommended specific datasets that they would like to see added. Participants also recommended that CetMap be expanded to include pinnipeds and to incorporate the inland waters of Washington in the data products. The spatial and temporal resolution of the data products were discussed, including the existing limiting factors and the prospect and utility of achieving finer spatiotemporal resolution in the future. In addition, participants asked about the relationship between CetMap and other online data or mapping resources, such as OBIS and the Marine Cadastre. Participants inquired about the standards for including datasets in CetMap. Finally, participants made recommendations for editing the text on the website that provided information about each of the data products.

Biologically important areas (BIAs):
One station focused on BIAs, including the process used to develop this product. Participants were generally excited about the availability of this information. Some participants expressed caution regarding the interpretation and use of this qualitative type of information and suggested that these products should undergo further vetting within the scientific community. Many discussions revolved around how this contextual ecological information could be used to improve or interpret quantitative analyses and facilitate and enhance management decisions.

Database and Website Structure:
Tim Haverland was present at a station dedicated to the CetMap database and website structure. He discussed technical aspects relating to the processes of acquiring, storing, and displaying information. Participants made recommendations about the placement of buttons and links, the content or presence of specific citations and disclaimers, and the nomenclature used to identify species in the data products. Participants requested interactive displays alternative data formats, and a section highlighting information that was newly available on the website. Participants inquired about the ability of CetMap to transfer information with other online information repositories.

GIS Data and Maps:
Working group members from the Marine Geospatial Ecology Lab at Duke University presented information and answered questions at the station devoted to CetMap GIS data and maps. Participants were interested in how each of the data products were displayed on maps. Participants made recommendations to facilitate interpretation of existing maps, such as changing symbology, geographic projections, and labeling, and including time stamps or version numbers on the data products. In addition, participants requested analytical tools for manipulating data displayed on the maps.

INVITED PRESENTATIONS - MANAGEMENT CONTEXT: OVERVIEW

Although Day 1 was predominantly focused on presentation and discussion of the CetSound tools themselves, the need for these tools to be closely linked to NOAA's management needs, the other symposium-sponsoring agencies and many of the stakeholders present at the symposium, was highlighted. To ensure that all symposium attendees were provided with sufficient background regarding a selection of prominent management contexts that were considered relevant to CetSound tool development, four presentations were provided. Two of these presentations highlighted statutes that have, to date, provided NOAA's main authority to manage the impacts of ocean noise on cetacean populations (Endangered Species Act and Marine Mammal Protection Act). An additional presentation highlighted ocean planning as a component of the new National Ocean Policy, and supporting geospatial database and mapping visualization tool development initiatives that share CetSound objectives. A final presentation detailed the multi-federal agency requirements of the National Environmental Policy Act, and in particular the development of robust assessments of cumulative impacts associated with proposed activities. This background was revisited on Day 2 during discussion of potential management applications of the CetSound tools.

PRESENTERS WRITTEN SUMMARIES

U.S. Endangered Species Act

Craig Johnson, NOAA, NMFS, Office of Protected Resources

1. **The Endangered Species Act**

The Endangered Species Act (16 U.S. Code 1531 et seq., ESA) is designed to protect and recover species of plants and animals that are listed as endangered or threatened with extinction. Four provisions of the ESA would benefit from any effort to map the distribution of cetaceans and sound: (1) the process of assessing whether species of marine mammals warrant listing as endangered or threatened; (2) designation of areas that are critical to the conservation or recovery of marine mammals protected by the ESA; (3) the process of developing and implementing recovery plans for those species; and (4) interagency consultations, which require other federal agencies to seek NMFS' help to insure that any action those agencies authorize, fund, or carry out is not likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat that has been designated for those species.

2. **ESA threats assessments and cumulative impacts**

Listing, recovery planning, and Interagency Consultations all require NMFS to identify natural and anthropogenic threats facing endangered or threatened species, assess the status of those species and populations in light of those anthropogenic threats, and prescribe measures to counter those threats and improve the status of these species. Threats assessments for endangered and threatened cetaceans have been historically been challenging because these species are wide-ranging (exposing them to multiple stressors on an annual basis), they are long-lived (which allows the effects of stressors to accumulate over long periods of time), and they freely cross international boundaries. Because of this combination of factors, any attempt to assess the threats facing these species must consider cumulative impacts. Specifically, these are impacts that occur when endangered or threatened cetaceans (1) are exposed to stressors sufficiently close in time that the effects of one exposure do not dissipate before a subsequent exposure occurs; (2) exposed to stressors that are so close in space that their effects overlap, (3) exposed to stressors that have qualitatively and quantitatively different consequences for the ecosystems, ecological communities, populations, or individuals exposed to them because of synergism (when stressors produce fundamentally different effects in combination than they do individually), additively, magnification (when a combination of stressors have effects that are more than additive), or antagonism (when two or more stressors have less effect in combination than they do individually); (4) exposed to stressors that have small, individual effects that increase in their significance as they accumulate; and (5) exposed to stressors that alter their population dynamics (National Research Council 1986).

3. **The challenges of assessing the impacts of noise**

Assessing the effects of noise-producing activities on endangered and threatened cetaceans has been challenging because (1) noise in marine systems propagates over relatively large oceanographic areas, (2) noise typically originates from multiple sources, (3) coastal and marine systems are not inherently "quiet," (4) the primary consequence of exposing cetaceans to "noise" appears to be behavioral or physiological, which are difficult to translate into demographic currency, and (5) reliable data on the spatial and temporal distribution of most species is limited, particular in marine ecosystems. Attempts to consider the cumulative impacts of multiple noise-producing activities on endangered and threatened cetaceans compounds all of these challenges.

4. **CetSound products**

The mapping tools that are being developed as part of the CetSound project will be a major advance in our ability to manage endangered and threatened cetaceans under the U.S. Endangered Species Act for several reasons. First, these map products provide information on cetacean densities over large oceanographic areas. Second, these tools provide information on sound fields resulting from different kinds of activities at different times of the year over large oceanographic areas. In combination, these tools position us to identify the species exposed to different sound sources, where that exposure occurs, the intensity of that exposure, seasonal patterns associated with that exposure, animal densities within and adjacent to ensonified areas, and temporal variation in those densities. This information will facilitate more robust assessments of the threats facing endangered or threatened cetaceans that would support listing, critical habitat designations, recovery planning, and interagency consultations.

References

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Ecological knowledge and environmental problem-solving. National Academy Press, Washington, D.C.

Marine Mammal Protection Act
Jolie Harrison, NOAA, NMFS, Office of Protected Resources

In 1972, Congress enacted the Marine Mammal Protection Act (MMPA), stating the following findings: marine mammals are resources of great international significance; certain species are, or may be at risk of, extinction or depletion as a result of man's activities; marine mammals should not be permitted to diminish beyond the point at which they cease to be significant functioning element of the ecosystem, and; the primary objective of their management should be to maintain the health and stability of marine ecosystem. This is a powerful statement, and clearly speaks to the need to maintain a broad scope that considers species- and ecosystem-level impacts.

To serve this broader goal, the MMPA put a prohibition on the take of marine mammals, with certain exceptions, one of which is the issuance of incidental take authorizations(ITAs), which is implemented through Section 101(a)(5). This is only one part of the MMPA, but it is the part pursuant to which many noise-producing agencies and industries are actively engaged with NOAA to ensure compliance, and it necessitates the sorts of analyses that the CetSound tools are designed to facilitate. This is the section of the MMPA that this presentation was focused on.

Section 101(a)(5) of the MMPA allows for NOAA to issue ITAs provided that two key findings can be made: 1) the total taking will have a negligible impact on the affected species (or stock), and 2) the total taking will not have an unmitigable adverse impact on the availability of the affected species or stocks for subsistence uses. Further, NOAA must clearly set forth the permissible methods of taking, include the appropriate means of mitigating the impacts, and set forth the required means of monitoring and reporting. The primary work in issuing ITAs is conducting the analyses to determine whether the activity will have a negligible impact (defined as – an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through annual rates of recruitment or survival) and to identify/design, in consultation with the applicant, the most appropriate mitigation (those that will effect the least practicable adverse impact) and monitoring measures.

The CetSound tools were created to help improve our comprehensive understanding and assessment of the impacts of human-induced noise on marine mammals and other protected resources. As implemented to date, Section 101(a)(5) has been a comparatively narrowly focused management framework and the emphasis has been project-specific, single sound-source focused, and driven by the needs of the applicants. However, the MMPA does include a mechanism to analyze multiple activities being conducted over a large area and longer timeframe (e.g., 101(a)(5)(A) 5-year regulations). Additionally, NOAA's issuance of MMPA authorizations requires an analysis under the National Environmental Policy Act, as well as an Endangered Species Act consultation, both of which include cumulative impact evaluations.

Under Section 101(a)(5), NOAA processes ITAs for a diverse array of activities that cover a wide range of spatial scales (the repair of one pier versus Navy sonar training activities throughout the world's oceans) and a wide range of temporal scales (multiple annual rocket launches that take a few minutes each versus oil and gas exploration in the Arctic that spans the summer months and has been going on for more than 20 years). However, the one thing that almost all of the activities (estimate 95%) assessed have in common is that they impact marine mammals through the generation of underwater noise.

Ideally, the comprehensive evaluation of the effects of underwater sound-producing activities on marine mammal species would include understanding of: the presence, distribution, and density of the species in the vicinity of the activity and throughout its range; the spatial, temporal, and spectral characteristics of the associated sound field, and; the context of the sound exposure (e.g., behavioral state, age, and experience of the animal, what other activities are happening in the area, etc.). Currently, there are several challenges in conducting MMPA analyses. Quantitative evaluation of the direct impacts is limited to treatment of noise as single point-sources, with heavy focus on received level (thresholds), although other factors are considered qualitatively. Marine mammal density data can be lacking or difficult to access, and consideration of context of sound exposure is not always possible (especially quantitatively). Cumulative impact assessments are largely qualitative and based on a generalized overlay of footprint of activities and distribution/density of marine mammals without ideal consideration of species range and regional sound field. The information needed to inform best mitigation choices, at regional or more project-specific scales, not always available. Last, monitoring could be crafted to better target needs if available species and sound field information were more accessible and organized (know gaps).

The CetSound products are intended to help address these challenges by better describing and depicting the necessary cetacean and sound information (at broad spatial and temporal scales) and to make the supporting data more accessible. Following are a few of the specific ways that these products could potentially work alone, together, or in conjunction with other emerging quantitative tools to help address these issues. SoundMap tools could allow for: quantitative look at masking and communication interference; quantitative assessment of the effects of multiple sources in a sound field, and; characterization of the ambient/base-level sound in area, allowing for a signal-to-noise ratio evaluation. The CetMap tools include enhanced marine mammal density and distribution data accessibility and new models filling gaps that should assist both Federal Agencies and public in analyses, as well an important area characterization that provides contextual info to help understand likely significance of sound exposures. Together, the CetSound products: cover large spatial scales to support regional and species-based planning; provide better and more accessible information to support design of better mitigation, and organize the data in an accessible way that should facilitate targeted monitoring to fill known gaps.

The purpose of this presentation was not to pre-determine how, exactly, NOAA will use these products for MMPA decisions, but rather: 1) to serve as an introduction to the discussion of potential management applications that will occur on Day 2 by describing how we got where we are, with a focus on MMPA management challenges; 2) to explain why NOAA encouraged and supported the development of these products, and; 3) to reiterate the broad charge of the MMPA and emphasize the importance of keeping in mind the large scales (spatial and temporal) in which marine mammal species ranges and human activities overlap.

Ocean Planning: Spatial Data and Tools to Support Ocean Planning
David Stein, NOAA – National Ocean Service, Coastal Services Center

President Obama signed an Executive Order establishing a National Policy for the Stewardship of the Ocean, Coasts, and Great Lakes on July 19, 2010. That Executive Order adopts the Final Recommendations of the Interagency Ocean Policy Task Force and directs Federal agencies to take the appropriate steps to implement them. The Executive Order strengthens ocean governance and coordination, establishes guiding principles for ocean management, and adopts a flexible framework for effective coastal and marine spatial planning (CMSP) to address conservation, economic activity, user conflict, and sustainable use of the ocean, our coasts and the Great Lakes.

In addition to this emerging framework, additional well-established processes demand spatially-explicit information, including consultations under several federal statues and environmental impact assessment. Common data needs for these processes include physical attributes (bathymetry), human use and use impact patterns (including noise footprints), marine life use patterns (including distribution and density of cetaceans), and habitat attributes (distribution, quality/status). To support these needs, several national scale systems are being developed in the US, including Ocean.Data.Gov, the NOAA CMSP Data Registry, and MarineCadastre.gov.

Ocean Data.Gov is a robust national IMS dedicated to coastal and marine scientific data. It is compatible with existing Federal information resources, has effective governance and accountability across agencies, builds upon existing national data systems and initiatives and is focused on end user. The goals of this system include: to build capacity in the development of spatial data, data standards, mapping products, and decision support tools; to provide a central location for regional ocean planning practitioners to access system design guidance and learn from other regional efforts; and to establish a network of practitioners. Ocean.Data.gov is now live and has received feedback from 40+ stakeholders. This feedback and new requirements are being used in developing a project plan based on Phase 2 focus areas (data inclusion at state/regional level, integration with other national system, an enhanced Decision Support Toolkit and Outreach and engagement).

The work of the NOAA Ocean Planning Data and Tools Team is focused on the overarching goal to identify and make NOAA data and tools available for ocean planning. Specific objectives thus include support for the development of Ocean.Data.Gov under the leadership of the National Ocean Council (NOC), development of the NOAA CMSP Data Integration Plan in close coordination with other NOAA data management and national efforts, and to identify decision support tools currently in operation within NOAA of value to CMSP constituencies. This effort supports a data and services registry: a collection of Web-accessible NOAA geospatial data deemed essential for local, regional, or national-level CMSP processes. Registry data sets are provided in a variety of formats accessible for download, and many can be easily previewed using ESRI's new ArcGIS.com map viewer.

Finally, MarineCadastre.gov is a marine information system developed to support offshore renewable energy planning (EPACT 2005) which is co-led by NOAA and the Bureau of Energy Management (DOI). It provides authoritative data, map viewers, tools for the renewable energy community. The Cadastre has been issue driven to date, focused on renewable energy siting and permitting. Currently, it has only incorporated federal authoritative data sets, but is starting to accept on a case by case basis, data sets that are in common use and generally accepted by CMSP/Renewable Energy Planners. Beyond the datasets themselves, the Cadastre has developed viewers to provide access to the data , to provide capacity to produce maps for distribution, and as screening tools for decision support. The viewers are customizable and are driven by partner needs and collaborations. For example, the CetSound products could be used to augment the site suitability tools and ship tracking information (AIS) analyzed by the Cadastre team could be used to refine the SoundMap shipping noise products.

To summarize, ocean planning processes require high quality, easily interpreted, authoritative data. Many data portals exist for different audiences and it is not a problem for the same data to be in multiple portals as long they all point back to the authoritative sources. There are significant data gaps in living marine resources and human uses, and the products provided via CetSound would significantly augment the information base for ocean planning. Discussion questions raised for the next steps of CetSound development include:

1. What are the most important caveats that should be raised about the data or interpretation of it with regard to a specific regulation?
2. Are there sound or density thresholds for species and/or times of year that could be used to create relative impact maps (e.g. high, medium, low)?
3. Would there be utility in having a visualization/data products working group that could have an ongoing dialog about the data products most needed by stakeholders?

URLS:

- http://Ocean.Data.Gov
- http://egisws02.nos.noaa.gov/cmspgisdataregistry/
- http://MarineCadastre.gov

National Environmental Policy Act - <u>Cumulative Impacts</u>
Ellen Athas, Senior Counsel, White House Council on Environmental Quality

The National Environmental Policy Act (NEPA) was signed into law on January 1, 1970. NEPA's charge is to: encourage productive and enjoyable harmony between man and his environment; promote efforts which will prevent or eliminate damage to the environment and biosphere; and enrich the understanding of the ecological systems and natural resources important to the Nation. It states that it is the continuing policy of the Federal government to use all practicable means and measures to create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements of present and future generations of Americans. NEPA is the first of the many environmental statutes that were passed in the 1970s and is considered the Magna Carta of environmental laws. NEPA requires agencies to undertake an assessment of the environmental effects of their proposed actions prior to making decisions. Two major purposes of the environmental review process are better informed decisions and citizen involvement, both of which should lead to implementation of NEPA's policies.

NEPA also created the Council on Environmental Quality, and CEQ was given many responsibilities, including the responsibility to ensure that Federal agencies meet their obligations under the Act. CEQ oversees implementation of NEPA, principally through issuance and interpretation of NEPA regulations that implement the procedural requirements of NEPA. CEQ also reviews and approves Federal agency NEPA procedures, approves of alternative arrangements for compliance with NEPA in the case of emergencies, and helps to resolve disputes between Federal agencies and with other governmental entities and members of the public.

The NEPA regulations set out the steps and considerations for proceeding with an Environmental Impact Statement. First, agencies must draft a "Purpose and Need" statement to describe what they are trying to achieve by proposing an action. Then, the lead agency or agencies must, "objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated." The agency must analyze the full range of direct, indirect, and cumulative effects of the preferred alternative, if any, and of the reasonable alternatives identified in the draft EIS. For purposes of NEPA, "effects" and "impacts" mean the same thing.

The CEQ Regulations define a cumulative impact as:

> The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

40 C.F.R. § 1508.7

Consideration must be given as to whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by identifying an action as temporary or by breaking it down into small component parts.

Four distinct steps assist in assessing cumulative effects. First, the reviewer must look at all the alternatives that have been determined to be reasonable. Then, there must be a study of the present effects of all past, present, and reasonably foreseeable future actions. Third, the reviewer must assess the extent that effects will add to, modify, or mitigate the effects. Finally, the reviewer should document the cumulative effects of the actions considered on the affected environment.

In reviewing legal challenges to cumulative effects assessments, courts give deference to an agency's interpretation of its own regulations. Agencies will also receive deference for their own scientific findings. A careful and thorough review of impacts should survive legal scrutiny, but, more importantly, provide for good decision making and a transparent public process.

DISCUSSION PANEL 1: OVERVIEW

On both Day 1 and Day 2, four panelists were invited to provide remarks to specific questions and engaged in a guided discussion with the symposium participants and the Working Group members. On Day 1, the panel was comprised of the following people: Bill Ellison (Marine Acoustics, Inc.), Bill Streever (British Petroleum), Rob Williams (University of St. Andrews), and Bob Gisiner (Navy Living Marine Resource Program).

These panelists were invited to provide brief remarks addressing the following four questions:

1. Identify additional datasets or modifications that should be made to the underlying models or methodologies.
2. Identify specific improvements to the presentation and visualization of the mapping products.
3. Is there sufficient information regarding methods and assumptions to understand how current products were created?
4. Identify specific improvements regarding the accessibility of modeled results to users.

The panel remarks were followed by a 60-minute discussion with the audience participants, the CetSound working group members, and the panelists. The comments, suggestions and questions highlighted the following topic areas:

- Sound Field Working Group
    - Use of LEQ in sound measurements
    - Assumptions of models, testing robustness with sensitivity analyses
- Cetacean Density and Distribution Working Group
    - Biologically Important Areas: Need to figure out how to use these tools for management purposes.
- General
    - Concern regarding potential to misinterpret data, discussion regarding need for training to properly use these tools
    - Visualization needs, including the ability to zoom in temporally for sound data, the need for tools that present the underlying variability in the data, breaking down the temporal data to show chronic noise issues.
    - Spatial scale was chosen based on both data availability and the inherent ecological scales within the different systems. Where some users may want finer-scaled products, this is not necessarily appropriate.
    - Caveats and warnings: Need to be clearly stated so that the appropriate use of the data products is extremely clear.

Detailed written opinions were provided by all of the panelists and can be found below.

PANELIST WRITTEN SUMMARIES

William Ellison, Marine Acoustics, Inc.

There has been a long standing need for more comprehensive density and distribution databases for marine life that might be potentially affected by anthropogenic sound. This issue has been at the forefront of every forum on ocean noise issues for the last decade. I applaud the effort demonstrated at the current workshop, especially the overarching visualization tools demonstrated. One of the more important goals of such a tool is to demonstrate to the public, regulators and users the broad breadth of the available data (especially along the US coastline) on a seasonal basis. However, for one who must use such data repositories to assess specific seasonal impacts from either individual or aggregated sound exposures, the data presented must still be augmented by the specific species behavior and movement data. It appears (as explained by the software developer) this data is provided as one mines down through the tool to specific peer reviewed and/or gray literature that provides this information species by species for site specific seasonal behavior, i.e. not in the database per se, but a reference that may be available to dig out and look it up. As both AIM and ESME need such movement data to be as accurate as possible, this is an important and critical observation on the utility of this software for making assessments in support of regulatory requirements.

From a software utility view, it might be productive to have a workshop where users such as AIM and ESME can interact with the software developers/managers in an ongoing dialog on data character, quality and method of access.

An alternate view of this issue that I find concerning (and mentioned during my turn as a panelist) is that the compelling graphics may lead to attempting a correlative risk assessment based solely on a simple visual overlay of a sound field with the visual distribution data depicted at the workshop. There was a talk on day #2 that appeared to actually attempt such an assessment. Such an approach ignored the fact that the context of the animals' behavior (e.g., cow calf interaction, feeding, migrating, dive patterns….) as well as the interaction in a temporal/spectral/spatial sense is critical to a useful evaluation, especially if the evaluation is one where the behavioral response is paramount.

An additional concern is that a great deal of attention was devoted to commercial shipping noise, a true concern but one where regulatory controls of the 'noise' component of shipping impact may not be viable. However, as so clearly pointed out in the ESA talk, such broad noise fields are the pedestal upon which further noise exposures must rest, not only from a PCAD perspective (i.e. animals already unduly stressed by shipping noise, and thus more susceptible to other impact) but also from straightforward aggregated exposure levels in a spatial planning assessment. This also raises the specter of animals perhaps reacting more strongly to the presence and movement of nearby traffic (esp. small boat traffic and whale watching vessels) than they are to the sounds produced by these activities. Would it be possible to also provide within the database structure a measure of the level of activity in a given area, say Cape Cod Bay? In my opinion this may be a better measure of animal avoidance and harassment than the static noise fields now being proffered as the primary assessment determinant.

A significant improvement to the scope of the existing database would be to provide seasonal prey field information where available. Past field research efforts including the NGW work off Sakhlin, blue whale distribution in the channel islands, summer right whale movements on the New England coast and summer bowhead distributions in the Arctic have all demonstrated this collocation of animals and prey as a powerful method of mapping likely animal location. Further the severity scale of moving animals away from a feeding area must also be considered.

Finally, it is worth noting that the tools such as those presented at the workshop also provide the basic foundation for examining the effects of global climate change on animal distribution and abundance. It is timely that this effort appears to have gained enough momentum to carry forward as a baseline to assess such changes.

Bill Streever, British Petroleum

<u>Q1. Identify additional datasets or modifications that should be made to the underlying models or methodologies.</u>

The CetMap tool, when completed, will be an excellent first stop for anyone involved with environmental planning or assessments of projects with the potential to affect marine mammals, such as seismic exploration. Two key modifications will make it even more useful:

- Include all marine mammals, not just cetaceans, since most users are likely to have to address all marine mammals, in keeping with the Marine Mammal Protection Act.
- Develop a scheduled maintenance program for updates or revisions to assure that the most current information is generally available and to allow users to see exactly when the site was last updated and when it will be updated again.

The SFWG tool is both technically and visually very impressive, and its creators should be complimented for having taken a first but very important step toward an improved understanding of what might be thought of as "seascape-level acoustic footprints." However, I am concerned that it might be seen by some members of the regulatory and regulated community as something more than a first step. If it is applied to management questions in its current state of development, it will probably increase, rather than alleviate, confusion. Most management requirements in this arena, and most of the technical literature behind these requirements, rely on sound pressure levels (SPLs) and sound exposure levels (SELs), while the tool relies on equivalent levels, or Leq, which as I understand it is a sound exposure level averaged across time. If it is possible to manipulate these averages to better understand Leq on a day-to-day or hour-to-hour basis, the tool might be more useful, but that capability was not apparent to me during the symposium. Further complicating matters, the Leq as presented appears to show only a single tone or one-third octave band, rather than a broad band average. While the tool can illustrate differences in average sound levels over large areas, that average has little bearing on what animals passing through an area will experience. For example, one of the maps in the SFWG tool indicates reasonably high noise levels in the Beaufort Sea. This map is based on average conditions through the open water season in 2008, but in fact seismic operations are often planned for times when whales are not present (pre- or post-migration), making average conditions meaningless in terms of potential impacts to bowhead whales. Also, 2008 was atypical of the past decade, so the map leaves an impression of unrealistically high sound levels in general, when there was little or no open water seismic activity during some years. Lastly, animals probably avoid at least some of the highest sound levels, and therefore would not experience the average Leq for a given area even if they migrated through the area during a seismic survey.

Modifying the SFWG tool so that it shows (or can show, at the user's discretion) broadband and tonal SPLs (both peak and root mean square) and SELs at a meaningful spatial scale and on a day-to-day or month-to-month basis would be extremely challenging and probably not worthwhile without a specific purpose in mind. Assuming that the SFWG tool will continue to rely on Leqs, two key modifications that would improve the tool are:

- A required pop-up window that has to be read and accepted by the user that explains, in simple terms, the difference between different metrics (SPL, SEL, and Leq).
- A warning on every screen that cannot be turned off or blocked, even on printed versions of the tool's output, saying something along the lines of "This output should not be used to generate sound exposure estimates for marine mammals or other wildlife due to the averaging approach that was used," with a dropdown box explaining the limitations of the method.

Despite the obvious shortcomings of the current version of the SWFG tool, it is nevertheless a clear step toward a seascape-level understanding of underwater acoustic footprints. With further development, and with a highly trained workforce, CetMap and SWFG could conceivably be used together to better understand how both individuals and stocks of whales are exposed to underwater sounds.

Q2. Identify specific improvements to the presentation and visualization of the mapping products.

In addition to comments presented in response to other questions, a key factor in improving presentation and visualization requires moving beyond the actual products to the broader need for training. Anyone using these tools should have significant training in marine mammal survey techniques and underwater acoustics. With that in mind, I strongly encourage NOAA to introduce a training program to accompany the release of these tools. In fact, use of these tools to encourage support of a series of seminars or workshops, and perhaps even to provide the foundation for this series of seminars or workshops, could well prove to be their most lasting impact.

Q3. Is there sufficient information regarding methods and assumptions to understand how current products were created?
Few users will understand how the SFWG tool was created based on information available on the site as it was demonstrated during the symposium. Many users will not understand how Leq is computed or what it means relative to other metrics presented on a decibel scale.

Q4. Identify specific improvements regarding the accessibility of modeled results to users.
See above. In addition, for the SFWG tool, ensure that users understand that the Leq computed on the east coast is very different than that computed for Alaska, in that there is probably greater inter-year variability in Alaska, in that Alaska data primarily represent averages of impulsive sounds rather than continuous shipping sounds, and in that the Alaska data are based on a portion of the year, rather than the entire year.

Rob Williams, Sea Mammal Research Unit, University of St Andrews

Thank you very much for the invitation to see and comment on the approaches used in NOAA's Cetacean Density and Distribution Mapping (CetMap) and Underwater Sound Field Mapping (SoundMap) Working Groups. Taken together, the CetSound initiative represents one of the most exciting and ambitious developments I have seen in marine conservation and management in many years. I applaud the funders, who showed tremendous foresight in launching this program, the technical teams who have taken their work to this impressive stage, and the conference organizers who showed laudable willingness to subject the philosophical approach, data, analytical methods and preliminary results to outside scrutiny at an early stage. I am pleased to see efforts to tackle habitat and sound field mapping at the spatial scales at which cetaceans live their lives. This work is needed, and I give the overarching concept my strongest endorsement. We need maps of cetacean density, and good, reliable predictions of the natural and anthropogenic sound fields in which those cetaceans live. Overall, I welcome this effort. More importantly, I strongly encourage giving this team the resources it needs to complete the ambitious set of tasks that have been identified. The work I have seen to date convinces me that this team is well on its way to having tools and products that can be adapted and used both within the US and globally in a quantitative and spatially explicit risk assessment framework. I strongly encourage those making funding decisions to allow this work to be completed, because it is nearly there. My comments should be taken as an endorsement of funding the final steps, rather than as a criticism of anything done to date. I encourage the continued development of these tools and products, because they will raise the bar for how the rest of the world integrates noise and cetacean density maps into marine spatial planning and decision-making.

Think PBR when outlining data needs: density (with uncertainty), and noise (with uncertainty)

The global marine mammal research community has taken a cue from the precautionary spirit of the US Marine Mammal Protection Act and the Potential Biological Removal (PBR) calculation, which incorporates uncertainty in abundance estimates in setting limits to allowable harm. It is clear that the CetSound teams are anticipating their outputs as inputs to some future, spatially explicit, quantitative risk assessment. Ultimately, we do not want pretty maps. We want scientific information to evaluate whether anthropogenic noise will have a "negligible impact" on a stock presumed to be in an area. The Guidelines for Assessing Marine Mammal Stocks (GAMMS) spell out assessment rules in a transparent way. In my view, we need PBR and GAMMS counterparts for spatial data and acoustic risk assessments. To me, PBR's best attribute is the reward for science implicit in using N_{min} rather than N_{best}. There are at least two kinds of uncertainty in cetacean abundance estimates: the variability of the system, because habitat changes and whales move; and the variability due to the measurement process. It is important to quantify and present uncertainty clearly, because we can do something about the second one. Almost any desired degree of precision can be achieved if we spend enough money on science to increase effort and number of sightings. As we do that, variance gets smaller, N_{min} approaches N_{best}, and PBR generally goes up until we reach some point of diminishing return.

Looking at the maps in the CetMap tools, one could easily make maps that are just as pretty using probability of occurrence, but what we really want in a risk assessment is a good prediction of density (number of animals per unit area), and a good estimate of how much confidence to have in that density estimate. It is important to remember that ultimately, the maps we want are abundance estimates, and we should review the maps as critically as we review abundance estimates in stock assessments. As an aspirational statement, we could imagine conducting a PBR calculation at the level of an individual grid cell. I think that is a useful way to think about what I would set as a goal. Imagine each cell in those maps as a survey area in which you predict abundance and estimate how much confidence to have in that abundance estimate. If you start with that goal, you can see that we still have a lot of work to do to put the scientific outputs of the various NOAA Science Centers in common currency, because the labs have different scientific cultures and traditions, budgets and sample sizes, and they study species in widely differing habitats and with different life histories. What we want to avoid is a situation where cetaceans in one region are subject to higher allowable take levels than another because the two regions use different methods to quantify variance in their density and distribution maps.

Putting Science Center outputs in common currency

A recent analysis showed that SWFSC may have conducted more cetacean line transect surveys than the rest of the world put together (*1*). That globally unique dataset has allowed the SWFSC team to do things that few other labs have attempted. In my conversations with Karin Forney at this meeting, I learned that when developing habitat models for the Pacific, the SWFSC team found that inter-annual natural variability was an order of magnitude larger than the line-transect based sampling variance. As a result, many of their scientific outputs quantify variance across annual prediction grids (*2*). In the other NOAA regions, there may only be one survey in each area, and all we could do is quantify encounter rate variance within that one survey: interannual variability is no doubt also present and may be large, but it is unquantified. As a result, that could lead to a situation where more data (ETP and US West Coast) may appear paradoxically to result in higher variability, lower allowable takes, and ultimately serve the opposite function as the "reward for science" implicit in the PBR calculation. This warrants serious consideration. In the distance sampling community, Sharon Hedley, Simon Wood and Mark Bravington are developing new variance estimators for spatial models from line transect survey data (e.g., (*3*)). I strongly support the philosophical decision that was made to bundle the CetMap products in such a way that it is impossible to download the best point estimate of density without also downloading some measure of associated uncertainty or confidence. As the technical teams know, there is still a lot of work to do to put the outputs of the different teams and NOAA science centers in a common currency, given the regionally uneven research efforts and sample size, and I encourage decision makers to fund the work necessary to complete this task. Standardizing across regional datasets will be difficult, because the surveys were designed for different purposes and with different budgets, and consequently have differing, imperfect measures of uncertainty. Ideally we would like variance estimates for both the process and sampling components to be included. In reality, we may never be able to estimate the process variance in rarely-surveyed regions, so a minimum step will be to ensure the sources of uncertainty that can be estimated are clearly noted, and somehow clarify the terminology we use when presenting variance estimates. Regrettably, this may involve a "lowest common denominator" approach, whereby the data-rich regions have to reanalyze data to quantify only the sources of variance that can be quantified in the data-poor regions. It is not my place to proscribe a particular solution, but I strongly encourage a technical working group be given adequate resources to discuss how to standardize abundance and variance estimates from the six NMFS Science Centers, because a preliminary look at the CetMap tools suggests that they are not yet directly comparable.

Including species studied through photo-ID

The CetMap team has done a great job of compiling density estimates, but one of the outstanding technical tasks is to incorporate information from cetaceans studied using methods other than line transect surveys. As an extreme example, southern resident killer whales are studied through an annual photo-ID census by the Center for Whale Research. Every individual in the population is known from birth to death. The demographic data represent the gold standard for any cetacean population. They are also entirely missing from spatial planning tools like CetMap, because it is difficult to assign a mark-recapture abundance estimate (or its extreme case, a census) to a particular space. Methods exist to estimate density from photo-ID data, and spatially explicit capture-recapture tools (*4*) are an exciting field of statistical research. Many of the best studied or critically endangered cetacean populations in waters under US jurisdiction are studied using methods other than line transect surveys. I encourage those making funding decisions to allocate sufficient resources to conduct spatially explicit capture-recapture analyses to allow us to include such populations (e.g., North Atlantic right whales, southern resident killer whales, Sarasota Bay bottlenose dolphins) in marine spatial planning tools like CetMap.

Reward for filling in data gaps
If we keep "PBR on the scale of a grid cell" in mind as an aspirational statement, I think there needs to be a reward as the accuracy and precision of our distribution estimates improves. If I were applying for a take authorization, I would be disappointed if risk assessments treated well studied areas in as precautionary a way as an area that has never been surveyed. Both data-rich and data-poor areas need to be filled in with colored maps, but we need a way to evaluate risk differently when using maps based on great data and those based on a few sightings or expert guesses. Ultimately, there needs to be an incentive to fill in data gaps. The CetMap tools have a placeholder for this by ranking the outputs. I like that the CetMap outputs are color-coded, depending on whether they're based on data (smoothed or raw); model predictions from data; or expert opinion, because we will need to treat those categories in a way that there is a penalty for introducing noise into areas that are data gaps or highly uncertain areas. From a management perspective, I see a need for a reward or incentive for improving the quality and quantity of data available to bring a region up from a lower-quality category to a higher-quality category. Expert elicitation is a practical way to go to guess at what might be in unsurveyed areas, but (a) it is better to predict from models, (b) we should not be relying on models as a substitute for empirical data, and (c) I would avoid having that expert-driven approach try to reach consensus. By capturing the uncertainty/variability in expert opinion, we can try to gauge the confidence in the resulting density map.

Quantifying uncertainty in noise predictions
The sound field maps are an exciting development. Much of the technical discussion I heard focused on which point estimates to present: the temporal, spectral and spatial resolution. I strongly endorse the overarching approach. I also encourage those in charge of funding decisions to equip the SoundMap team with sufficient resources to give some associated measure of uncertainty. Currently, there is some reference to validation exercises that are not in the public domain. Some approach is needed to quantify uncertainty, whether it is analytic or empirical (difference between predicted and some sample of field measurements). I have some appreciation and sympathy for how hard-won these point estimates are. As with the CetMap exercise, the task in incomplete until we have an associated measure of uncertainty. This can be hard to quantify, but doing so is essential. Again, taking a lesson from the CetMap team, I think it is essential to "bundle" the noise products so that users cannot download point estimates without also downloading the associated measures of uncertainty.

In our work in Canada's Pacific EEZ, Christine Erbe and Alex MacGillivray recently conducted a sound field mapping exercise to model cumulative energy from shipping activities (*5*). The approach included a placeholder "error term" for each cell, through "(1) a comparison of the simple *TL* model to a range-dependent parabolic equation (PE) model along 10 radii spanning the EEZ, (2) a sensitivity study of the noise map to variability in seafloor and water column parameters, and (3) a comparison to field measurements" (*5*). No doubt the SoundMap team has a similar (or better) method for quantifying uncertainty, but the message is that (a) it is an essential part of the output, and (b) some variability is easily quantifiable, whereas others may need to be bounded by expert elicitation in the same way we do for cetacean maps in unsurveyed areas.

Combining cetacean density and sound field maps in a spatially explicit risk assessment
We need to anticipate that risk assessments will add or multiply the uncertainty the density and noise products (*6*). To be consistent with the precautionary approach of MMPA, we will need to imagine evaluating risk through some combination of the upper bound on a noise surface and the upper limit of cetacean density. (I do not know enough about the Incidental Take Authorization process to know how much of this already takes place, but it underscores the importance of getting the uncertainty terms accurate and internally consistent in both the CetMap and SoundMap tools.) Acknowledging uncertainty in both parameters may result in orders of magnitude higher estimates of "take" than the lower or best estimate of noise and the lower or best estimate of cetacean density. As members of both technical teams know, there is still a lot of work involved in integrating the two pieces of information. My concern is that the draft maps from the two working groups look so good that those making funding decisions may get the impression that the task is largely complete, and underestimate how much work remains to integrate the two sources of information. In parallel, a management discussion needs to be had that gauges how much risk is allowable. Based on our experience with MMPA, though, it is clear that any framework for decision-making must facilitate making good (i.e., risk-averse) decisions under uncertainty, and that requires some sort of penalty for uncertainty. I think that both the CetMap and SoundMap working groups are well on track for providing excellent outputs, but I encourage the completion of their tasks by putting all cells in the same currency, quantifying uncertainty and developing a decision-support framework that (like PBR) has a built-in reward for having data-rich areas. Otherwise, there will never be an incentive to fill in the gaps with real data, or improve our guesses with defensible model predictions. The CetSound team has the skills and data to combine the noise and cetacean outputs in a defensible, rigorous way if they are given adequate time and resources to see their job through to completion. I would encourage those allocating funding to ensure that one of the outputs of this globally unique effort is a methods paper, along the lines of the Guidelines for Assessment of Marine Mammal Stocks, to serve as a transparent set of Guidelines for Assessing Impacts of Chronic Ocean Noise on Marine Mammals.

If the tasks can be completed as planned, this program will set the standard for the way that this work gets done worldwide. Having come so far, so quickly, it is essential that these tasks get funded to see the outputs (methods, point estimates, uncertainty estimates, and a framework for integrating the two products) peer-reviewed and published in the primary literature. I congratulate everyone involved in pulling these products together, and thank you very much for inviting me to see it first-hand.

1. K. Kaschner, N. J. Quick, R. Jewell, R. Williams, C. M. Harris, *PLoS ONE* 7, e44075 (2012).

2. J. Barlow *et al.*, *Predictive modeling of cetacean densities in the Eastern Pacific Ocean*. (U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, Calif., 2008).
3. R. Williams *et al.*, *Conservation Biology* 25, 526 (2011).
4. D. L. Borchers, M. G. Efford, *Biometrics* 64, 377 (2008).
5. C. Erbe, A. O. MacGillivray, R. Williams, "Mapping ocean noise: Modeling cumulative acoustic energy from shipping in British Columbia to inform marine spatial planning. " (Curtin University, Perth, Australia, 2012).
6. J. Harwood, *Biological Conservation* 95, 219 (2000).

Robert Gisiner, U.S. Navy, N45

The symposium format and the two Cetacean and Sound Field working group products are a good start at organizing a growing body of data on both cetacean distribution and the distribution of anthropogenic sound in US waters. More time was allotted to NOAA-selected speakers addressing potential uses of the data analysis tools than was provided for discussion by symposium attendees. It would be good to see development of a one or two hour introductory tutorial for new users to help them explore the tools a little more thoroughly, but as a first glance, this symposium did enable the reviewers and other attendees to get some hands-on time with the tools and assess their merits, even if discussion was limited.

The CetMaptoolkit was very impressive, not only for the degree to which habitat-correlated density estimation has progressed, but also for the way in which lower quality data and new data sources such as tagged animal data, mark-recapture (photo-ID) and acoustic data, were used to fill information gaps while preserving the greater uncertainty one should retain when using poorer data sources. While the focus was on mapped density products, I was particularly impressed by the color-coded tables of data types sorted by species, season and location. The color coding for data quality offers the non-expert user a quick insight into the likely uncertainty attached to any data products for a given species, region and season, something that is not always preserved in many population estimation and spatial density mapping tools.

Mapping of sound fields poses more challenges in many ways, but the initial tools offer a good means for undertaking further development. Quite a bit of the discussion time focused on the use of L_{eq} as an averaged measure of relative 'noisiness'. The physics and biology of underwater sound make it difficult to come up with a universal metric; SPLR, SEL, band-averaged weighting or other metrics all fall short under certain contexts. It is sufficient for now that L_{eq} can serve as a kind of 'straw man' for weighing the pros and cons of alternatives.

Perhaps the most positive aspect of the process was the inclusion of members from various organizations, selected for their expertise rather than for any one organization's needs or interests. If this project continues to grow and update the CetMap and SFWG tools, and I hope it does, then it is imperative that the interdisciplinary and multi-organizational structure of the working groups be preserved and, if anything, expanded. As constituted for this first round of work, the committees were still strongly skewed to NOAA staff interests and expertise, but the strength of the outside experts in the group provided much-needed balance and “outside the box” thinking.

While the development of Biologically Important Areas (BIA) or “hotspots” had been a goal of Lubchenko’s January 2011 letter to CEQ, and therefore a goal for the working groups, the working groups correctly determined that the data were not capable of supporting such an analysis and instead focused on geospatial density estimation as a first step. It was unfortunate therefore, that NOAA chose to go ahead with the creation of a BIA work product, and to do so without consultation with the expert working groups, or any other kind of external expert review. The defects of this incomplete and highly flawed piece of work were only made more apparent when viewed in comparison with the CetMap and Sound tools. Among the most serious defects of the BIA products include inconsistent and often vague definitions of the geographic bounds of the BIAs, inconsistent use of the available information which resulted in very restrictive definitions for some species and overly broad definitions for others, and poorly defined criteria as to what constitutes a Biologically Important Area in the first place.

In summary, NOAA has performed a great service to the public and stakeholder community by assembling an interdisciplinary expert team from multiple organizations to build a “starter kit” of CetMap and Sound Field tools. The NOAA internal-only BIA work products lack the accountability of process and quality of the CetMap and Sound Map tools and should not be included on the website. Both Pat Halpin, lead developer of the CetMap toolkit and Jessica Redfern, a NOAA quantitative biologist, proposed excellent ways of generating BIA information that are more consistent and accountable than NOAA’s initial attempt. NOAA should support the demonstrated effectiveness and quality of this working group process by continuing their efforts, and abandon internal-only processes like BIA, which lack accountability, transparency and other hallmarks of good scientific process.

DAY 2: OVERVIEW

John Quinn (Navy) and Walter Cruickshank (Bureau of Ocean Energy Management) provided opening remarks for the symposium's second day. Both speakers highlighted the roles that their agencies had played in supporting the CetSound initiative, noting the promise they felt the effort represented for improved assessments of environmental impacts associated with noise producing activities offshore. . These remarks were followed by a series of presentations highlighting some of the potential management applications for the tools and products developed during the CetSound project. In the afternoon, four panelists were invited to provide comments addressing management applications of the products, either as presented or pending further development, followed by a 60-minute discussion engaging all participants of the symposium on the same topic. Following this discussion, symposium members were divided into nineteen "breakout" groups, and were asked to discuss and provide written comments on a series of directed questions. Each group then presented a summary of their comments to all participants in a round-robin setting. Finally, the Symposium concluded with remarks by Tim Ragen of the Marine Mammal Commission, and Richard Merrick of NMFS. Tim Ragen summarized the views expressed by many during the meeting that the effort, though impressive, would necessitate sustained commitment to meet its goals of informing management decisions. Richard Merrick acknowledged this need, and offered his assistance to guide the effort's next steps.

INVITED PRESENTATIONS - POTENTIAL MANAGEMENT APPLICATIONS: OVERVIEW

Seven participants were invited to evaluate the CetSound tools prior to the Symposium, and prepare presentations discussing the potential management applications for the CetSound products. On Day 2, each of the following presentations was given:

- Cetacean Mapping Applications: Risk Assessment and Identification of Priority Habitat (Jessica Redfern, NOAA)
- Including Underwater Noise in Assessments of the Cumulative Impacts of Human Activities on Marine Ecosystems (Carrie Kappel, National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara)
- Integrating Underwater Sound and Cetacean Density Estimates into Regional Coastal and Marine Spatial Planning: New Dimensions for Analysis (Pat Halpin)
- Endangered Species, Cumulative Impact Assessments, and Potential Applications of CetMap and Sound-Field Mapping (Craig Johnson, NOAA)
- Cumulative Acoustic Footprints Over Multiple Scales: From Bottom to Top, From Noise Metrics to Biological Influences (Chris Clark, Bioacoustics Research Program, Cornell Laboratory Of Ornithology, Cornell University)
- Population Consequences of Disturbance (PCoD) Model and Future Applications (Mike Weise, Office of Naval Research)
- Empirical Noise Mapping to Support Management of Resources and Visitor Experience in National Parks (Kurt Fristrup, National Park Service)

Several of these presentations are available in PDF format on the CetSound website. Additionally, the presenters contributed written summaries of their presentations, included below.

PRESENTER WRITTEN SUMMARIES

Cetacean Mapping Applications: Risk Assessment and Identification of Priority Habitat
Jessica Redfern, NOAA

The integrative and comprehensive framework for managing diverse uses of the marine environment provided by marine spatial planning (MSP) has the potential to reduce conflicts among users and between users and the environment. Spatially-explicit risk assessments are a requirement of MSP because they link the distribution of key species to anthropogenic activities. The foundations of these risk assessments are maps of species distributions. The NOAA Cetacean Mapping Working Group (CMWG) has provided maps of species distributions throughout U.S. Exclusive Economic Zones.

Risk Assessment: Jessica V. Redfern, Megan F. McKenna, Thomas. J. Moore, John Calambokidis, Moncia L. DeAngelis, Elizabeth A. Becker, Jay Barlow, Karin A. Forney, Paul C. Fiedler, Susan J. Chivers

We conducted a spatially-explicit assessment of ship-strike risk for humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*), and fin (*B. physalus*) whales in the Southern California Bight (SCB) using habitat models, the highest quality of species distribution available in the CMWG products, built with seven years of line-transect data. Specifically, the models were used to predict whale distributions and calculate risk for alternative shipping routes by summing the predicted number of whales within each route. Even simple overlays of the predictions from the whale-habitat models with alternative shipping routes (Figure 1) show a clear tradeoff in ship-strike risk for humpback and fin whales. They also show that blue whales are distributed more evenly through our study area than humpback and fin whales; consequently, none of the routes considered in our analyses showed an appreciable reduction in risk.

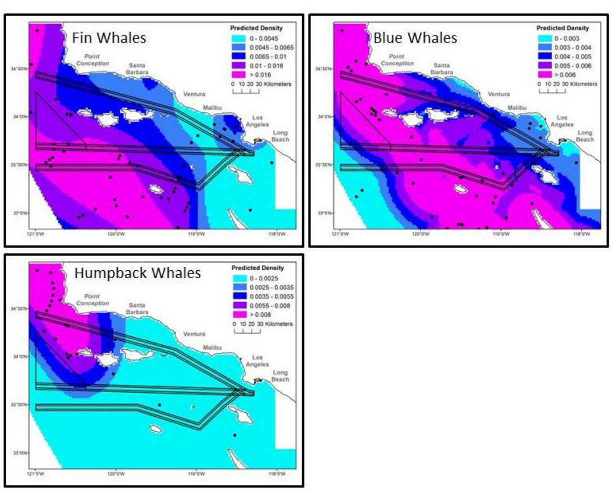

Figure 1. An overlay of predictions from whale-habitat models with alternative shipping routes in the Southern California Bight.

Identification of Priority Habitat: Jessica V. Redfern, Rob Williams, Daniel M. Palacios, Fernando Félix, Corey Sheredy, Thomas J. Moore, Kristen Rasmussen, Ursula Gonzalez-Peral, Jorge Urbán R. , Linda Nichol, and Lisa T. Ballance

Many species of baleen whales migrate long distances between breeding and feeding areas. These species are exposed to anthropogenic threats in their feeding and breeding areas and along their migration routes; threats include entanglement in fishing gear, ship strikes, ocean noise, contaminants, and climate change. Mitigating these threats requires a transboundary, systematic planning approach. We use three species of baleen whales in the eastern tropical Pacific (ETP) to explore several components of the planning process. The ETP is a 20 million km^2, open-ocean system that is seasonally occupied by migratory blue and humpback whales from both northern and southern hemispheres; it also hosts important numbers of resident Bryde's whales. We use 10 years of large-scale survey efforts in offshore waters to compare two methods for predicting species density: habitat models (using sea surface temperature, salinity, and chlorophyll, mixed layer depth, and sea floor depth as predictor variables) and inverse distance weighted (IDW) interpolation of daily density estimates. The habitat models are equivalent to the highest quality of species distribution available in the CMWG products. For humpback whales, we also predicted the location of breeding areas using an envelope model built from mother-calf sightings in coastal surveys off Mexico, Costa Rica, Panama, and Ecuador. The resulting distribution map is similar to the important areas CMWG product. Different metrics for delineating critical habitat (e.g., protecting a percentage of a population, protecting areas of known occurrence, or protecting known breeding or feeding areas) were applied to the density grids for each species. There was substantial overlap in the areas identified as critical habitat by the different modeling methods and critical habitat metrics (Figure 2). These areas represent relatively robust predictions of critical habitat and are candidates for further management actions. Some of the areas identified as critical habitat by the habitat models did not overlap with the areas identified by the IDW interpolation (Figure 2), which identifies only those areas containing sightings. These areas require further research to determine their importance for the species.

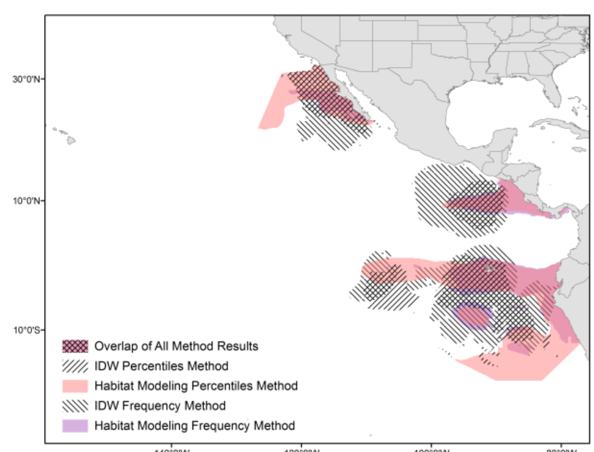

Figure 2. Priority habitat for blue whales identified by multiple methods and criteria.

Including underwater noise in assessments of cumulative impacts of human activities on marine ecosystems

Carrie V Kappel, National Center for Ecological Analysis and Synthesis

The oceans provide a host of benefits to people, but growing pressures have resulted in an increasingly crowded ocean. This has led to conflicts, ecosystem degradation, and declines in benefits to people. The existing management frameworks generally deal with a single species or sector at a time, despite the interconnectedness of the ecosystem. This largely reactive, siloed approach has proven inadequate. A more coordinated and ecosystem-based approach to managing multiple coastal and marine activities was codified in the new National Ocean Policy (Executive Order 2010). An important component of this approach is quantifying and confronting cumulative impacts of human activities over appropriate temporal and spatial scales. This emphasis on cumulative impacts has been a part of environmental law for decades (e.g., National Environmental Protection Act and Endangered Species Act), but few tools have been available to quantify cumulative impacts and make them actionable in the policy sphere.

Finally the science is beginning to catch up to these mandates. New efforts to collect and compile human use data are shedding light on what is happening in the oceans and where, (e.g., as evidenced by the products of the NOAA Sound Field Mapping Working Group, SFWG). New tools to digest and combine these large human use datasets with ecological data are beginning to reveal a picture of cumulative impacts of human activities on marine ecosystems and species. One such framework allows us to quantify and map the combined effects of multiple human activities, accounting for their varying impacts on different types of marine ecosystems (Halpern et al. 2007, Halpern et al. 2008). The resulting maps can be used to identify areas that are relatively untouched by human activities and those that are likely to be heavily impacted. The framework does not prescribe any particular course of management action: outputs of the model can be used to inform management decision making in a variety of contexts, including conservation priority-setting, marine protected area design, ocean planning, and siting of new ocean uses.

Up until now, underwater noise has not been included in cumulative impact maps, because data have not been available at appropriate scales, and because transient, acute events have previously been the primary focus of science and management. The data layers produced by the SFWG provide an opportunity to include chronic underwater noise in maps of cumulative impacts for the first time. I demonstrate how this can be done with a case example from Massachusetts, where comprehensive ocean planning is underway (Commonwealth of Massachusetts 2009).

To model cumulative impacts in state and federal waters off Massachusetts, I combined data on the distribution of 15 different marine ecosystem types, distribution and intensity of 22 ocean and land-based human activities that affect marine waters (ranging from nutrient pollution to fishing), and vulnerability of each ecosystem to each of those activities and its associated stressors (Kappel et al. 2011). To incorporate underwater noise, I focused on average annual chronic noise, primarily associated with commercial ship traffic. I used the SFWG's summed chronic noise layer for 50Hz, a frequency broadly relevant to chronic noise sources and low frequency active species, and 15m depth, which includes most of the study area, but avoids very shallow water (Fig 1a).

The resulting maps reveal a pattern of high human use in the waters off Massachusetts. Important fishing areas, shipping routes, and ports stand out as areas of high impact (Fig 1b). Stellwagen Bank National Marine Sanctuary, because of the confluence of human uses within its borders, also is an area of high impact, in part because it is noisy (Fig 2 a,b). This approach allows us to visualize a human-induced impact, (underwater noise), that is “out of sight, out of mind” and occurs at spatial, temporal and frequency scales outside human experience, and place it in the context of other ongoing impacts. This will facilitate the management of noise as one of many stressors faced by wide-ranging marine animals and ecosystems.

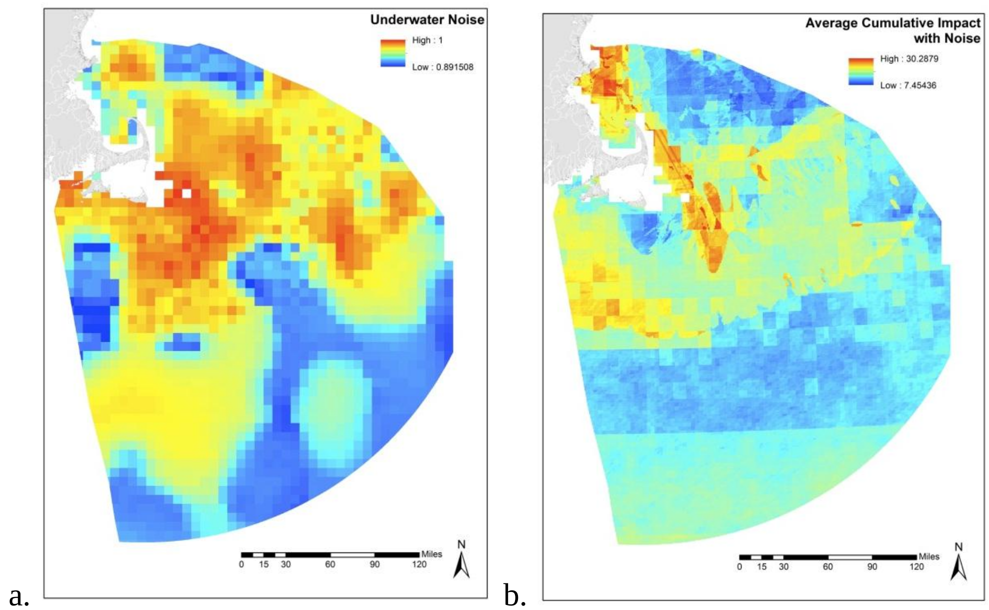

Figure 1. a) Chronic underwater noise from commercial ships and passenger vessels at 50Hz and 15m depth, log transformed and scaled from 0 to 1, based on data from the NOAA SFWG; b) Cumulative impacts of human activities, including noise, on marine ecosystems.

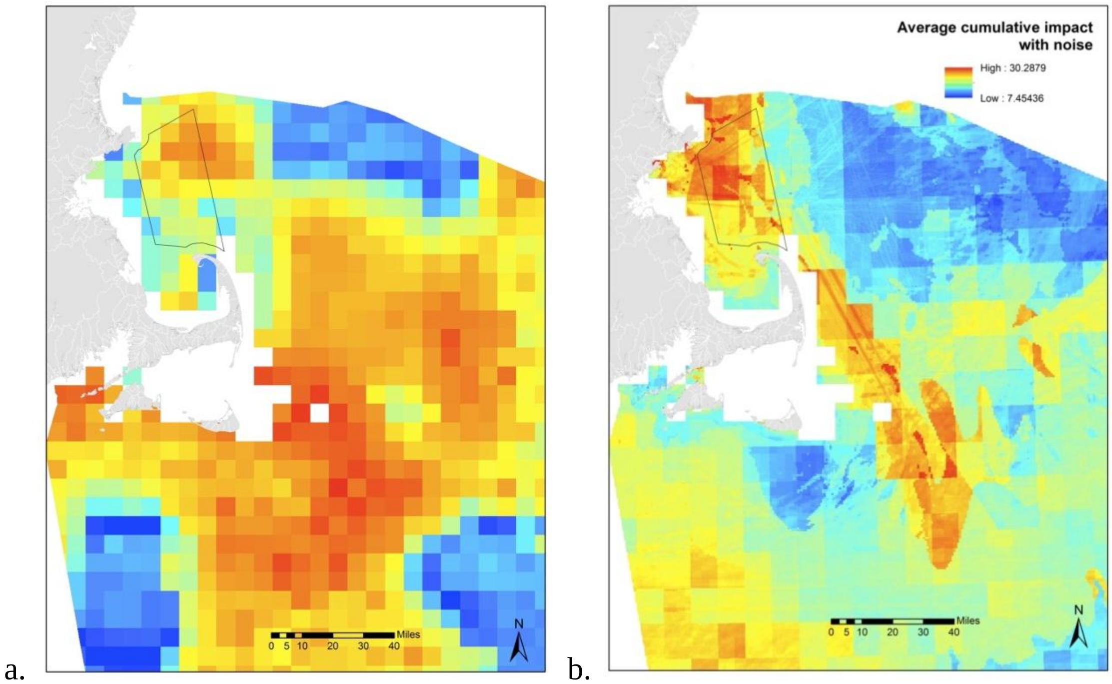

Figure 2. a) Chronic underwater noise within the Stellwagen Bank National Marine Sanctuary (outlined) and surrounding waters; missing pixels are <15m depth - no data; b) Cumulative impacts of human activities, including noise, on marine ecosystems of SBNMS and surrounding waters.

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Integrating underwater sound and cetacean density estimates into regional coastal and marine spatial planning: new dimensions for analysis

Patrick Halpin and Jesse Cleary, Marine Geospatial Ecology Lab, Nicholas School of the Environment, Duke University Marine Lab

In this presentation we discussed issues concerning the integration of underwater sound and cetacean density estimates into Marine Spatial Planning (MSP) in the United States. Our goal was to stimulate workshop discussion on the integration of this information into practical planning applications. Our focus was on exploring three core questions:

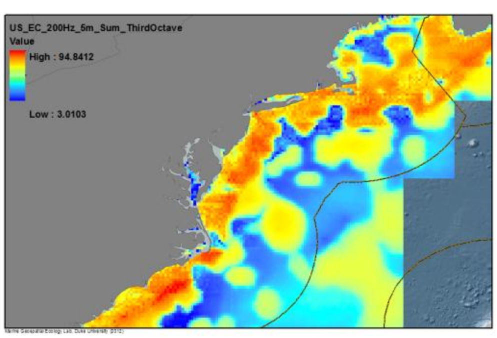
- How do we characterize and map acoustic habitats?
- How do we characterize acoustic habitat degradation?
- How do we integrate acoustic habitats into CMSP?

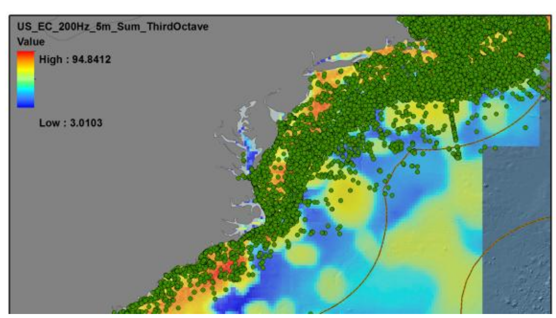
Acoustic habitats and sound field data differ from other aspects of marine spatial planning because:

  – Sound sources may be spatially/temporal distant from the management problem area (not a direct spatial correspondence);
  – Separation of event noise from chronic noise from ambient noise may not be clearly defined;
  – Cetacean's integrate noise exposure over large areas and long time periods (cumulative impacts)

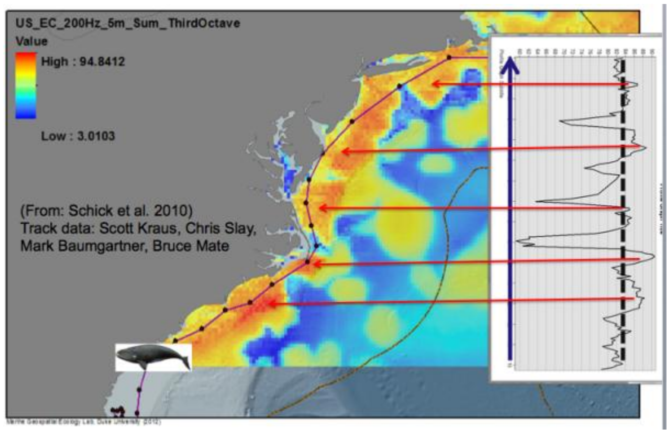
Our conclusion is that standard GIS map overlay methods may not be as directly applicable for acoustic applications of MSP.

In addition, we found noteworthy correspondence between the patterns of chronic sound gradients estimated from shipping activity and marine mammal observations along the mid-Atlantic region. The general explanation for this spatial correspondence is that cetaceans and humans both preferentially use the coastal shelf environment.



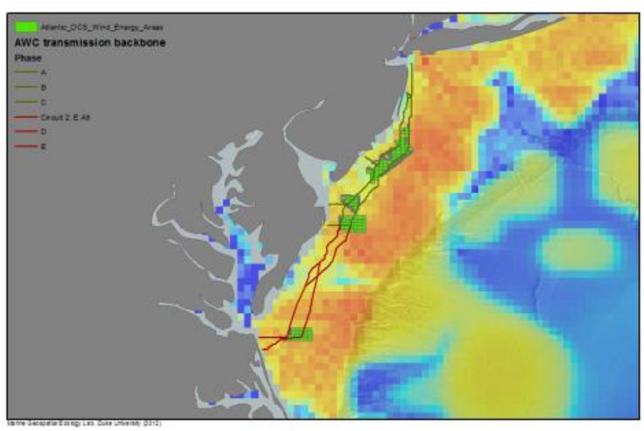


We also tracked the migratory paths of North Atlantic Right Whales to demonstrate the expected exposure of migratory whales to chronic sound fields during their seasonal migrations between calving and foraging areas. This preliminary illustration depicts areas of high potential chronic noise exposure across the migratory route.

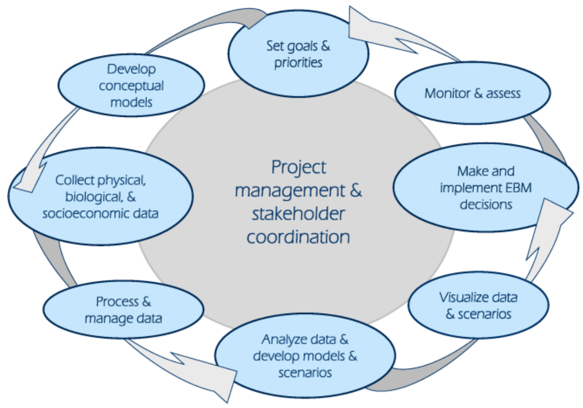


We also mapped the spatial distributions of functional hearing groups of cetacean species (high-frequency, mid-frequency and low-frequency per Southall et al. 2007) to examine the spatial distributions of these groupings versus chronic noise patterns.

We mapped the expected distribution of chronic sound and current lease-block areas now under consideration for future wind-energy development. We also illustrated example patterns of noise events, such as pile driving for wind-energy turbine installations to depict how these types of specific noise events can be depicted in relation to cetacean density patterns and chronic noise.



Finally, we concluded with a depiction of the Marine Spatial Planning decision-making process to raise discussion on where are the most appropriate points in the planning process to consider ocean noise and acoustic habitats (after Curtice *et al.* 2012).


Set goals & priorities
Monitor & assess
Make and implement EBM decisions
Visualize data & scenarios
Analyze data & develop models & scenarios
Process & manage data
Collect physical, biological, & socioeconomic data
Develop conceptual models
Project management & stakeholder coordination

Endangered species, cumulative impact assessment, and potential applications of CetMap and sound field mapping

Craig Johnson, NOAA - Fisheries, Office of Protected Resources

1. The Endangered Species Act

The Endangered Species Act (16 U.S. Code 1531 *et seq*., ESA) is designed to protect and recover species of plants and animals that are listed as endangered or threatened with extinction. Four provisions of the ESA would benefit from any effort to map the distribution of cetaceans and sound: (1) the process of assessing whether species of marine mammals warrant listing as endangered or threatened; (2) designation of areas that are critical to the conservation or recovery of marine mammals protected by the ESA; (3) the process of developing and implementing recovery plans for those species; and (4) interagency consultations, which require other federal agencies to seek NMFS' help to insure that any action those agencies authorize, fund, or carry out is not likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat that has been designated for those species.

2. ESA threats assessments and cumulative impacts

Listing, recovery planning, and Interagency Consultations all require NMFS to identify natural and anthropogenic threats facing endangered or threatened species, assess the status of those species and populations in light of those anthropogenic threats, and prescribe measures to counter those threats and improve the status of these species. Threats assessments for endangered and threatened cetaceans have been historically been challenging because these species are wide-ranging (exposing them to multiple stressors on an annual basis), they are long-lived (which allows the effects of stressors to accumulate over long periods of time), and they freely cross international boundaries.

Because of this combination of factors, any attempt to assess the threats facing these species must consider cumulative impacts. Specifically, these are impacts that occur when endangered or threatened cetaceans (1) are exposed to stressors sufficiently close in time that the effects of one exposure do not dissipate before a subsequent exposure occurs; (2) exposed to stressors that are so close in space that their effects overlap, (3) exposed to stressors that have qualitatively and quantitatively different consequences for the ecosystems, ecological communities, populations, or individuals exposed to them because of synergism (when stressors produce fundamentally different effects in combination than they do individually), additively, magnification (when a combination of stressors have effects that are more than additive), or antagonism (when two or more stressors have less effect in combination than they do individually); (4) exposed to stressors that have small, individual effects that increase in their significance as they accumulate; and (5) exposed to stressors that alter their population dynamics (National Research Council 1986).

3. The challenges of assessing the cumulative impacts of noise

Assessing the effects of noise-producing activities on endangered and threatened cetaceans has been challenging for several reasons. First, noise in marine systems propagates over relatively large areas so cetaceans can be exposed to noise from distant sources at the same time they are exposed to proximate sources. In addition, noise typically originates from multiple sources and many of those sources have similar spectral qualities, which complicates the process of establishing causal relationships between exposing cetaceans to a particular source of noise and cetacean responses to an exposure. Further coastal and marine systems are not inherently "quiet," so cetaceans are exposed to multiple acoustic stimuli at any particular point in time. As a result, it is difficult to determine which of those competing acoustic stimuli will capture the attentional resources of cetaceans. This confounds our ability to determine whether any responses we observe result from a cetacean's exposure to a particular acoustic stimulus rather than some competing stimulus. Finally, with a few important exceptions, acoustic stimuli appear to be "processive" stressors (stressors that require cognitive processing to effect a response) rather than "systemic" stressors (stressors that effect a response without cognitive processing, Herman and Cullinan 1997). That is, acoustic stimuli affect cetaceans primarily through behavioral or physiological, pathways. These pathways have traditionally been difficult to translate into demographic currency.

NOAA-Fisheries uses a series of sequential analyses to assess the effects of human activities on endangered and threatened species and designated critical habitat. We begin by identifying those components of an action that are sources of stressors. Then we consider how those stressors are likely to be distributed spatially over time. Then we overlay the spatial distribution of stressors on the spatial distribution of endangered and threatened cetaceans and other species, which sets up our exposure analyses.

Exposure analyses are the most critical because the most effective methods of mitigating the effects of human activities on free-ranging species has been to avoid exposing them to a suite of stressors, avoid exposing them to particular stressors in a suite, or to change the nature, timing, duration, or intensity of any exposure. Therefore, our exposure analyses try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an Action's effects and the populations or subpopulations those individuals represent.

Once we identify which endangered and threatened species and designated critical habitat are likely to be exposed to potential stressors and the nature of that exposure, we determine whether and how those species and critical habitats are likely to respond given their exposure. This step represents our response analyses. The final steps of our analyses — establishing the risks those responses pose to listed resources — are different for listed species and designated critical habitat (these represent our risk analyses). These risk analyses begin by identifying the probable risks actions pose to individuals, then integrate those individuals risks to identify consequences to the populations those individuals represent, and conclude by determining the consequences of those population-level risks to the species those populations comprise. At the level of individuals, we measure risks using the individual's current or expected future reproductive success which integrates survival and longevity with current and future reproductive success (Stearns 1992). At the level of populations, we measure risks using abundance, variance in abundance, reproduction rates, and extinction probability. At the level of species, we measure risks using number of populations or occurrences, temporal trends in the abundance of those populations, and extinction probability.

These components of our risk analyses allow us to explicitly accumulate effects over time and space, consider interactions between stressors, small incremental effects, and effects that result from changing the dynamics of populations of endangered and threatened cetaceans.

4. Cetacean mapping products

The mapping tools that are being developed as part of the Cetacean Mapping project will be a major advance in our ability to manage endangered and threatened cetaceans under the U.S. Endangered Species Act for several reasons. First, CetMap would provide a common database on cetacean densities within a particular geographic area that is available to be used by NMFS, regulated industries, and other stakeholders. Second, the density data would support our exposure analyses, which is a critical component of any attempt to assess the status of populations of listed cetaceans in a particular area. Third, these tools provide information on sound fields resulting from different kinds of activities at different times of the year over large oceanographic areas. In combination, these tools position NMFS to identify the species exposed to different sound sources, where that exposure occurs, the intensity of that exposure, seasonal patterns associated with that exposure, animal densities within and adjacent to ensonified areas, and temporal variation in those densities.

This suite of information will facilitate more robust assessments of the threats facing endangered or threatened cetaceans that would support listing, critical habitat designations, recovery planning, and interagency consultations. More importantly, it will allow these threat assessments to begin to consider the cumulative impacts of sounds on the distribution and abundance of endangered and threatened cetaceans and other species.

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Cumulative Noise Footprints over Multiple Scales: From bottom to top, from noise to biological influences

Christopher W. Clark, Bioacoustics Research Program, Cornell Lab, Cornell University

There is no doubt that marine mammals, especially cetaceans, depend on the acoustic modality for most of their life-critical behaviors such as communication, navigation, foraging, and predator detection. Although the functional significance of many of the sounds produced by marine mammals remains uncertain or unknown, a large body of research has documented that they produce a great variety sounds under a variety of context. In terms of audition, although the auditory capabilities for some pinnipeds and odontocetes have been studied, understandings of hearing in mysticetes are almost entirely based on inference and deduction (Southall et al.2007). These constraints are important when considering the potential impacts and influences of anthropogenic sounds on marine mammals and for assessing the spatial and temporal scales over which such sounds might impose costs on individuals and populations.

The science-to-management translation of concerns over man-made sounds and marine mammals has focused almost exclusively on measuring or estimating received sound levels at individual animals as a result of short-term, close-range exposures to a limited number of acoustic events or a single type of acoustic event. This acute, dose-response paradigm precludes the assessment of long-term, large-scale cumulative influences of anthropogenic noises (i.e., chronic noise) on the ocean's acoustic environment. Any functional, effective assessment must focus on present-day, real-world situations in which multiple sound sources, either of the same type (e.g., commercial ships) or multiple types (e.g., commercial ships and seismic air gun surveys) contribute to and modify the ocean acoustic environment.

To translate and eventually understand how chronic noise dynamics in the ocean acoustic environment influence marine mammals and marine ecosystem over ecologically meaningful scales we must change from the existing acute, dose-response paradigm to a chronic noise paradigm. This transition from the acute, single-source, small-scale paradigm to a chronic, cumulative, large-scale paradigm is now underway. Key components of this acute-to-chronic transition include: a) the conceptualization of the problem from an ecological perspective that places the full suite of marine mammals within an acoustic, ecological framework bounded by spatial, temporal and frequency dimensions of their sound production and auditory perception domains; b) the combining of science and technology to develop and apply a systems approach to the problem; c) the accumulation and integration of multi-year, ocean region data sets (e.g., global commercial ship traffic, collections of long-term acoustic recordings); and d) the formation of small groups of skilled scientists and engineers to demonstrate the value of the chronic, cumulative, large-scale paradigm through a limited set of use-cases.

Given the assumption that we can successfully build the analytical mechanisms for quantifying chronic noise dynamics in the ocean acoustic environment as a result of multiple sound sources, the next challenge is to develop and apply methods that convert chronic noise metrics into some form of biological "impact." Given the dependence of marine mammals on the acoustic environment, a chronic, noise-based change in a species-specific acoustic environment can impose a cost in the form of lost opportunities to engage in critical activities. To demonstrate, I show how an empirically-informed, noise analysis modeling system was applied to: a) map the dynamics of cumulative noise from commercial shipping off Boston, MA (i.e., changes in acoustic environment), b) estimate lost communication space for a seasonally resident group of North Atlantic right whales, *Eubalaena glacialis*, in the context of long-range communicate (Clark et al. 2009, Ellison et al. 2011), and c) predict the dynamics of a communication masking metric for this group over a 1-month time period (Hatch et al. 2012, Figure 1 below). This example demonstrates how one can translate chronic noise into a species-specific cost to a critical acoustic activity.

The second empirical example I presented focused on the dynamics of noise footprints from seismic air gun surveys. Specifically, those analyses revealed several important and mostly ignored spatial and temporal features of the noise fields generated by seismic surveys: a) the original source impulse propagates and is above normal background noise levels out to ranges of many hundreds of kilometers from the source and b) the noise levels for the no-noise time periods between those original impulse events are elevated by as much as 25-30 dB as a result of reverberation and reflections (Guerra et al. 2011). This second example demonstrated how the system could be used to model cumulative influences of shipping noise and a seismic air gun survey on the ocean acoustic environment used by right whales for long-range communication.

In summary, we demonstrated a mechanism that applies a systems approach to the chronic noise paradigm to quantify the spatial, temporal and spectral dynamics for an ocean acoustic environment based on the cumulative contributions of multiple, empirically documented, commercial ships off Boston. When applied to calling right whales those cumulative noise results were converted into An example of how such cumulative noise results can be converted into a biological cost was provided for calling North Atlantic right whales and showed that they lose nearly two-thirds of their opportunities to communicate as a result of communication masking. This same approach can be applied for multiple types of anthropogenic sound sources and for multiple biological contexts.

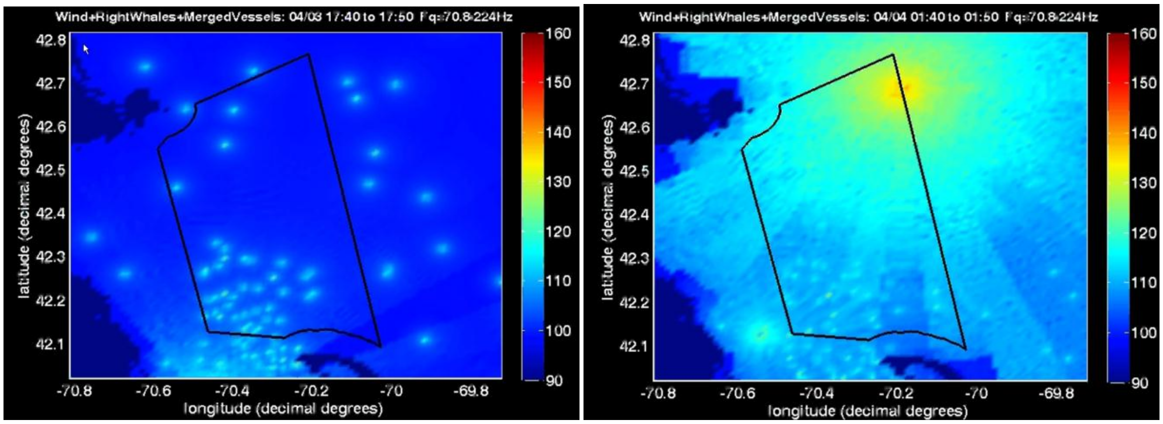

Figure 1. Example of spatial noise field distributions (71-224 Hz, RMS re 1 µPa) during two 10-minute samples for calling North Atlantic right whales without ships (left) and calling North Atlantic right whales with noise from discrete AIS-identified ships (right). Data from NOPP research project Cornell University, NOAA Stellwagen Bank National Marine Sanctuary, and NMFS Service Northeast.

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Population Consequences of Acoustic Disturbance (PCAD): Future Applications

Michael Weise, Office of Naval Research, michael.j.weise@navy.mil

In 2005, the U.S. National Academy of Sciences convened a National Research Council (NRC) committee that examined how marine mammals respond to anthropogenic sound. The committee outlined a conceptual structure for studies of the potential population---level effects of changes in behavior of marine mammals, which they termed population consequences of acoustic disturbance (PCAD). Developments since the committee's report was published, and advances in research that were not considered explicitly by the committee, have made it possible to transform this framework into a more formal set of models.

The Office of Naval Research convened a collaborative group of researchers from 2009 to 2012 to meet regularly to examine the population-level effects of sound exposure and other stressors on marine mammals. The non-exclusive objectives of the group include:

- Explore how the conceptual model developed by the NRC committee might be translated into a formal mathematical structure
- Consider how the above model might be parameterized with existing or emerging data on the responses of large vertebrates to disturbance
- Define conceptual approaches for investigating transfer functions (e.g., time---energy budgets, trait---mediated responses)
- Expand work by the NRC to include sensitivity analyses on different transfer functions

The working group identified the most robust marine mammal datasets available that span a range of taxonomic groups and reproductive strategies (i.e. income vs capital breeders) to be used as case studies to develop and parameterized the quantitative framework. The four case studies were the Northern and Southern Elephant Seals, Coastal Bottlenose Dolphins, North Atlantic Right Whale, and the Beaked Whale. This group first met from 28 September through 1 October 2009, when it developed a model for analyzing energy change during foraging trips by elephant seals (*Mirounga angustirostris* and *M. leonina*) and the effects of this energy change on pup survival. At its second meeting in March 2010 the group began to develop a similar model for coastal populations of bottlenose dolphins (*Tursiops* spp.). The group met again in September 2010 to examine how disturbance might affect northern right whales (*Eubalaena glacialis*) and other baleen whales. At its fourth meeting, in April 2011, the working group developed a similar model for Blainville's beaked whales (*Mesoplodon densirostris*) on the Atlantic Undersea Test and Evaluation Center (AUTEC) range.

Lastly, at the last meeting of the Phase I PCAD working group meeting in October 2011, the working group revisited the PCAD conceptual model following the development of the quantitative framework to see if it reflected our efforts. Based on our efforts over the last three years, we made the following modifications to the PCAD framework and developed a new conceptual PCoD model (Figure 1):

- the developing quantitative framework can be used for any type of disturbance, therefore, we replaced acoustic disturbance with more general or other types of disturbance,
- this framework also encompasses the physiological effects of disturbance (right whale case study), therefore, we expanded the conceptual model to include behavioral and physiological change,
- the original PCAD model had a life function stage was replaced with health or condition of the animal, and subtopics survival and breeding were moved to vital rates and subtopic migration, feeding, nurturing, and response to predator were moved under behavioral response,
- Lastly, the new framework incorporates acute changes in behavioral and physiology that have direct effects on vital rates; whereas, the chronic effects of behavioral and physiological changes directly affect the health or condition of the animal.

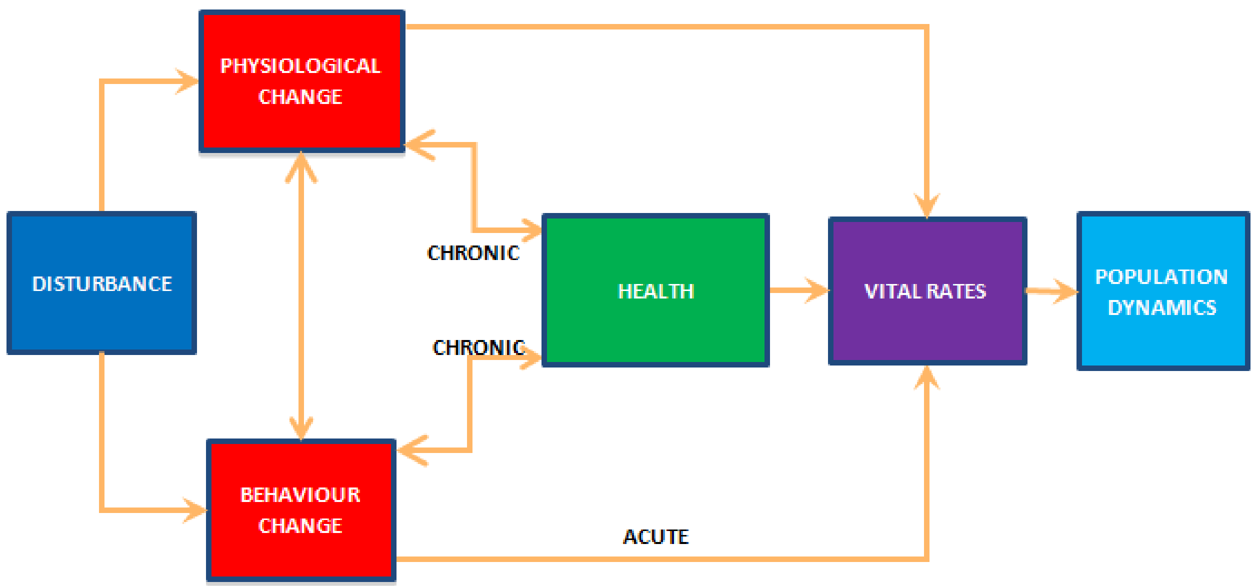


Figure 1. Conceptual model for Population Consequences of Disturbance (PCoD). This model was adapted from the original PCAD model (NRC 2005) based on the input and experience from three years of efforts to develop a quantitative framework to link behavioral and physiological disturbance with population-level consequences.

Modeling nonpoint sources of sound to support acoustic resource management in U. S. National Parks

Kurt Fristrup, Dan Mennitt, and Kirk Sherrill, U. S. National Park Service

The U. S. Environmental Protection Agency uses the term nonpoint source pollution to refer to water and air pollution arising from innumerable distributed sources or spatially continuous sources, often spread across large areas. This term can also apply to sounds: rustling vegetation and raindrops falling on the ocean surface are prominent examples of nonpoint natural sound sources. Anthropogenic noise may also be treated as nonpoint sources when the sources are too numerous or too poorly documented to treat individually. In the marine environment, noise sources near shore are both numerous and difficult to document and characterize. Small boat traffic, harbor traffic, construction, and industrial activity are likely to project significant noise in marine environments near shore.

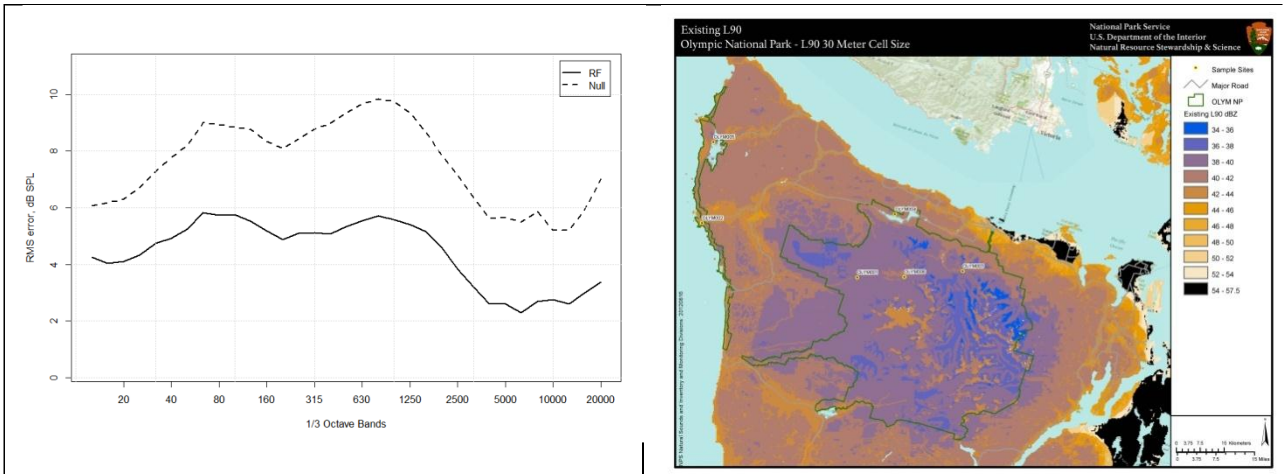
An alternative approach to explicit physical modeling of noise sources and propagation in marine environments near shore is statistical, using geospatial maps of factors likely to correlate with noise production to predict sound levels measured at a wide variety of coastal locations. Many long-term recordings have been collected in shallow water, and the rate of accession is growing rapidly. If several research groups were prepared to share summary measurements extracted from their recordings, then adequate spatial coverage for this kind of model either exists or will be available shortly. In order to demonstrate the feasibility of this approach to sound level mapping, this report summarizes a recent National Park Service (NPS[1]) effort to develop a geospatial sound mapping tool for terrestrial environments.

NPS initiated development of this geospatial sound model for reasons that also apply to National Marine Sanctuaries. Natural sound levels vary spatially, so models are needed to map the capacity of natural environments to effectively mask incoming noise. Protected natural areas experience considerable noise exposure from sources located outside their boundaries, so noise mapping must encompass regional scales. Migratory and nomadic organisms that constitute important components of these protected natural areas spend considerable fractions of their time elsewhere, so management of these species must account for the range of noise exposures that they experience throughout the region. Noise plausibly affects patterns of movement and habitat selection on regional scales. For all of these reasons, there is a clear and immediate need for tools that can noise and natural sound levels across broad spatial scales.

The NPS data offered an extensive spatial data set for testing the feasibility of an empirical geospatial noise model. These data encompassed 270 thousand hours of acoustical monitoring

[1] Ironically, NPS is often used elsewhere to denote NonPoint Source pollution.

from 190 sites located in National Parks across the contiguous United States. The geospatial model relates summary statistics of measured sound pressure levels to explanatory variables such as topography, climate, hydrology and anthropogenic activity. A tree-based machine learning algorithm – Random Forest – was used; it does not incorporate any *a priori* knowledge of source characteristics or acoustic propagation. The next two figures illustrate the accuracy of the resulting geospatial sound model. Figure 1 summarizes the accuracy of the geospatial model and provides a map illustrating its use. The model accuracy of 2-5 dB must be interpreted in the context of the precision of the measurements (ANSI Type 1 sound level meter – 1 dB) and the expected variation in sound level statistics for a 30 day sample from each site, which is on the order of 3 dB. Both the null and fitted standard errors are inflated by outliers from exceptional sites.



a) b)

Figure 1a) The left panel illustrates the standard deviation of the original measurements and the residual error of the 1/3rd octave band Random Forest models – one Random Forest for each spectral band. The right panel shows the predicted map of sound levels for the Olympic Peninsula. The sound level metric fitted by this model was the L90, the sound level exceeded 90 percent of the time. ANSI Standard S12.9-1 recommends the L90 as a measure of the residual or background sound level that remains after the contributions of all identifiable sound sources have been removed.

Figure 1b) Displays the agreement between predicted and measured 1/3rd L90 octave spectra for four sites that illustrate the range of outcomes.

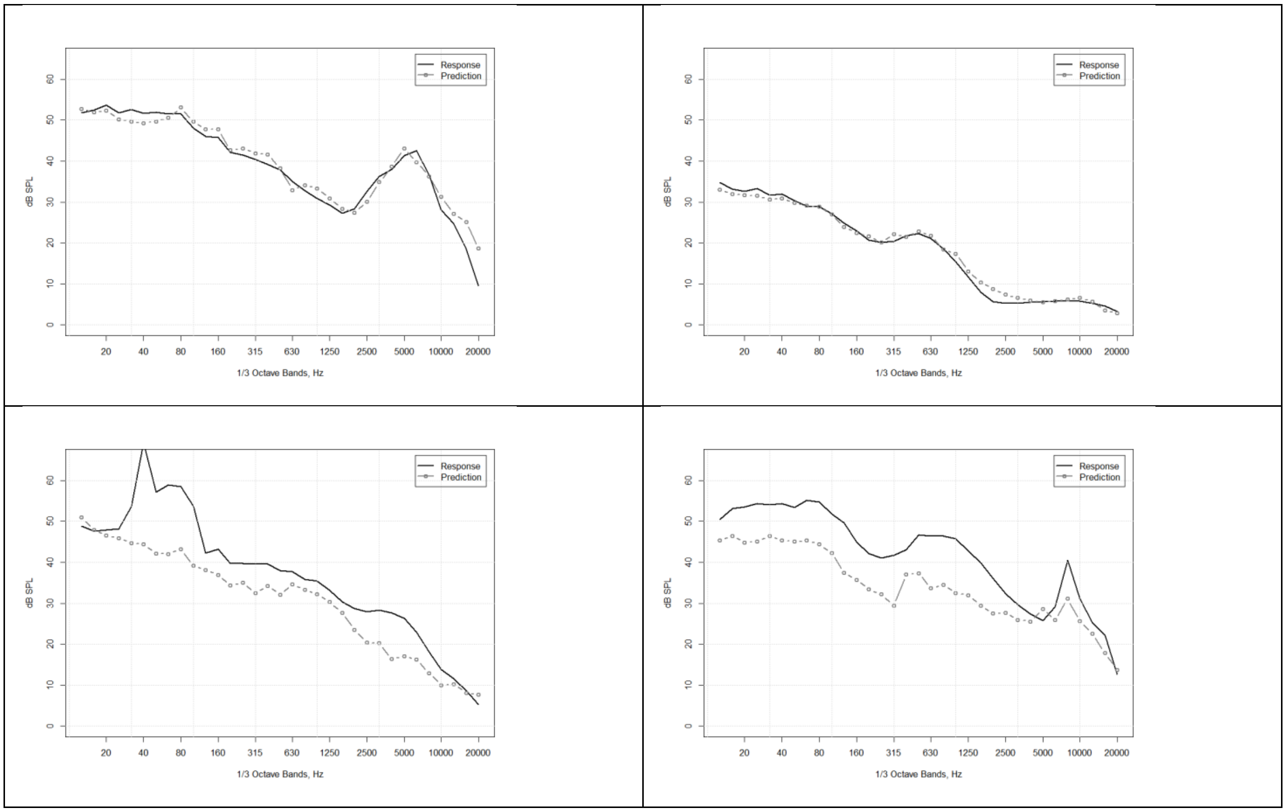


Figure 2. Example comparisons of the response and model prediction spectra. The first row illustrates sites with close agreement between the model and the measurements. The bottom left panel illustrates a site where the model missed a significant source of low frequency noise. The bottom right panel illustrates a site where the model captured the spectral shape, but underestimated the level.

The geospatial model can also provide estimates of the sound levels that would exist in the absence of noise. This is estimated by setting the geospatial variables that represent anthropogenic activity to their minimum values, and predicting the result. Figure 3 illustrates the existing L10 levels – the sound levels that would be exceeded 10 percent of the time – for a section of southwest Utah that encompasses Zion National Park and Cedar Breaks National Monument. It also displays the predicted increase of those levels above natural conditions due to anthropogenic noise.

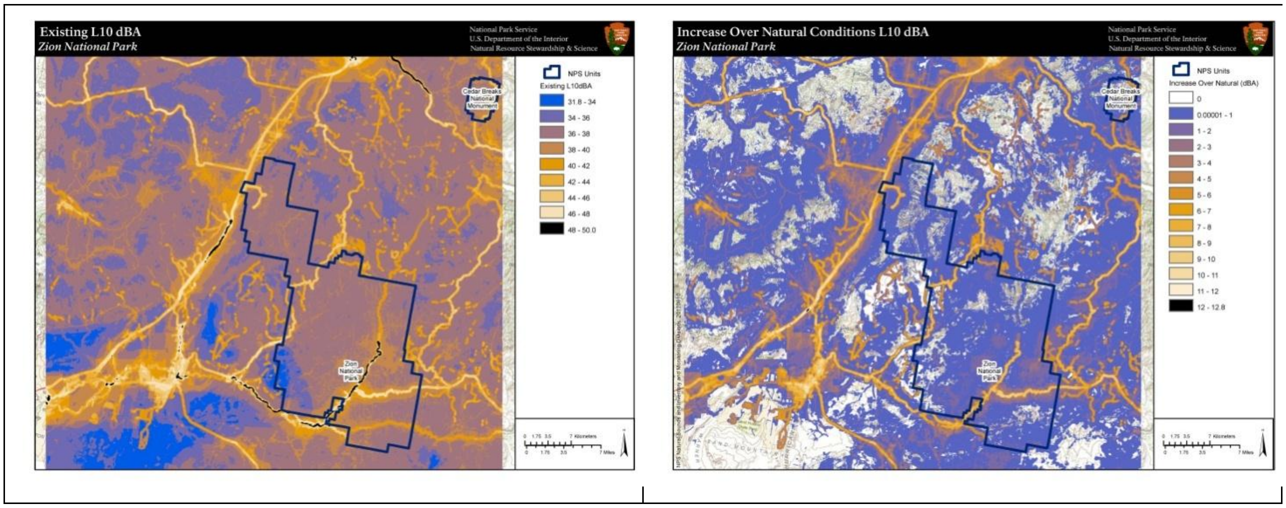


Figure 3. Comparison of the existing L10 sound levels and the predicted increase of those levels above natural conditions due to anthropogenic noise. Natural conditions were estimated by setting the anthropogenic predictor variables to their minimum values.

The success of this NPS geospatial model suggests that an analogous effort for marine noise would be fruitful. This type of empirical geospatial noise model may be the only practical approach to address the innumerable shallow water sources that contribute to marine noise levels. Machine learning tools like Random Forest also offer a promising framework for comparing measured sound levels with the aggregate output of the products developed by the NOAA noise mapping workgroup.

PANELIST DISCUSSION: SUMMARY OF REMARKS

On Day 2, the panel was comprised of the following people: Michael Jasny (Natural Resources Defense Counsel), Bill Streever (British Petroleum), Tim Ragen (Marine Mammal Commission), Kathy Metcalf (Chamber of Shipping of America).

These panelists were invited to provide brief remarks addressing the following question:

How should (or should not) the working group products be applied in management contexts?

1. Applicability for use by Federal managers and a wider range of stakeholders
2. Caveats and limitations
3. Integration with other science-based decision support tools

The panel remarks were followed by a 60-minute discussion with the audience participants, the CetSound working group members, and the panelists. The comments, suggestions and questions highlighted the following topic areas:

- We need to focus attention on the relationship between observed effects and consequences.
- Evaluating behavioral response – it may be informative but may also be misleading, trying to measure behavioral response cannot capture loss of acoustic habitat, and we cannot determine the impact of this loss.
- Ecological traps are well-known in terrestrial systems, where there may be a high density of animals in areas that are not reproductively beneficial for them. What factors will improve our ability to account for animal distribution?
- We need to think about better risk assessment, how we draw the line between industry and marine mammal impacts, how do we look at regulatory issues and scale noise against other known impacts?
- Products from this project are too general, much detail has been lost but the details are behind the results and we need to figure out how to use them to their full potential.

Detailed written opinions were provided by several of the panelists and can be found below.

PANELIST WRITTEN SUMMARIES

Michael Jasny, Director, Marine Mammal Protection Project, NRDC

To begin with, it's worth saying that this has been a remarkable effort, and one that has already exceeded the expectations that those of us in the NGO community have had for it. Not only has it consolidated and advanced the science in ways that could prove enormously useful for marine mammal conservation, but it has done so with brilliant transparency, making it an important resource for the marine mammal community at large. One hopes this effort will have a steady future funding stream – for maintenance, growth, field validation, development of management applications, and, to be a little idealistic, for aid in capacity building in other regions. It seems to me this effort would have substantial justification for help from regulated agencies, given its potential utility in the MMPA and ESA regulatory processes. In this regard, it's worth pointing out that the vast majority of take authorizations issued under the MMPA each year have an acoustic component.

One focus of future effort must be the application of the cetacean and noise-mapping tools to habitat-based management. At least initially, I see two unavoidable questions: (1) Which species do you prioritize for mitigation, and (2) How do you deal with data gaps for those species that are relevant to management decisions (e.g., seasonal gaps or inadequate resolution in the data)? As to the first, Dr. Liz Alter, while an NRDC fellow, developed a vulnerability algorithm for determining focal species: basically a scoring matrix taking into account factors like site fidelity, growth rate, minimum abundance, and frequency-specific sensitivity. We can offer that as a starting point.

For sector-based mitigation, the cetacean maps and models are providing data for one part of the equation. The other part of the equation is user need. To my mind, the best alternatives analysis that any party has conducted for any acoustic activity must surely be NAVFAC's alternatives analysis for the Navy's 2009-2014 Atlantic Fleet Active Sonar Training EIS. Even though the CNO ultimately abandoned that analysis, it was not for lack of quality: NAVFAC's alternatives were an inventive, well-informed integration of predictive habitat-density modeling and specific operational need. That kind of development on the "need" side is essential, especially for programmatic NEPA compliance. It would be unfortunate to spend so much effort development the CetMaps, and not obtain commitment from other action agencies, particularly the Navy and BOEM, to integrate operational data into the management equation.

For multi-sector or species/habitat-focused mitigation, it will be necessary to establish meaningful, scalable conservation goals. On this score, I would recommend consulting Agardy et al. 2007, *i.e.*, the report of the first workshop organized by the Okeanos Foundation, on spatial-temporal mitigation of noise-generating activities, which suggests an adaptive, Bayesian methodology for identifying would-be protected areas. It will also be necessary to find a regulatory vehicle for accomplishing cumulative impact mitigation beyond a single activity. Optimally you'd want comprehensive statutory or regulatory authority, like the MMPA's commercial fishing regulations, or you'd want something like the EU's Marine Strategy

Framework Directive, which sets conservation targets but doesn't prescribe how they are to be accomplished with the EU's federal system; but you have to work with what you have. One vehicle for endangered species – particularly species like the North Atlantic right whale for which noise is a significant concern – may be recovery plans under ESA, although recovery plans do not in themselves create any binding obligations. Another may be the Commerce Secretary's general regulatory authority under the MMPA.

Kathy Metcalf, Chamber Shipping of America

Kathy Metcalf, Chamber of Shipping of America (CSA), discussed the history of CSA involvement with the issues of ship strike mitigation and noise from commercial vessels. She noted that CSA was involved from the outset in discussions relating to ship strike mitigation management on the East Coast of the US relative to the North Atlantic Right Whale which led up to the finalization of regulations mandating reporting and speed restrictions in seasonal management areas. She also indicated that CSA was and continues to be active in "getting the word out" as to what is required in these areas as well as why it is necessary. She also noted that CSA participated as a member of the Joint Working Group for the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries which was charged with evaluating potential management strategies for the reduction of ship strikes and noise in the approaches to San Francisco Bay. A report of the JWG was presented to the sanctuary advisory councils in early June. Finally she outlined CSA's work with various delegations to the International Maritime Organization's Marine Environment Protection Committee which has agreed to place commercial shipping noise on its agenda. The issue has been referred to the Design and Equipment Subcommittee for further work towards the development of ship quieting guidelines for new vessels.

Noting this extensive history of involvement with these issues, she indicated that the single most important piece of the solution to these important issues was the need for adequate spatial and temporal data to justify possible management strategies, a piece which is usually missing at least early on in the deliberations on these issues. She indicated that CSA welcomes the cetacean and sound mapping efforts and work products discussed at the conference and sees them as critical tools in designing rational and effective management strategies which ultimately benefits the marine environment and its resources while still facilitating the orderly flow of maritime trade to and from the United States. Equally as important are the use of these tools to illustrate to the maritime industry that certain strategies and potentially negative impacts are necessary for the protection of the marine environment and that such strategies will have been decided based on good science and sufficient data.

Tim Ragen, Marine Mammal Commission

Utility of the cetacean and sound mapping tools

The products of the cetacean and sound mapping working groups have great potential value to the scientific study, management, and conservation of cetaceans and marine ecosystems. Those products compile and integrate large amounts of data on the distribution of cetaceans and human-generated sound and, in doing so, provide an important spatial and temporal context for assessing exposure of cetaceans to sound.

Strengths: Science is a process of identifying, characterizing, and understanding patterns. The strengths of the cetacean information lie largely in the integration of data from multiple sources and pertaining to multiple species to indicate habitat use patterns, including such things as feeding and reproductive areas and migratory corridors. When taken together, they indicate potential biological hotspots, or areas that are of biological importance to multiple species. Conversely, they also may indicate areas of less value to cetaceans or areas where more surveys are needed (i.e., research gaps).

The strengths of the sound data also lie in the integration of large amounts of data to project sound levels throughout ocean basins. Such information may be of considerable value in describing the salient features of marine soundscapes, their changes over time, and potential effects on cetaceans. The sound data almost certainly will provide important guidance for management of sound sources over space and time.

Both types of data also may apply to other types of management challenges involving other risk factors (climate disruption). In addition, the products of both working groups provide a useful model for collaboration among scientists with varying types of expertise and from varied agencies and organizations. As demonstrated in the workshop, such collaboration has the potential to produce results that exceed those of any single individual or group.

Further strengthening: The scientific process is not simply an accumulation and depiction of data. With regard to the cetacean data, users must be informed about and cognizant of the limitations of the data they are using. To that end, contributors of cetacean information must provide clear and comprehensive descriptions of their data, the manner in which they were collected, and the assumptions involved in their collection, analysis, and reporting. Peer-review and publication are intended to assess scientific rigor and contributors should include information regarding whether their data and analytical results have been peer-reviewed and published. Indeed, all elements of the scientific process are designed to provide a basis for confidence that data were collected and analyzed in an unbiased and objective manner. These elements are equally important to the development and use of these mapping tools.

With regard to the sound data, similar constraints and considerations apply. Modelers must describe the sources of their data, the methods used to integrate and project sound over time and space, and the error associated with such projections. Model verification involves assessment of the soundness of model structure and processes, whereas validation involves assessment of the model results compared to some standard (preferably actual sound measurements). Both processes are vital as the utility of the sound mapping results depends largely on model soundness and accuracy.

Finally, if the purpose of this effort is to determine the impacts of human-generated sound on cetaceans, then it must be expanded by adding a third component dealing with cetacean responses. In some important respects, the mapping efforts fall within a category of studies referred to as stimulus-response. In essence, the mapping products help characterize the stimulus only. For animals as complex as marine mammals, the response will vary as a function of a number of variables in addition to sound level (e.g., species, age, gender, physiological state, experience, environmental conditions, various other sound characteristics). Understanding responses will require study of a variety of topics, particularly physiology and behavior. When feasible, behavioral response studies can be particularly useful in describing potential sublethal effects of exposure to sound.

Availability of data

In almost any scientific context, data are, or should be, neutral. Certain exceptions are or might be made for security reasons. However, the products of the cetacean and sound mapping working groups are not an exception to this rule. With that in mind, all potential users should have access to the data and work products discussed in the meeting. In addition, some screening process must have been used to determine which data are included in the mapping databases. The criteria used in the screening process should be described.

Accomplishments of the working groups

The most useful accomplishments of the cetacean and sound working groups are that they have developed tools to (1) aggregate data from multiple sources to create a broad, synthetic assessment of cetacean distributions and (2) project low –frequency sound levels on ocean basin scales. These tools enable action and regulating agencies, industries, conservationists, and concerned stakeholders to better understand the potential effects of human-generated sound on marine ecosystems. The tools can be made readily available to interested parties, provide a broad context for understanding sound effects, and provide a useful guide for future research efforts aimed at understanding and regulating the effects of sound as well as the effects of other human activities.

Qualifiers for use of the mapping tools

The primary qualifiers for the working group products are, or should be, those that apply to any scientific endeavor. To use and draw conclusions from the data, users must take into account the data's strengths and limitations. Data and analyses should be thoroughly described and transparent and analytical procedures reproducible. The date of data collection will be particularly important because many marine ecosystems are changing rapidly. Maximizing the data's value will require integration with information on the behavioral ecology of the species involved and the pertinent environmental conditions.

Integration and application of the mapping tools and data

The cetacean and sound mapping working groups should continue their efforts. Whenever possible, their products should be integrated with those of related efforts. The sound and cetacean mapping products are potentially very valuable for looking at overlap of multiple risk factors and marine mammal populations over time or space. Presentations at the workshop demonstrated the utility of the data for identifying areas where sound overlaps with other risk factors to create potentially significant cumulative effects. The working group products also should be helpful for assessing areas where sound levels are unacceptably high, as well as areas where sound levels are lower and therefore additional sound may be more tolerable. When integrated with efforts to characterize the population consequences of acoustic disturbance, cetacean and sound mapping may provide insights into sound effects on vital rates and population status that are otherwise very difficult to detect with the current set of scientific tools and methods. And clearly, cetacean and sound mapping products could be invaluable for guiding coastal/marine spatial planning exercises.

Bill Streever, British Petroleum

Q1. Applicability for use by Federal managers and a wider range of stakeholders.

CetMap, once it is fully populated and if it is maintained, will provide an excellent starting point for anyone trying to inventory cetaceans present in different regions. For example, it could be an excellent starting point for stakeholders preparing requests for take authorizations under the Marine Mammal Protection Act.

The SFWG tool may be useful as an educational tool capable of leaving decision makers (for example, congressional staffers) with a general impression of relative anthropogenic sound levels around the United States. However, it will only be valuable for leaving a general impression and, as it currently exists, will have little applicability for applied management problems. With significant additional development that would allow it to move beyond information about average sound levels over larger areas, and that would allow it to assess ways in which aggregate sound is experienced by animals passing through a particular region, it could contribute to addressing key questions about cumulative effects.

Q2. Caveats and limitations.

As noted elsewhere, CetMap only includes cetaceans, and many Federal managers and other stakeholders will need information on all marine mammals. Also, without a scheduled maintenance program, CetMap will be out of date and increasingly unusable over time.

The SFWG tool is an excellent first step toward an improved understanding of seascape-level acoustic footprints. However, because it currently relies on a Leq metric based on a limited number of frequency or one-third octave bands averaged over time, it will have little use as a tool for determining, even in a very rough sense, acoustic conditions experienced by the animals themselves. Importantly, it will have a very limited ability to identify gains made from key mitigation methods that are in use or could be in use in the future. For example:

- Because the SFWG tool averages across time, it may not readily identify differences in potential impacts from two projects, one designed to operate in periods before migrating whales arrive in a particular area and another designed to operate during the peak migration period.
- The SFWG tool will not identify differences in acoustic conditions experienced by animals exposed to operations that shut down when animals are seen within an exclusion zone and a project that does not shut down for animals inside of an exclusion zone.
- The SFWG tool may have a limited ability to illustrate the benefits of proposed methods to reduce peak sound pressure levels that rely on marine vibrators as an alternative to conventional air gun arrays. The SFWG tool developers should be encouraged to compare hypothetical marine vibrators and air gun arrays that produce comparable sound energy, with and without the assumption that marine vibrators will successfully eliminate frequencies above about 150 Hz, to assess the tool's sensitivity.

<u>Q3. Integration with other science-based decision support tools.</u>

Both tools could be to some degree integrated, at least in terms of user accessibility, through a website portal with links to other related tools, such as:

- The Acoustic Propagation Visualizer developed by Marine Acoustics, Inc. on behalf of the government.
- The Cornell library of marine mammal sounds.
- The PAMGuard site.
- The DOSITS site.

BREAKOUT GROUP DISCUSSIONS: OVERVIEW

At the close of the workshop on Day 2, participants were divided into groups of approximately 5-8 people. Two groups were each asked to address in writing one of several questions. The questions and summarized responses from each the participants are listed below.

QUESTION 1: In the context of the management frameworks summarized on Day 1 (ESA, MMPA , NEPA, and Ocean Planning), describe the top two or three most valuable immediate uses for each of the working group products (CetMap and SFWG) and for an integration of the two.

Most valuable immediate uses for CetMap products:

- Providing current, consolidated, agree-upon density data for compliance applications.
- Identifying data gaps to help focus survey efforts or identify areas that require additional monitoring.
- Using the existing model as a framework for integrating additional data sources, specifically identifying the specifications (metadata) needed for integrating data, and how agencies can organize their data for efficient integration
- Using the tool for ocean planning in region where a future/ proposed activity is planned, and for performing alternative analysis under NEPA (i.e., adjust planning after looking at the density/ area of importance/ seasonality in regions where there is flexibility in operations/ proposed activity).
- Improving current analyses that exist for mitigation, specifically updating density estimates

Most valuable immediate uses for the SoundMap products:

One group felt that although they could see the direction and potential benefits of the sound field mapping tool, they did not see any immediate use within current management frameworks. However, both groups highlighted some potential future uses:

- Potential for use in the discussion of cumulative effects of noise on marine life, and for putting the acute noise in the context of chronic noise sources . However, there is concern about the differing scales and what specific acoustic analyses would be appropriate (e.g. depth, frequency, etc).
- Potential initial tool for ocean planning to provide data on ambient noise and for inclusion into cumulative analysis for NEPA documents to help characterize the environment.
- Potential use in forecasting, and scenario building
- Template for future modeling by providing examples with detailed description of data sets used for the model.

Integration of the tools:
Both groups saw the integration of the tools as difficult, and although the potential exists, the tools were considered not yet ready for immediate use within a management framework. Their suggestions included:

- Using one specific example, such as the Arctic region, to work out tool integration.
- Assure the overlay of cetacean and sound data on common scales
- Adding sound fields attributed to other anthropogenic sources and cetaceans
- Using the noise map as a variable in the habitat predicting model

Some final thoughts:
These tools need to be living efforts, meaning that those using the data for management need to have access to the models in near real-time so important updates (i.e., new data sources) can be incorporated into the management framework. Coordination between agencies for planning and mapping of different human activities, not just the species and noise, is very important.

QUESTION 2: For each of the working group products (CetMap and SFWG) in their current form, please describe the most important two or three caveats /cautions that should be explicitly considered when applying these products in a management context and what measures could be taken to overcome these caveats limitations.

Overall Suggestions:

- Simple and clear documentation of data limitations and caveats associated with each of the products should be available to the user, independently from the information available in the metadata. This could take the form of a pop-up descriptive document for each region.
- A process (and associated institutional support) needs to be established to update both the data sources and the products as new information becomes available, and this needs to be clearly detailed on the website.

Caveats for CetMap products:
For use of data in a regulatory context, and for user to be able to effectively compare data between regions, the following suggestions were highlighted:

- Uncertainty and limitations regarding underlying datasets need to be acknowledged/ elevated on the website, including limitations regarding geographic areas surveyed, seasonality, and data collection methods. If the quality of data for particular species varies between regions, this should be apparent to the user.
- Data are currently broken down by species, but regulators often need stock-level information.
- Website presentation needs to be improved so that users know which tiers can be used to calculate abundance.

- Information needs to be clearly provided regarding data controls, integration of multiple datasets, and compatibility with other data sets.
- Information on program management, the status of long-term funding, and the future of the program should be explicitly addressed.
- Documentation for the BIA is also critical, and designated important areas should be available for download as shapefiles. Given that these may be interpreted as "exclusion" or "high use" zones, it is important to effectively document the rational and data underlying the areas.

Additional suggestions for future improvement include:

- Consideration should be given to incorporating additional information beyond density values to better characterize the ecological use of habitats by different species. This information could be incorporate as additional data layers, including life-history characteristics or behavior (e.g. feeding, breeding,etc).

Caveats for SoundMap products:

- Effective documentation is needed on data quality and limitations. There are well known limitations to the quality of the data. With the VOS data, for example, tracks are interpolated. With the sediment data, there are some regions of the globe that are very well surveyed, while the data may be weaker in other places.
- It was recognized that there may be other and better data sources (particularly within specific regions), but that some of these data are not accessible or have limitations on use.
- This group also recognized the symposiums concern over the specific noise metric used. The challenge with these metrics is that the most appropriate metric is often determined by the question being asked; and, therefore this is an area where user feedback will be critical.
- It is also important to document how models with be standardized, including data input and output.
- Models need to be updated with empirical data.

QUESTION 3: Please recommend 2 or 3 specific mechanisms for securing the regular maintenance (and needed improvement) of these working group products to ensure their continued utility for Federal managers and the public (e.g., money, staffing, timing of updates, synergies with other supported efforts).

- Someone needs to take ownership.
  - Who owns this and is responsible for the long-term maintenance? Several alternatives were identified as possible options.

- Who can provide intellectual guidance? A mixed agency group (NOAA, BOEM, Navy, MMC, etc) could be established, but staff participation needs to recognized through performance plans.

- Expanding involvement (productive partners), federal partnerships: formalizing long-term structure
  - Strategic planning and the establishment of goals is very important, including a mission statement, a business plan

- Regularize the data flow and commitments so that it is not an extraordinary process to do this one time thing
  - The expectation is that the next generation of surveys, models, etc will be input.
  - The data stream needs to be defined, for example:
    - Data acquisition program: Duke would be face-to-face with researchers to get the data: V&V process, software updates
    - Data products would pass to NOAA S&T to keep database and do the day-to-day maintenance,
    - A steering committee that would work with innovative, R&D product/tool/application development; have an educational outreach subcommittee: new tools

- Develop mechanisms to secure future funding, for long-term stability

QUESTION 4: Within the bounds of the initial CetMap and SFWG efforts, describe two or three technical improvements that should be prioritized in order to better address (e.g., increase accuracy or reduce uncertainty) the management issues discussed at this symposium and provide a specific recommendation of how to implement these improvements for each (e.g., spatial, temporal or spectral scales; output metrics chosen).

Overall Technical Improvements:
Both groups identified a number of changes that would improve the overall utility of the CetMap and SFWG tools. One group stressed that these improvements will require a firm commitment of future funding and personnel resources, including the maintenance of the two working groups.

Their suggestions including the following:

- In any form of public interface there should be a plain language “primer” screen that explains the nature and origin of any of the data and provides any necessary caveats about its potential inappropriate interpretation use. This is currently done to some extent in the one-page info screens but the group felt that these are too technical for a general public. A specific caveat would be that some of the event layers are wholly specific to a particular year and season.

- Ensure that the time scale of applicability / averaging of any of the data products presented to the user is clearly specified as part of the graphical map or layer, so that correct conclusions are drawn about any overlaps between sound and cetacean layers.
- In a future interactive interface, the user should be able to sample the underlying databases (both SoundMap and CetMap) at any desired time and duration period so that temporally compatible information can be extracted. This will allow meaningful correlation of data where the time scales are important. In the Beaufort, for example, industry tries to run all seismic surveys in the earliest possible part of the open water season, before the incoming migration of cetaceans. If sound and cetacean density data are presented on a seasonal scale, this fact is missed entirely.
- Information about temporal variability of any time averaged data (whether sound or cetaceans map layer) should be made available to the user, for example as a standard deviation. More broadly, other forms of uncertainty (computational, parametric etc.) should also be presented so that the values are not taken in absolute.
- Metadata and accuracy details need to be provided for sound models.
- Provide a single 'best' density product for each cetacean stock and identify those that are ESA-listed.
- Allow overlays of multiple products
- Additional information should be included, such as ocean sound sources (for sound models), and diving behavior and hearing sensitivity ranges.

Additional specific suggestions for CetMap include:

- Would be most useful to have one single 'best' for each species or stock
- Separate stocks (by name, indicate ESA-listed stock); use consistent naming convention for files/species/stocks.
- OBIS data – would be useful to be able to get more detailed information on precise dates and sources of shown observations points.
- Different symbols for different types of data on observation plots
- Include on website links to information on sound sensitivity ranges (low, medium, high) and diving depths of marine mammals.
- Expand to include pinnipeds (and other marine mammals)
- Areas of Importance
    - Conduct additional peer-review to support end-user buy-in
    - Allow on-line visualization of areas of importance along-side density (menu of overlays to check?)

Additional specific suggestions for SoundMap include:

- In the SoundMap product, Leq over a fixed time period (e.g. a year or a season) was not considered to be an appropriate metric for all uses. The scale of time averaging should be adaptable to the activity of relevance. If the maps are not interactive, the time scale of applicability should be clearly specified in the presentation of the data.

- Incorporate other METOC (meteorological and oceanographic data) sound models (e.g. wind from weather buoys, scatterometer, ice cracking noise, passive acoustic data collected by industry and others [e.g. Conoco Phillips buoys in Arctic]).
- Need for metadata. Characterize uncertainty and sound sources included in sound layers explicitly (e.g. add statement "Accurate to within *n* db" or "This area includes only global shipping and passenger vessels") – Could implement this through metadata showing sound sources, accuracy, assumptions, years, etc.
- Some end-users will use their own sound mapping products
- On a longer-term basis, the group noted the value of implementing an on-line sound field forecasting tool where users can input the source level properties of a geographic distribution of activities and have a propagated sound layer generated "on the fly" over any desired spatial scale. This clearly is beyond the current status of the tool.

QUESTION 5: Using your understanding of the modeling and methods used in the CetMap and USFWG efforts, and referencing the presentations and demonstrations of the maps and interfaces used to convey these products, describe two or three additional visualization techniques, for both working group products, that would significantly improve the utility of the products for Federal managers or the public.

The top priorities that were identified were:

- Visualizing uncertainty: oblique views of data with error shown as negative/positive thickness or height. Side-by-side views of model outputs vs error surfaces. Moving windows showing modeled values, error values, and sources of error (low number of observations, poor correlation with environmental variables).
- Visualizing multiple species for the same model, or multiple data sets for the same model and species; sound layers at multiple depths for a given frequency. More like a GIS capability?
- Visualizing time: animate data over time
- Visualizing multiple depth/frequency layers

QUESTION 6: Describe the two or three most important potential expansions of both working group products outside of the bounds of the original CetMap and SFWG efforts (e.g., add consideration of pinnipeds or fish in Cetmap, expand SFWG to additional areas, etc.) and include a brief description of why these expansions are important.

Two groups worked together to compile the following recommendations.

The most important expansions identified for the CetMap effort were:

- **Provide "best practice" guidelines** for a common standard for data collection and submission to CetMap. This could be accomplished through the formation of another working group. This group should determine a grade structure for new data (e.g. peer review), and explicitly define the categorization of data quality.
- **Incorporate density estimates from photo-ID datasets.** This would involve acquiring spatially explicit capture data from photo-ID.
- **Find a method for dealing with variance or uncertainty.** This group noted that there are well-established methods for defining the variance associated with density estimates.

The most important expansions identified for the SoundMap effort were:

- **Explicitly state the assumptions of vessel acoustic characteristics.** This group noted that noise is related to ship speed and other characteristics. They recommended including more types of vessels, and parsing out vessel acoustic information more carefully based on speed.
- **Export the uncertainty of noise estimates.** As with CetMap data, it is suggested to display the variance within the acoustic data layers.

QUESTION 7: In the context of the management frameworks summarized on Day 1 (ESA, MMPA, NEPA, Ocean Planning), describe two or three potential valuable applications of these CetMap and USFWG products (either integrated with each other or independently) that were not discussed at the Symposium.

This group identified three main applications that they felt important to highlight or reiterate, though given the background of the members in their group, they found it challenging to link these explicitly to management frameworks.

- **Relating to Climate Change**s - These tools can be used for monitoring/investigating changes related to climate change; CetMap with regard to changes in cetacean behavioral ecology; SFWG with regard to changes in sound transmission with changes in ocean heat & acidity. These products that are static when used over time and with Oceanography at regional scales could be useful for investigation of impact of climate change. Under ESA climate change a major issue. (How exactly, needs to be articulated). We wanted to reiterate this point that was made by Bill Ellison earlier.

- **Integration with Observation Systems** - Consider these tools and try and integrate them with Ocean Observing Systems – get recorders on moorings, to help not just detection of animals but also monitoring of sound and ambient noise. Products from this could be extend the use of data from OS and be linked with tool development of the broader ocean observing effort. These tools are not widely known to other oceanographers and ocean observation community. OS can also help new information coming in and linked to these products (CetMap and Sound mapping) and so would facilitate data exchange and streaming new data in and keeping products updated.

- **Outreach and Public Education** – These tools can inform public and policy makers to create awareness and grasp that noise is an important consideration. Informing that portion of the public that does not have a clue about ocean noise pollution. Halpern map shows that no part of the ocean pristine, used to about chemical pollutants, but not noise pollution. Animations are a creative part of communicating (sun on right whales) and could be used to create more public awareness on this issue.

- **Gap analysis** - will become part of the effort

These applications have various intersections with management frameworks, how exactly these specifically relate to these statues still need more definition.

QUESTION 8: Assuming the availability of tools that allow managers/users to accurately predict the presence, density, distribution, and behavioral context of marine mammals and other marine wildlife, as well as the spectrally-discrete distribution of anthropogenic sound, both over large spatial and long temporal scales: What are the benefits and challenges of setting "managing quiet places of importance within US waters" as the conservation goal?

- Quiet for quiet's sake does not make sense. Choose the primary resource preservation or restoration goals, and focus effort to achieve the greatest gains.
    - Restoration could be more critical than preservation of lesser disturbed sites, because human impacts are plausibly concentrated in locations that were formerly highly productive and biologically crucial.
    - Preserving quiet places should not be given precedence over restoring degraded areas.
    - Should we put noisy activities in places that are already heavily disturbed.
        - Not if there are still are animals there, because the location could be on the margin.
        - Locations have naturally high background sound levels are plausibly less sensitive.
    - Decide what is important in terms of uses, decide what is important in terms of biological resources: joint prioritization.
- How do we assess changes in noise levels on top of a substantial current baseline.
    - Problem of asserting that presence of animals testifies to lack of impact.
    - Need an historical perspective, because current distributions may not accurately represent habitat preferences (abandoned gray whale breeding lagoon).

- Failure to leave a bad habitat could represent lack of options or ecological traps.
- Are cetaceans that occur in high levels of natural sound are more tolerant of anthropogenic noise?
- Challenge if identifying historical reference, identifying desired future condition, and reconciling these with current conditions and proposed uses.

- Sanctuaries can be designated to protect a variety of resources.
  - Management priorities must derive from foundation documents (including establishing legislation).
  - Difficult of dealing with multiple uses, and addressing noise within that context.
  - Challenge as a sanctuaries manager is dealing with each action on a project by project basis, even though impacts are closely related and cumulative effects trigger rejection of a project.
  - Could sanctuaries set an overall budget, and then allocate portions of that budget to each project (market-based solution?). Common pool resource management approach seems promising (Elinor Ostrom).
  - Regulation can promote innovation.
  - Is first come, first serve the appropriate way to allocate allowable environmental impacts (water rights in the west).
  - Need to explicitly address the opportunity costs of regulation – inherent in economic impacts in a NEPA analysis. Much larger issue, outside the scope of this symposium.
- Adaptive management with shorter permitting periods, conditional revisions, and the like will be required to address sequential nature of permit requests and balance.
  - Recognize the importance of advance studies and monitoring – with controls – in advance of each action, to document the change that results.
  - Overall management of aggregate impacts: Budgets – how will this symposium's products and other science support development of thresholds that trigger management action.
  - How do we equip field personnel with tools to monitor and enforce regulations?
  - Fishing is an example of an adaptively managed environmental impact.
  - Permitting is in place for exceptions to regulations, but sound is only considered through consultation in Sanctuaries (not enforceable).
- Local management of noise does not seem practical.
  - Distances are simpler and more readily accepted criteria
  - Sound levels are more complicated, and have only been addressed through consultation.
- Could this project generate impact assessment frameworks that plausibly generalize across species?
- Biologically important areas are the most problematic part of the symposium's products, so investing substantial effort to defend those places is doubly problematic.
  - Assessing the importance of hearing and the functional significance of frequency bands for each species should play into the impact assessment.

- Marine mammal maps could be integrated to develop sensitivity indices in terms of density, diversity, and plausible vulnerability.
    - This would require a temporal dimension
  - Marine mammals are a small portion of the ecosystem that is under management.
- Recognize the practical concern that making progress on achievable actions rather than tackling the critical and controversial issues.
- It is important to announce conservation goals independent from and – where possible – in advance of proposed actions to avoid perceptions that priorities do not represent cryptic opposition to projects.
- Mindful communication strategies are crucial
  - It is incredible that the sponsors and participants in this symposium have come together, and done so much to identify shared interests. Sustaining this kind of effort will be crucial to continued progress in building the tools and successful implementation.
  - Public education is crucial, to help citizens and politicians develop an informed foundation for their opinions and decisions.
  - Educating congressional members and staff should receive special attention. Visual tools convey rich data in a more evocative way. Focus on telling a compelling and memorable story that provokes lasting interest, rather than presenting a more complete outline.
  - Successful demonstrations of these tools in a management context would be persuasive in making a good case for legislative and broad agency action

QUESTION 9: Assuming the availability of tools that allow managers/users to accurately predict the presence, density, distribution, and behavioral context of marine mammals, as well as the spectrally-discrete distribution of anthropogenic sound AND additional geospatial knowledge of other types of wide-ranging and chronic impacts faced by marine mammals (e.g. chemical pollution, fishing gear, large and/or fast-moving ships, predicted shifts in prey distribution due to climate change): What are the benefits and challenges of setting "minimize cumulative impacts to discrete marine mammal populations/stocks within US waters from multiple chronic stressors, including noise" as the conservation goal?

The most important idea: Have to disaggregate stressors.

Key assumptions

- Don't know how stressors are interacting with each other
- Assuming perfect knowledge of
  - sound
  - other stressors, and
  - marine mammal density, distribution and behavior

- Assuming stress translates into impact on populations

Benefits

- Examining interactions give us a more holistic view of overall stress to the animals
- Would ostensibly be more effective in terms of achieving conservation goals than regulating individually

Challenges

- Finding the boundaries of the problem – so many different combinations
- How do we weigh different factors?
- Would all species respond in the same way to a given stress?
- What is unit of measurement? How do we measure response?
    - Ultimately population size?
- Need environmental baseline as well as current conditions, and anticipate the future
- How do you regulate unless you know the relative contributions of each factor?
- Have to have solid ways to regulate each stressor
    - Issues of equity – some stressors may be easier to regulate than others
    - There will never be a time when we have perfect knowledge
    - Difficulty defining what it means to "minimize" – isn't zero the minimal?

QUESTION 10: Assuming the availability of ecosystem-scale data that allow managers/users to accurately predict the presence, density, and distribution of marine wildlife, their relationships to their physical environments and to each other, as well as the spectrally-discrete distribution of anthropogenic sound AND additional geospatial knowledge of other human-induced impacts: What are the benefits and challenges of setting "minimize cumulative impacts to ecosystems from multiple chronic stressors, including noise" as the conservation goal?

One group summarized the benefits and challenges according to the table below:

BENEFITS	CHALLENGES
• Proactively address the competitive issues between various stakeholders, reveal true tradeoffs	• (Can be a challenge too.)
• Baseline for assessing climate change impacts (esp. via CetMap models)	• How to deal with lack of data / information when needing to weigh the different stressors

• Facilitate stakeholder process and buy-in	• Taking the sector by sector comparisons and comparing them with each other to come up with the best solution – potentially unwieldy with many sectors
• Make more efficient decisions that maximize ecosystem value, identifying potential win-wins	• Bounding the “ecosystem-scale” area
• More people less unhappy more of the time	• Data availability (scale/resolution) to support an equal weighting of conservation values in comparison to economic costs associated with other ecosystem services
• Transparency	• Cultural differences in social preferences or values for different ecosystem services may lead to different levels of protection in different areas unless there is a broader mandate or target set
• Ecosystem less degraded, better protected, potential target for restoration	• Identifying key stressors and understanding their effects
• Some benefits are to areas outside of the defined planning area	• Quantifying benefits to outside areas is a challenge
• Reduce regulatory necessity and litigation	• Lack of existing or adequate structures to support the necessary multi-sectoral stakeholder processes
• Application to fine-scale area-based management processes	• Once thresholds are set how do you quantify there efficacy and success of the predicted conservation benefit
• Very helpful for addressing discrete situations in a defined space	•

CONCLUSIONS & RECOMMENDATIONS

The Mapping Cetaceans and Sound Symposium provided an open and positive forum to share SoundMap and CetMap Working Group products and brainstorm potential management solutions with participants from a wide range of engaged constituencies. The effort received broad support for both the work conducted and the open process.

While acknowledging the work that remains to be done, the SoundMap products were lauded as a ground-breaking first step in the effort to quantitatively characterize chronic and cumulative noise across large spatial and long temporal scales. The CetMap products built on a large body of existing cetacean density and distribution data, and then compiled and organized both existing and new data into a data discovery tool that facilitates effective use by both regulators, noise producers, and the public. Participants (Federal, non-Federal, and international) emphatically supported the need to continue to move forward in the maintenance and development of the SoundMap and CetMap tools.

The symposium planners created multiple mechanisms for participants to provide technical input on the Working Group tools, both during and after the Symposium. Participants were particularly appreciative of dialog focused on how the SoundMap and CetMap tools could potentially be applied in management decisions, through panelist presentations, facilitated discussion, and breakout groups.

Based on the feedback received during and since the Symposium, we have identified the following broad recommendations to support the continued development of the CetSound tools and their application to managing the impacts of ocean noise on cetaceans across broad spatial and temporal scales:

1. Institutionalization of the CetSound Effort within NOAA. In order to ensure the maintenance and continued development of the CetSound tools for NOAA and public use, NOAA leadership and line-office leadership must be fully engaged. Specifically:
    a. NOAA leadership should be further briefed and their input solicited in support of long-term effort
    b. Appropriate cross line office policy and science leadership and staff should be formally designated to direct the continuing effort , and
    c. Technical staff and the necessary infrastructure should be secured to ensure a reliable and flexible platform for the archiving, presenting, and analyzing evolving data products.
2. Integration of CetSound Effort with NOAA-wide Goals and Programs. CetSound staff must engage with multiple NOAA offices and programs to ensure continued integration of CetSound effort and products with broad NOAA conservation priorities and efforts related to ocean noise. Specifically:
    a. Further development of the CetSound tools should be linked to the development of a coherent and comprehensive cross-office NOAA ocean noise strategy. NOAA

implements multiple Federal statutes with the authority to manage noise impacts to marine species, and conducts science under multiple programs that can inform the management of noise and its effects on marine species. The integration of the CetSound effort with NOAA ocean noise management and science priorities is necessary to direct the development of the most effective tools.

b. Further development of CetSound tools should exploit synergies with ongoing NOAA programs or efforts that can contribute data, data products and/or expertise towards common goals (e.g., NOS Coastal Services Center Multi-purpose Marine Cadastre, OAR Pacific Marine Environmental Laboratory)

3. Creation of Forums and Mechanisms to Receive External Input. The explicit collaboration of the CetSound team with multiple external stakeholders is necessary for the continued success of this effort, both because of the scientific expertise (both acoustic and biological) that exists outside of the agency, and because of the need to fully understand the needs and constraints of a regulated community in order to best manage any resource. The CetSound effort needs to establish the means to continue to systematically engage external stakeholders (Federal, non-Federal, and international), specifically:
    a. To enhance the accessibility and user-friendliness of the tools (e.g. visualizations vs. analytical formats)
    b. To assist in prioritizing the further development of the CetSound tools based on emerging regulatory questions shared by multiple agencies (e.g., analysis of predicted vessel traffic patterns in the Arctic, addition of pinnipeds to distribution and density mapping)
    c. To ensure that the tools are used effectively to inform evaluations or decisions made under multiple management contexts (e.g. EISs by multiple agencies, applications for permits/licenses submitted by industries).

    Multiple US government, non-federal and international efforts were identified that overlap with CetSound objectives. Given the limitations of NOAA's management authorities and the wide-ranging nature of noise and cetacean species, success in ocean noise management necessitates broad partnerships. Such forums include international efforts focused on quieting particular source types (e.g. International Maritime Organization Correspondence Groups) and developing science plans associated with multi-lateral partnerships (e.g. International Quiet Ocean Experiment, EU Marine Strategy Directive).

4. Identification of Mechanisms for External Funding. Multiple entities have expressed interest in either continuing to support or beginning to support this effort. NOAA needs to put in place mechanism(s) to allow NOAA receipt of external funds to be used to support CetSound science and outreach priorities (e.g. NOAA RFP) or to allow multiple parties to support proposed work to advance these priorities directly(e.g., National Oceanographic Partnership Program RFPs).

5. Outreach and Education. The initial CetSound products were highly visual in nature and were geared towards deliverability of best available science to a wide range of users. This focus must be retained and expanded in future efforts, particularly if the effort seeks to link further tool development to the development and implementation of a comprehensive management strategy. The need to better inform and engage the broader public regarding ocean noise and its impacts on marine life was articulated as a clear goal, specifically:
   a. Development of products and methods (e.g. visual supports for media interactions, special events at aquariums/film fests etc.) to educate the public regarding the impacts of noise on ocean resources, especially the more chronic effects that take place across larger spatial and temporal scales
   b. Development of products and forums (e.g. tutorials, workshops) to provide technical education within the regulated and regulator community to support a more robust analysis of noise impacts, and specifically the use and further development of CetSound tools.
   c. Development of effective presentation products (e.g. webinars, briefings etc.) to support relationship building within NOAA with a variety of synergistic efforts/programs (see above)

APPENDIX A: LIST OF ACRONYMS

SoundMap or SFWG — Underwater Sound-field Mapping Working Group
CetMap or CMWG — Cetacean Density and Distribution Mapping Working Group

Organizations:
ANSI — American National Standards Institute
API — American Petroleum Institute
AUTEC — Atlantic Undersea Test and Evaluation Center
BOEM — Bureau of Ocean Energy Management, US Department of Interior
BRP — Bioacoustics Research Program (Cornell University)
CEQ — Council on Environmental Quality
CSA — Chamber of Shipping of America
FWS — Fish and Wildlife Services
IFAW — International Fund for Animal Welfare
IWC — International Whaling Commission
MARAD — Maritime Administration, U.S. Department of Transportation
MMC — Marine Mammal Commission
US Navy:
- CNO — Chief of Naval Operations
- CPF — Commander, US Pacific Fleet
- LMR — Living Marine Resources Program
- NAVFAC — Naval Facilities Engineering Command
- NUWC — Naval Undersea Warfare Center
- ONR — Office of Naval Research

NGO — Non-governmental organization
NOAA — National Oceanic and Atmospheric Administration, US Department of Commerce
NMFS/NMFS —National Marine Fisheries Service
- NEFSC — Northeast Fisheries Science Center
- NERO — Northeast Regional Office
- NMML — National Marine Mammal Laboratory
- NODC — National Oceanographic Data Center
- NWFSC — Northwest Fisheries Science Center
- NWRO — Northwest Regional Office
- OAA — Office of Assisted Administration
- OHC — Office of Habitat Conservation
- OPR — Office of Protected Resources
- SERO — Southeast Regional Office
- S&T — Office of Science and Technology
- SWFSC — Southwest Fisheries Science Center
- SWRO — Southwest Regional Office

NOS — National Ocean Service
- CBNMS — Cordell Bank National Marine Sanctuary
- CMSP — Coastal and Marine Spatial Planning
- CSC — Coastal Services Center
- GFNMS — Gulf of Farallones National Marine Sanctuary
- IOOS — Integrated Ocean Observing System

ONMS — Office of National Marine Sanctuaries
OAR — Oceanic and Atmospheric Research
NOC — National Ocean Council
NPS — National Parks Service, US Department of Interior
NRC — National Research Council
NRDC — National Resources Defense Council
NSF — National Science Foundation
PNNL — Pacific Northwest National Laboratory (Department of Energy)
WWF — World Wildlife Fund
USCG — US Coast Guard
USGS — US Geological Survey

Terms:

AIS — Automatic Identification System
BIA — Biologically Important Areas
CMSP— Coastal and Marine Spatial Planning
U.S. EEZ — United States Exclusive Economic Zone
EIS — Environmental Impact Statement
ESA — Endangered Species Act
ETP — Eastern Tropical Pacific
GAMMS — Guidelines for Assessing Marine Mammal Stocks
GIS — Geographic Information System
IDW — Inverse Distance Weighted
ITA — Incidental Take Authorizations
Leq — Equivalent levels
MEOC — Meteorological and Oceanic Data
MMPA — Marine Mammal Protection Act
MSP — Marine Spatial Planning
NEPA—National Environmental Policy Act
OBIS — Ocean Biogeography Information System
OS — Observation Systems
PBR — Potential Biological Removal
PCAD — Population Consequences of Acoustic Disturbance
PCoD — Population Consequences of Disturbance
R&D — Research and Development
RFP — Request for Proposals
SCB — Southern California Bight
SEL — Sound exposure level
SPL — Sound Pressure level
S&T — Science and Technology
VOS — Voluntary Observing Ship Program
V&V process — Verification and Validation

APPENDIX B: MEETING AGENDA

DAY 1: WEDNESDAY, MAY 23

9:00 - **NOAA Leadership Greeting** (Sally Yozell, Director of Policy, NOAA) - 10 min

9:10 - **Overview of Working Groups and Symposium** (Jolie Harrison, NOAA and Leila Hatch, NOAA) - 15 min

9:25 – **Underwater Sound Field Working Group (SFWG) Mapping Tools**
- Goals and Overview (Leila Hatch) - 10 min
- Products and Details (Mike Porter, Heat, Light and Sound Research) - 20 min

9:55 - **Cetacean Density and Distribution Working Group (CetMap) Mapping Tools**
- Goals and Overview (Sofie Van Parijs, NOAA) - 10 min
- Products and Details (Pat Halpin, Marine Geospatial Ecology Lab, Duke University) - 20 min

10:25 - BREAK – 15 min

10:40 - **Management Context Discussions** (Leila Hatch introduces) - 5 min
- MANAGEMENT CONTEXT: U.S. ENDANGERED SPECIES ACT (Craig Johnson, NOAA) - 20 min
- MANAGEMENT CONTEXT: MARINE MAMMAL PROTECTION ACT MMPA (Jolie Harrison) - 20 min
- DATA AND TOOLS TO SUPPORT OCEAN PLANNING (David Stein, NOAA) - 20 min
- CUMULATIVE IMPACTS AND ANALYZING PROPOSALS (Ellen Athas, Council on Environmental Quality) - 20 min

12:05 - **Logistics Announcement** (Leila Hatch) - 5 min

12:10 - LUNCH BREAK - 90 min

1:40 - **Interactive Presentation and Discussion of CetMap and SFWG Tools**
- Room 1 (lead by Sofie Van Parijs and Megan Ferguson, NOAA, with CetMap support) - 55 min
- Participants switch rooms – 5 min
- Room 2 (lead by Brandon Southall, Southall Environmental Associates, and Leila Hatch with SFWG support) - 55 min

3:35 - BREAK – 15 min

3:50 - Panel and Plenary Discussion of CetMap and SFWG Tools (Leila Hatch introduces) - 5 min

- Panelist presentation (Bill Ellison, Marine Acoustics, Inc.) - 5 min
- Panelist presentation (Bill Streever, British Petroleum) - 5 min
- Panelist presentation (Rob Williams, University of St. Andrews) - 5 min
- Panelist presentation (Bob Gisiner, Navy N45) - 5 min
- Full plenary discussion (Leila Hatch guides) - 60 min

5:15 - Closing Remarks and Day 2 Reminders (Leila Hatch) - 15 min

5:30 - ADJOURN DAY ONE

DAY 2: THURSDAY, MAY 24

9:00 - Opening Remarks by Navy and Bureau of Ocean Energy Management (BOEM)

- Navy Leadership (John Quinn, Acting Director Energy and Environmental Readiness Division for the Chief of Naval Operations) - 10 min
- BOEM Leadership (Walter Cruickshank, Deputy Director, BOEM) - 10 min

9:20 - Potential Management Application Presentations (Jolie Harrison introduces) - 15 min

- CETACEAN MAPPING APPLICATIONS: RISK ASSESSMENT AND IDENTIFICATION OF PRIORITY HABITAT (Jessica Redfern, NOAA) - 20 min
- INCLUDING UNDERWATER NOISE IN ASSESSMENTS OF THE CUMULATIVE IMPACTS OF HUMAN ACTIVITIES ON MARINE ECOSYSTEMS (Carrie Kappel, National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara) - 20 min
- INTEGRATING UNDERWATER SOUND AND CETACEAN DENSITY ESTIMATES INTO REGIONAL COASTAL AND MARINE SPATIAL PLANNING: NEW DIMENSIONS FOR ANALYSIS (Pat Halpin) - 20 min

10:35 - BREAK – 15 min

10:50 - Resume Potential Management Application Presentations

- ENDANGERED SPECIES, CUMULATIVE IMPACT ASSESSMENTS, AND POTENTIAL APPLICATIONS OF CETMAP AND SOUND-FIELD MAPPING (Craig Johnson) - 20 min
- CUMULATIVE ACOUSTIC FOOTPRINTS OVER MULTIPLE SCALES: FROM BOTTOM TO TOP, FROM NOISE METRICS TO BIOLOGICAL INFLUENCES (Chris Clark, Bioacoustics Research Program, Cornell Laboratory Of Ornithology, Cornell University) - 20 min

- Population Consequences of Disturbance (PCoD) Model and Future Applications (Mike Weise, Office of Naval Research) - 20 min
- Empirical Noise Mapping to Support Management of Resources and Visitor Experience in National Parks (Kurt Fristrup, National Park Service) - 20 min

12:10 - Wrap Up Morning/Logistics (Leila Hatch) - 5 min

12:15 - LUNCH - 90 min

1:45 - Panel and Plenary Discussion of Potential Management Applications (Leila Hatch introduces)- 5 min

- Panelist presentation (Michael Jasny, Natural Resources Defense Counsel) - 5 min
- Panelist presentation (Russell Tait, ExxonMobil) - 5 min
- Panelist presentation (Tim Ragen, Marine Mammal Commission) - 5 min
- Panelist presentation (Kathy Metcalf, Chamber of Shipping of America) - 5 min
- Full Plenary Discussion (Leila Hatch guides) - 60 min

3:10 - BREAK - 15 min (organize tables for break out groups)

3:25 - Instructions for Breakout Groups (Leila Hatch organizes) - 5 min

3:30 - Breakout Group Discussions - 1 hr

4:30 - Report-outs from breakout groups - (Leila Hatch organizes) - 30 min

5:00 - Marine Mammal Commission Remarks (Tim Ragen) - 15 min

5:15 - Closing Remarks

- Jolie Harrison - 10 min
- NOAA leadership (Richard Merrick, Director of Scientific Programs and Chief Science Advisor, National Marine Fisheries Service, NOAA) - 5 min

5:30 - ADJOURN MEETING

APPENDIX C: COMMITTEE AND WORKING GROUP PARTICIPATION

Steering Committee

Leila Hatch (Co-chair) NOS Stellwagen Bank NMS (Co-chair SoundMap)
Jolie Harrison (Co-chair) NMFS OPR (CetMap)
Brandon Southall NMFS S&T; SEA, Inc. (Co-chair SoundMap)
Jason Gedamke NMFS S&T (SoundMap)
Sofie Van Parijs NMFS NEFSC (Co-chair CetMap)
Megan Ferguson NMFS NMML (Co-chair CetMap)

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