OPEN SCIENCE MEETING FOR AN
INTERNATIONAL QUIET OCEAN EXPERIMENT
UNESCO HEADQUARTERS
PARIS, FRANCE
30 AUGUST-1 SEPTEMBER 2011
Sponsorship of the Meeting:

The SCOR/POGO Planning Committee for the meeting is grateful for the sponsorship of the Scientific Committee on Oceanic Research (SCOR) and the Partnership for Observation of the Global Oceans (POGO), and for staff support provided by both organizations. The committee thanks the Intergovernmental Oceanographic Commission (IOC) of UNESCO for hosting the meeting, supporting some of the local costs, and providing excellent staff support. Finally, we acknowledge financial support from the Alfred P. Sloan Foundation for the meeting.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization of the Meeting</td>
<td>6</td>
</tr>
<tr>
<td>An Introduction to the Meeting</td>
<td>7</td>
</tr>
<tr>
<td>About this Book</td>
<td>8</td>
</tr>
<tr>
<td>Facilities at UNESCO</td>
<td>8</td>
</tr>
<tr>
<td>Programme Summary</td>
<td>11</td>
</tr>
<tr>
<td>Detailed Programme</td>
<td>13</td>
</tr>
<tr>
<td>An Introduction to the Discussion Sessions</td>
<td>17</td>
</tr>
<tr>
<td>Discussion Papers</td>
<td>19</td>
</tr>
<tr>
<td>Notes for Visitors to Paris</td>
<td>51</td>
</tr>
<tr>
<td>List of Participants</td>
<td>55</td>
</tr>
</tbody>
</table>
ORGANIZATION OF THE MEETING

SCOR/POGO Planning Committee:
Ian Boyd, co-chair, Sea Mammal Research Unit, University of St. Andrews
George Frisk, co-chair, Florida Atlantic University/Woods Hole Oceanographic Institution
Christine Erbe, JASCO Australia
David Farmer, University of Rhode Island (ret.)
Roger Gentry, ProScience Consulting, LLC
Anthony Hawkins, Loughine Ltd.
Peter Tyack, Woods Hole Oceanographic Institution
Micheal Weise, U.S. Office of Naval Research

Meeting Coordinators:
Ed Urban, Executive Director, SCOR
Sophie Seeyave, POGO
Tom Gross, IOC/UNESCO

Assistance with Meeting Preparation:
Elizabeth Gross, SCOR
Simonetta Haond, IOC
Lora Carter, SCOR
AN INTRODUCTION TO THE MEETING

About the Sponsor Organizations
SCOR is an international non-profit organization formed in 1957 to identify ocean research topics that would benefit from enhanced international action; it establishes working groups and other subsidiary bodies—either alone or in conjunction with other organizations—for detailed examination of problems related to the marine environment and international ocean science. SCOR also works with other international organizations to develop and sustain major international ocean research projects.

POGO is an international network of institutions and organizations that foster partnerships that advance efficiency and effectiveness in studying and monitoring the global ocean. Through its efforts, POGO has promoted observations underpinning ocean and climate science, interpreted scientific results for decision makers, provided training and technology transfer to emerging economies, and built awareness of the many challenges still ahead.
ABOUT THIS BOOK

We hope you will find this book to be helpful, both as a reference during the meeting and afterward. The list of participants includes all those who completed registration for the conference before this book went to print on 18 August 2011. Similarly, the discussion papers reflect the status of the program for the conference on that date.

The discussion papers are listed alphabetically, by the first author’s surname.

Any changes to the program will be announced and posted at the meeting and you are advised to look for these near the registration desk.

FACILITIES AT UNESCO

The UNESCO building contains many useful facilities for meeting participants:

- Automatic banking machine: when you enter the building, turn left before security and you will find a bank and ATM to the right of a small convenience store.
- Bank with exchange facilities - first floor, main building
- Cafeteria, a coffee bar with sandwiches and light snacks, and a formal restaurant - 7th floor, main building
- Coffee bar with sandwiches, light snacks, coffee and other drinks on the lower level (-1). Look for the “Bar des Conferences”.
- Internet Access will be available in the meeting rooms, although you may need to use Web mail, rather than your normal email program.

Entry to the UNESCO Headquarters

We are meeting in the Fontenoy Building of UNESCO Headquarters. Please use the entrance on the Place de Fontenoy side of the building. There is a guard outside the courtyard, whom you may need to tell you are attending an IOC or COI meeting. Once you have entered the glass doors, the registration desk will be to the left of the metal detector/xray machine. You will receive your badges (an official IOC meeting badge and a badge for our meeting with your name printed larger) and a map of the building that will show where the various meeting rooms are located.

The following page shows the UNESCO site with the approximate location of nearby hotels.
Paris Map with UNESCO and Hotels

PLAN D'ACCÈS - UNESCO - ACCESS MAP

Hôtel La Bourdonnais

Hotel de la Motte Picquet

Atel Hotel de Varennes

Hotel Baldi, Hotel Eiffel Segur

Hotel Derby Eiffel

Le Grenelle Paris Tour Eiffel Hotel

Paris Eiffel Cambronne

Hotel Bailli de Suffren

Entrée principale / Main Entrance:
7, place de Fontenoy
75007 Paris

Entrée Bâtiment des Conférences
Conference Building Entrance:
125, avenue de Suffren
75007 Paris

Entrée Bâtiment Annexe
Annex Entrance:
1, rue Miollis
75015 Paris

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PROGRAMME SUMMARY

The meeting has three components:

1. Plenary presentations to set the stage for discussions:
   - IQOE history and concept
   - What is known about long-term trends in ambient noise levels and the global economy? What is known about the biological effects of sound?
   - What is already possible using existing technologies? How could existing technologies be added to existing observing systems?
   - What is a soundscape and how should soundscapes be quantified and characterized?
   - Modeling and prediction of soundscapes

2. Discussion sessions to gather community ideas on priority research, observations, and modelling, as input to the IQOE Science Plan:
   - Observing Systems, including technology development
   - Scientific knowledge needed for industry and regulators
   - Ocean soundscapes
   - Designing research relating soundscapes (cumulative effects of many sources) to effects on organisms
   - Experimental approaches to understanding responses of organisms to specific sources

3. Reports back in plenary from the discussion sessions.

<table>
<thead>
<tr>
<th>Aug. 30</th>
<th>Aug. 31</th>
<th>Sept. 1</th>
<th>Sept. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plenary Presentations</td>
<td>Plenary Presentations</td>
<td>Reports back from Discussion Sessions</td>
<td>Chairs, Rapporteurs, and Planning Committee Meet to Draft Science Plan</td>
</tr>
<tr>
<td>Break</td>
<td>Break</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>Plenary Presentations</td>
<td>Discussion Sessions</td>
<td>Discussion Sessions</td>
<td></td>
</tr>
<tr>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
</tr>
<tr>
<td>Instruction about breakouts and Q&amp;A (all five groups in parallel)</td>
<td>Discussion Sessions</td>
<td>Discussion Sessions</td>
<td>Chairs, Rapporteurs, and Planning Committee Meet to Draft Science Plan</td>
</tr>
<tr>
<td>Break</td>
<td>Break</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>Discussion Sessions</td>
<td>Discussion Sessions</td>
<td>Plenary to discuss completion of science plan and implementation of IQOE</td>
<td></td>
</tr>
<tr>
<td>Reception</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Notes for Participants: Invited speakers will be expected to adhere to the allocated times for their talks. The chairs of the plenary sessions will be strict about the timing, in order to keep the conference running smoothly.

TUESDAY, 30 AUGUST

30 August (Tuesday)

Introductory Plenary Session
Session Chair: George Frisk

9:00 Welcome – Wendy Watson-Wright, IOC Executive Secretary and Assistant Director General, UNESCO

9:15 IQOE history and concept - Ian Boyd, University of St. Andrews

9:45 The future industrialization of the oceans – Paul Holthus, World Ocean Council

10:15 What is a soundscape and how should soundscapes be quantified and characterized? - Christine Erbe, JASCO Australia

10:45 Coffee break

Existing technologies that could be useful for characterizing soundscapes
Session Chair: Ian Boyd

11:15 Global Ocean Acoustical Observation System – Brian Dushaw, University of Washington

11:35 Autonomous Observation Systems - Doug Cato, Defence Science and Technology Organisation, Australia

11:55 Underwater naval acoustic systems - David Moretti, U.S. Naval Undersea Warfare Center


12:35 Comprehensive Test Ban Treaty Organization - Mark Prior

13:00 Lunch

14:30 Introduction to Breakout Groups – Ian Boyd and George Frisk

1. Observing Systems, including technology development
   Co-chairs: Brandon Southall (SEA, Inc.) and Brian Dushaw (University of Washington)
2. **Scientific knowledge needed for industry and regulators**  
   Co-chairs: *John Young* (Resource Access International, USA) and *Frank Thomsen* (DHI Water and Environment, Denmark)  
   Co-rapporteurs: *René Dekeling* (Defence Materiel Organisation, Netherlands) and *Jason Gedamke* (NOAA)  

3. **Ocean soundscapes**  
   Co-chairs: *Manell Zakharia* (NURC, Italy) and *Doug Cato* (University of Sydney)  
   Co-rapporteurs: *Christine Erbe* (JASCO Australia) and *Tony Hawkins* (Loughine)  

4. **Designing research relating soundscapes to effects on organisms**  
   Co-chairs: *Christopher Clark* (Cornell University) and *Jakob Tougaard* (Aarhus University)  
   Co-rapporteurs: *Peter Evans* (Sea Watch Foundation) and *Roger Gentry* (ProScience Consulting)  

5. **Experimental approaches to understanding responses of organisms to specific sources**  
   Co-chairs: *Vincent Janik* (University of St. Andrews) and *Robert Gisiner* (U.S. Navy)  
   Co-rapporteurs: *Patrick Miller* (University of St. Andrews) and *Sophie Brasseur* (IMARES)  

15:00 Begin discussion groups  
16:00 Coffee break  
16:30 Continue discussion groups  
18:00 Adjourn for Day  
Reception at UNESCO
**WEDNESDAY, 31 AUGUST**

Effects of Sound in the Ocean  
Session Chair: *David Farmer*

9:00  What is known about long-term trends in ambient noise levels and the global economy? – *George Frisk*, Florida Atlantic University/Woods Hole Oceanographic Institution

9:30  What is known about the biological effects of sound? – *Peter Tyack*, Woods Hole Oceanographic Institution

10:00 Continue discussion groups

11:00 Coffee break

11:30 Continue discussion groups

13:00 Lunch

14:30 Continue discussion groups

16:00 Coffee Break

18:00 Adjourn Meeting for the Day

**THURSDAY, 1 SEPTEMBER**

Reports Back from Discussion Groups  
Session Chair: *George Frisk*

9:00  Reports back from discussion groups and plenary discussion

11:00 Coffee break

11:30 Continue discussion groups

13:00 Lunch

14:30 Continue discussion groups
16:00 Coffee Break

Wrap-up Session
Session Chair: Ian Boyd

16:30 Plenary to discuss completion of science plan and implementation of IQOE

18:00 Adjourn Meeting for the Day
AN INTRODUCTION TO THE DISCUSSION SESSIONS

Aims of the Discussion Sessions

The discussion sessions are designed to encourage open discussion on research, observations, and modelling needed to increase our understanding of sound in the ocean and its affects on marine organisms. Participants will be asked to:

- Identify and prioritise key research questions
- Identify what we need to know to answer those questions and what are the impediments to success (if any)
- Identify promising approaches, including necessary observations, methods, emerging technologies, tools, and regional considerations/scales of study
- Identify the international collaborations and linkages required to answer the key research questions, including linkages to existing international research projects.

The results of the discussions will be presented in an IQOE Science Plan to be posted on the Web and distributed to research managers worldwide.

Discussion Session Themes and Subthemes

1. Observing Systems, including technology development
   a. Integration within existing systems
   b. New systems designed for IQOE
   c. How to extract useful scientific information from data collected for regulations
   d. Data collection (including standardization), quality control, analysis, reporting, management, and accessibility

2. Scientific knowledge needed for industry and regulators
   a. Noise monitoring, including characterisation and classification of sources (see also Theme 3)
   b. Defining biological significance
   c. Monitoring biological effects
   d. Ocean noise as an indicator of industrial activity

3. Ocean soundscapes
   a. Characterizing and classification of sources from received sound (might also be relevant in Theme 2 above)
   b. Creating sound budgets
   c. Propagation models
   d. Extrapolating from known human activities, physical factors, biological activity to predicting resulting contribution to soundscapes
   e. Predicting forward and backward in time
   f. Validation of ocean soundscape models through observations
4. **Designing research relating soundscapes (cumulative effects of many sources) to effects on organisms**
   a. Can we study the effects of quieting, rather than adding noise?
   b. Spatial and temporal scales
   c. Using opportunistic approaches
   d. Data collection (including standardization), quality control, analysis, reporting, management, and accessibility
   e. Essential variables – what should be globally measured by a GOOS?

5. **Experimental approaches to understanding responses of organisms to specific sources**
   a. Planned approaches and essential variables
   b. Spatial and temporal scales of experimental approaches
   c. Feasibility of different approaches
   d. New technology and innovation
   e. Data collection (including standardization), quality control, analysis, reporting, management, and accessibility
The environmental cost of marine sound sources

M.A. Ainslie (TNO, Delft, The Netherlands) and R.P.A. Dekeling (Ministry of Infrastructure and the Environment, DG Water, The Netherlands)

Cumulative acoustic exposure is used as an indicator for the risk of negative impact to animals as a consequence of exposure to underwater sound. The free-field energy of a single source, defined as the total acoustic energy that would exist in the source’s free field, is shown to be closely related to the total cumulative exposure added over a population of animals. On this basis, the free-field energy of an underwater sound source, referred to as its “energy cost”, is proposed as an indicator of its environmental risk. For otherwise the same conditions, the environmental cost so defined of a multi-beam echo sounder (frequency 100 kHz) is about 40,000 times less than that of a search sonar (1 kHz) of the same source level. In turn, the cost of the same sonar is about 300 times less than that of a pile driver of the same energy source level, implying that source level (or energy source level) alone is a poor indicator of environmental risk. The main reason for this is that source level takes no account either of the amount of space occupied by the sound once in the water, or of the time required for the sound to dissipate. The free-field source energy, which includes the effects of source directivity and decay time, is therefore useful as an indicator of the environmental cost of a marine sound source.

Global trends in low frequency ocean noise and shipping source level: principles and proposed experiment

Michael A. Ainslie (TNO, The Netherlands)

The global average underwater noise due to shipping traffic can be related to three characteristics of global shipping, the average source level and average tonnage of each ship and the total number of ships, and two environmental parameters, the absorption coefficient and critical angle [M. A. Ainslie, J. Acoust. Soc. Am. 129, 2497 (2011)]. If the number of ocean-going vessels and their average tonnage are known, the global average source level can be estimated from the average noise level by inverting this relationship in parts of the frequency spectrum dominated by shipping noise. An experiment is proposed to measure global ambient noise level using a global network of hydrophones operated by the Comprehensive Test Ban Treaty Organization [M. K. Prior et al., Proc. 4th International Conference and Exhibition on "Underwater Acoustic Measurements: Technologies & Results", Kos (Greece), June 2011, pp 1343-1350], and to use this measurement to infer the globally averaged source level associated with ocean-going ships. The simplicity of the proposed method leads to insight into possibilities for controlling the amount of shipping noise, and therefore to potential mitigation measures. The effectiveness of any mitigation measures can be monitored by measuring trends over time of shipping noise and average shipping source level. The feasibility of measuring such trends is considered.
Less costly assessment of biological effect of sounds on marine organisms: social events and developing projects as virtual experiments

Tomonari Akamatsu
National Research Institute of Fisheries Engineering, Hasaki, Kamisu, Ibaraki 314-0408, Japan

Social events and developing projects
In practice, shutting down underwater noise is extremely difficult (Boyd et al. 2011). Even controlling noise production in local area will be highly costly for a basic scientific experiment. Instead, social events may create test and control conditions of ambient noise. Namely Chinese spring holiday, economic collapse of a specific country or a festival in a fishing village could change local maritime traffic. Not only these social event but also natural disasters such as earthquake and typhoon can be considered as the noise exposure events to marine organisms. Another cost effective approach is to use a developing project as a big in situ experiment. Noise level, traffic, current, turbidity and migration or movement of marine organisms could be different before, during and after the project. In these years, various types of fixed and towed acoustic monitoring devices are available. Good examples are the extensive assessments of wind farm effect on harbor porpoises, which have been conducted in European waters (for examples; Scheidat et al. 2011, Susi et al. 2010). Developing stage of constructions can be used as the one-way experiment to compare calm and noisy environment. Monitoring social, economical and natural event are feasible using underwater cable networks and various fixed passive acoustic monitoring systems these days. Technical collaboration to monitor ongoing projects and events will be helpful for comparative studies. Obviously, no universal safe or lethal exposure threshold levels of sound for all marine organisms exist. It depends on species, exposure level, frequency spectrum, propagation, and temporal structure of noise. We need bigger sample size and number of species in different areas to have reliable estimation of the acoustic impact.

Review of previous and ongoing assessment
As seen in quickly developing countries in these decades, a lot of marine constructions such as bridge, tunnel, and airport were conducted in Japan during 1960s to 80s. Various sound exposure experiment, such as high speed ship, airplane, pile driving, and dynamite to the pelagic and benthic organisms had been conducted to observe impacts of sounds and vibrations created by these sources (Hatakeyama et al. 1997). Behavioral response of numbers of fish species for example sea bream, sea bass, Japanese anchovy and sardine were reported. Not only unique fishing methods using sound to herd fish school were reviewed, but also lethal level of blast damages were examined. The damage depended on the direction of receiving shock wave, even in same fish species. Abdominal side was more fragile than dorsal size at 21.9kg/m² pressure. Distance with no immediate injury from the blast centre was presented for eel, octopus, carp, sea bream and many other species. Review of these data seems quick method to collect biological effect of sounds on various species and avoid duplication of trials, although the limitations of measurement and analysis could be found. Same cases may be happening even now. Quickly developing countries in Asian, South American and African regions are conducting quite a lot of marine constructions and surveys. Since most of the results were published in domestic language, they have not been accessible worldwide. A comprehensive review of effect of sound on various fish and other species will be useful as seen in a good example of Marine Mammals and Noise (Richardson et al. 1995).
Listening to the Deep: live monitoring of ocean noise and acoustic events
André, M., van der Schaar, M., Zaugg, S., Houégnigan, L., Sánchez, A.M., and Castell, J.V.
Laboratori d'Aplicacions Bioacústiques, Universitat Politècnica de Catalunya (UPC),
Corresponding author: michel.andre@upc.edu

Originated in the European Sea-Floor Observatory Network of Excellence (ESONET) in 2007, the Laboratory of Applied Bioacoustics (LAB), from the Technical University of Catalonia (UPC, Barcelona Tech) is currently leading an international project titled “Listen to the Deep Ocean Environment (LIDO)” to apply and extent developed techniques for noise measurement and passive acoustic monitoring to cabled deep sea platforms and moored stations (André et al. 2008a, 2008b, 2011). The software framework, called S-SONS, is currently active at the ANTARES, France (http://antares.in2p3.fr/) neutrino observatory, the OBSEA, Spain (http://www.obsea.es) shallow water test site, the NEPTUNE Canada (http://www.neptunecanada.ca/) observatory, the JAMSTEC, Japan (http://www.jamstec.go.jp/e/) network of underwater observatories and at the NEMO, Sicily (http://nemoweb.lns.infn.it/) site after the observatory has been redeployed. Part of the system is being tested for suitability on autonomous gliders in collaboration with the NURC (Dassatti et al. 2011) and is implemented in several autonomous radio-linked buoys. The software contains several independent modules to process real-time data streams. Among these, there are dedicated modules for noise assessment, detection, classification and localization. To summarize the LIDO system, it takes as input an acoustic data stream and produces as output the characterization of the acoustic events that were detected in the data (written to an XML file), spectrograms for quick visualization and compressed audio. These outputs are then made available on the Internet where they can be viewed with a specific application. The public interface can be found at http://www.listentothedeep.net. It should be noted that the compressed audio is provided to allow users to listen to a sound stream with minimal bandwidth usage; but it is specifically not intended for scientific analysis. The raw data is optionally stored locally if there is an interest in subsequent research.

The noise measurement module computes statistics on fixed length intervals, such as sound maxima, RMS level and third octave levels, especially following the recommendations of the European Marine Strategy Framework Directive (2008/56/EC). In particular, the Descriptor 11.1 (Tasker et al. 2011) focuses on high amplitude impulsive anthropogenic sound within a frequency band between 10Hz and 10 kHz, assessed using either sound energy over time (Sound Exposure Level SEL) or peak sound level of the sound source, while the Descriptor 11.2 addresses background noise without distinguishable sources that can lead to masking of biological relevant signals, alter communication signals of marine mammals, and through chronic exposure, may permanently impair important biological functions. This latter indicator requires a set of sound observatories to enable trends in anthropogenic background noise to be followed (noise within the 1/3 octave bands 63 and 125 Hz, centre frequency).

The LIDO system is readily available for the scientific community and the industry and has demonstrated to have already answered most the questions listed in the following discussion session: Observing Systems, including technology development
In order to design an observing system, we must identify the space and time scales of the “thing” we are trying to observe. The “thing” is the underwater soundscape. The anthropogenic contribution is of primary interest, as it is expected to increase with increasing industrialization of the oceans. Since the ocean is extremely transparent to sound, the anthropogenic component can be expected to be a smooth function of space in the open ocean, peaking near or in shipping lanes, and again a reasonably smooth function in bays and inland seas, excepting peaks due to individual ships. At any single location, the soundscape will vary over multiple time scales: over minutes for nearby passing radiators (say, a ship), over hours as port activity rises and falls each day, over seasons as merchant ships adjust for annual weather and climate patterns, and over years as industrialization builds.

In terms of spatial scales, some effort must initially target a determination of these scales, and I think that cannot be done with optimal efficiency using fixed assets. I propose a fleet of Autonomous Underwater Listeners (AULs) with the capacity to move (or drift or be transported) through soundscapes of interest. These might be attached to or embedded into existing vehicles or floats, or comprise their own independent instrument. The measurement protocol is not excessive. For frequencies up to about 500Hz, we use a sampling rate of 2 kHz, and local processing to integrate about 3 minutes of omnidirectional acoustical data into an estimated power spectrum, which can then be compressed into one-third octave (OTO) band levels and stored. These are standard digital signal processing operations and could easily be implemented on a low-power application-specific integrated circuit (ASIC). I recommend a rate of about 1 integration per 5 minutes. I see data retrieval as the primary challenge: the data rate, even with OTO compression, could easily exceed that on current autonomous vehicle uplinks. Considerable data compression technology will be required. Data storage devices currently exist that can handle months of such data, but on-board storage will require AUL retrieval, which could be problematic.

One of the principal challenges in this concept would be interpreting the measurements of listeners over a multitude of trajectories in space and time and extracting some form of “time-mean” soundscape. It will also be necessary to develop “quiet” instruments that do not contaminate their acoustic records with platform (i.e., self) noise. Internationally recognized and supervised hydrophone calibrations will also be required. I would envision a measurement protocol in any one region lasting a full year, in order to observe a “full cycle” of human activities (and weather) in the area.

The measurement protocol and hardware described above could easily be adapted for incorporation into the nodes of current and future ocean bottom observing systems. The drawback of fixed assets is that they only measure the soundscape at a single location. However, the fixed assets can provide long-term (year after year) measurements.

The two measurement modalities easily complement one another. Once the fleet of AULs determines the spatial characteristics of a region's soundscape, we could adopt the paradigm that
the soundscape shape remains (mostly) the same but use a single point measurement, i.e., from an ocean observing node, to determine the level. The soundscape shape could be measured again after a few years to validate the model.

**Designing research relating soundscapes (cumulative effects of many sources) to effects on organisms**

Sophie Brasseur, IMARES, P.O. Box 167, Den Burg 1791AD, Netherlands, sophie.brasseur@wur.nl

Though there are strong indications that underwater sound will affect marine organisms in a negative way, there is very little proof as to how this may affect populations. In extreme cases, where hearing damage occurs or even death, effects are found in individual animals rather than populations. A good example is the cetaceans that have been reported to stand en masse after high levels of human disturbance.

In the majority of cases the organisms will hear the sound, maybe even suffer (temporary) hearing damage but no apparent change will occur. Apparent is the correct word as it must be a matter of perceiving for us, or being able to measure these changes at a level that would be meaningful to interpret population effects. Unless animals die directly as a result of the disturbance we are seldom aware of any effects.

On the one hand impressive advances are being made in measuring the hearing capacity of marine animals on the other however, there is very little advance in understanding how animal populations are affected when anthropogenic sound levels raise.

Relating soundscapes to animal distribution might give at least insight in how sound may influence habitat use and thus how sound may limit or define the accessibility to vital feeding or breeding grounds. Then one could fit sound as a factor in other existing hypothesis on energetics, population dynamics or other determining theory.

In the end a hypothesis should be defined: If (specific) sound is present this can affect survival, reproduction, or fecundity etc. through a defined pathway.

This is however as much an exercise in sound mapping as it is in understanding behavioural changes in the organisms. Crucial is to be able to create relevant soundscapes i.e. to interpret the noise as the organisms would perceive this, using the knowledge acquired in more or less controlled hearing experiments, and including environmental factors that are of importance.

A first step is to define differences in population parameters between relative quiet areas and relative noisy ones. Quieting, areas will not help unless very long term data is provided as in general the effect of sound is not understood well enough in marine mammals. By studying animals confronted with different sound levels within the distribution of one population, some indications should become apparent as to how a population could be affected.
Soundscape mapping in shallow water tidal-stream habitats
Caroline Carter & Ben Wilson (caroline.carter@sams.ac.uk), Scottish Association for Marine Science, Oban, Scotland

The development of marine renewables is set to accelerate in the near future, resulting in a large number of devices being deployed in the marine environment. The tidal-stream sector is at an early stage of development, so the effects of these installations are as yet unknown. Our research (including CC’s PhD project) is to consider the acoustic interactions between tidal-stream devices and marine mammals to understand how detectable these devices will be to animals though passive listening for their acoustic outputs. Device audibility will depend not only on device outputs and animal auditory sensitivity but also on the levels of ambient sound already in these environments.

Suitable areas for the deployment of tidal-stream devices are straits, sounds and headlands subject to fast moving currents. Whilst there is much data regarding ambient noise in deep water, there is very little information describing these shallow water tidal-stream areas (with typically hard bottoms, water turbulence and variable bed loads). Measuring underwater sound in a tidal-flow is problematic with issues from water flow over the transducer. We have developed a recording method using autonomous drifting hydrophone-recorder units and GPS; the hydrophone is moving with the tidal-stream and thus recording the environment rather than the flow of water. Multiple units can be deployed simultaneously from a small boat, upstream and across the target area to achieve good spatial coverage.

This method can be deployed many times during a tidal cycle resulting in the collection of a large amount of data and, following processing, is mapped to describe a spatial soundscape. These sound maps describe a snapshot of sound intensity in the area, and data collected so far over four tidal-energy relevant sites revealed considerable spatial heterogeneity of ambient sound intensities. High and low intensity areas varied at different frequency bands and there is an increase in noise levels as tidal-steam flow speed increases.

Ocean Soundscapes: their components and methods of characterization
Douglas H. Cato, Defence Science and Technology Organisation, and University of Sydney, PO Box 44, Pyrmont, NSW 2009 Australia. doug.cato@sydney.edu.au

Ocean soundscapes can be conveniently characterized as combination of the ambient noise which provides the general background noise, and what might be termed localised noise from identifiably individual sources. Examples of localized noise are the noise of a passing ship or whale, or the noise of pile driving.

Ambient noise is the background that remains after excluding noise from identifiable localized sources (Urick, 1983). An example of ambient noise is the background noise from a large number of ships across an ocean basin, where no individual ship is identifiable. This is the main anthropogenic component of ambient noise and is defined as traffic noise (Wenz, 1962). The other main components of ambient noise are the noise from sea surface motion (actually the bubbles formed as waves break) and biological choruses produced by large numbers of
individual animals (usually of the same species) calling so that it forms a continuous background noise. Noise from sea surface motion is known as wind-dependent noise, because it correlates well with wind speed, better than with any measure of wave motion. Wind-dependent noise is the most persistent of these components. Traffic noise varies throughout the world from dominating the low frequency ambient noise (less than a few hundred hertz) in regions of high traffic noise (e.g. North Atlantic) to negligible in regions where shipping is sparse (e.g. parts of southern hemisphere oceans). Biological choruses are widespread and occur at various times of day, often with consistent regularity. Rain noise is also an important component of ambient noise.

Characterizing soundscapes, estimating sound budgets, or predicting soundscapes requires characterizing both the ambient noise and the localized noise. Characterizing ambient noise in a region is best achieved by characterizing the individual components in terms of the frequency range, the temporal and spatial variation, with measurements sampled over the range of variation: diurnal, seasonal and varying weather. Modeling may be used to supplement the measurements. Wind speed measurements are required to separate out the wind-dependent noise from traffic noise and other residual noise, even in areas of high traffic noise. This provides a relationship of noise as a function of wind speed, with an estimate of other sources being obtained from data at low wind speeds. An anemometer moored near the acoustic recording system is the best way to do this, but more distant anemometers can be used, especially if calibrated against a local anemometer. Biological choruses can be characterized by analysis of measurements, but it is more effective to determine the sources of the choruses and relate sound production to their behavior, distributions and habitats.

Characterization of localized sources would generally be much more specific to the individual source. By measuring the source level and directionality of the source, the contribution of the source in different environments can be determined using propagation models and knowledge of its distribution and behavior. Characterization of persistent and multiple localized sources such as the shipping noise around the approaches to a busy port may also benefit from the approach used for ambient noise.

Natural soundscapes with no anthropogenic noise except over limited periods do occur and allow the range of natural soundscapes to be characterized.

Temporal variation in ambient noise is substantial, typically around 20 dB due to variation in weather and biological activity, with extremes of variation in excess of 30 dB. A 20 dB variation in background noise will cause a variation the distance over which a marine mammal can communicate by typically a factor of 10. Often the limiting noise for animal communication may the sounds of the surrounding conspecifics.

**Quiet Ocean Experiment: Comments on characterization and modeling ambient noise**

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Noise is generated by sound that has propagated through the ocean. Characterizing the noise field (i.e. understanding the ocean soundscape) involves two basic issues: measurements in the
ocean and numerical modeling of sound propagation. Measurement of the noise: this includes measurement of the noise intensity and directionality (both horizontal and vertical), and the statistics over a broad frequency band. Both the directionality and statistics will be different for different frequency bands, since different noise sources dominate different bands. The basic measurement system for ambient noise characterization should ideally consist of an array of hydrophones, with directional capability in the horizontal and vertical planes. This type of system is also a fundamental requirement for passive monitoring of marine animals. Long term measurement capability is essential to determine noise statistics and trends; deployed cabled observatories can act as monitoring stations at specific sites. The challenge is to determine critical regions for noise measurement that are not covered by existing observatories. 

Noise characterization also includes modeling of the noise field. Modeling involves two objectives: modeling the sound field of specific noise sources such as seismic air gun arrays or pile drivers; this is an essential component of understanding the impact of the noise source at specific locations in complex waveguide environments. This is a new requirement that demands a three-dimensional sound propagation model. Modeling also involves predicting the ambient noise field. Although there are many noise models that have been developed, prediction of the broadband noise intensity over time in a three-dimensional ocean environment is still a holy grail in ocean acoustics. 

Noise trends and data mining: recent work (Andrew, 2002; MacDonald, 2006; Reeder, 2007; and Chapman, 2011) has shown that the noise trend at low frequencies due to shipping is changing to a slower rate from the original trend established by Ross of ~0.55 dB/yr. New measurements in all the oceans are needed to confirm and quantify the new trend. One aspect that should not be overlooked in assessing noise trends is comparison with old data that represent benchmark measurements in well documented conditions. Data from previous surveys that were done in the southern oceans are particularly important because the density of shipping (and other human noise sources) is very low. The southern ocean sites provide real examples of quiet ocean conditions that allow measurement of specific types of noise sources in the ocean: biological; seismic; wind/rain. Comparisons can be made with these data in assessing noise prediction models for quiet ocean conditions, for instance in back-prediction of noise intensity in pristine natural conditions. 

Hydrophone Data Quality Control and Standardization
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Three emerging factors make it critical to standardize the quality control and data formatting of hydrophone data. These factors include:

- the International Quiet Ocean Experiment (IQOE), requiring worldwide exchange of hydrophone data,
- the emergence of digital/smart hydrophone technologies, which require new calibration techniques and significant metadata to account for the wide range of instrument settings, and
the significant global investments in ocean observatories, which are now starting to provide real-time and archived hydrophone data via the internet.

In order to enable the exchange, collation and meaningful use of data sets from multiple locations and system types a set of standards is required. Consideration of the following is required for the standards:

- **Calibration**
  - end to end; calibrations should encompass the entire system’s conversion from acoustic pressure to digital output. The emerging digital hydrophones have programmable gains, filters, and significant digital signal processing (DSP) selections which must be accounted for in the calibration and metadata. In addition to the conversion calibration the self-noise and dynamic range of the hydrophones versus frequency will determine the usefulness of systems for particular applications.

- **Data format and metadata**
  - Time - PTP timing protocols (µs) and accurately time synchronized sampling make it possible to correlate data from widely spaced systems.
  - Sample rate - what was the digitizing sample rate?
  - Self-noise and dynamic range versus frequency
  - Pressure resolution - how many useful bits are there in the dynamic range?
  - Gain, filter and DSP settings - what settings were used?
  - Calibration data – both end to end calibrations and legacy calibrations must be supported; legacy being the traditional dual data set i.e. analog hydrophone calibrations and digital system scaling
  - Data format - Lossless.
    - How will the digital data be formatted? One second records?
    - Ocean observatories require the ability to stream live hydrophone data. What are the contender formats? What about Metadata?
    - Should the format be playable on publicly available?
    - How to embed multiple correlated sensors (e.g., hydrophone arrays) into the same stream?

A working group to study and recommend a calibration standard for digital hydrophone systems as well as a standard for hydrophone data formatting is required. Ideally the working group would be sponsored by UNESCO, or perhaps IEEE, to give the standard international recognition.

**Quiet Ocean Experiment: The Use of Ocean Networks Canada Observatories**

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Characterizing sound in the ocean is a complex process. Sound propagates well in the ocean, but is reflected and refracted along its journey from a source (region) to the measurement site. Although the speed of sound is not frequency dependant, the attenuation of sound intensity is,
Cabled ocean observatories provide an ideal opportunity to collect ambient sound measurements. First, they have nearly unlimited bandwidth, allowing for very broadband measurements. Second, they do not have data storage limitations, as all data is archived at a data center and disk space is unlimited. Third, they are near permanent installations, and will provide the long-term archive necessary for quantification of marine soundscapes.

The University of Victoria has successfully installed and is fully operating two cabled ocean observatory networks covering the entire ocean depth range. The coastal network VENUS has four instrument locations in Saanich Inlet (1) and the Strait of Georgia (3), east of Vancouver Island. NEPTUNE Canada has nearly a dozen instrument locations spanning the inner shelf, the shelf break, the continental slope, the abyssal plane, and a deep tectonic ridge system. Together, these ocean networks represent an unprecedented system for designing, testing, and establishing long-term ambient sound measurements. In addition, real-time continuous auxiliary measurements such as temperature, salinity, and speed of sound profiles are available from existing sensors across the networks, thus providing a means for reconstructing the stratified acoustic ray-bending ocean environment.

Test deployments of broadband hydrophone systems are on-going, with several years of audio data already in the ONC archive. On VENUS, a directional hydrophone array has been deployed at several sites since 2006, while on NEPTUNE Canada, single hydrophones have been deployed at four key sites in 2009. A concurrent review of the two hydrophone system’s performance and a technology review are underway to develop a plan for the next generation of hydrophone systems for both VENUS and NEPTUNE. The goal is to have a common, reliable, broadband hydrophone array design that will allow for directional monitoring over the entire range of soundscapes represented by VENUS and NEPTUNE.

It is proposed that the Ocean Networks Canada ocean observatories, VENUS and NEPTUNE, be considered as one of the sites for long-term measurements of sound in the ocean, from near shore to the deep abyss.

**Passive acoustics as a requirement in ocean observatories**
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The global network of ocean observing systems is highly heterogeneous, spanning from autonomous or cabled deep-sea nodes to open-ocean stations and mobile platforms. As the set of facilities is requested to progressively harmonise its scientific objectives and technologies, the concept of observatory labeling was recently suggested as a means to help specify the requirements of the systems in order to respond as one interoperable network while maintaining
a range of regional, scientific and technological specificities. In European seafloor observatories, passive acoustics was recently introduced as one of the essential aspects to be covered besides biogeochemical variables and geophysics, highlighting that a shift towards truly inter- and multidisciplinary science is underway. When some cabled seafloor systems are already operating and include passive acoustic monitoring, e.g. NEMO-SN1 off-Sicily and the ALOHA off-Hawaii, open-ocean stations have not yet considered passive acoustics as a requirement. The technological challenge can be substantial depending on the objectives and the current technological status of the system. Technological disparities across systems are also still the rule rather than the exception and the cost of upgrading an observing node is a major limiting factor.

To set an IQOE some challenges have thus to be overcome:

1. Hardware and software technologies are available at all levels of the acquisition and processing chain. Identifying obstacles and reasons why passive acoustics has generally not been included in the science plans of current observatories may shed light on the methodology to reach the IQOE objectives.
2. Select a realistic implementation methodology including by separating short, medium and long term plans. Short-term could include autonomous systems with delayed mode processing, when long term should promote the inclusion of broadband communication and continuous power.
3. Obtain consensus on the interest of acoustics as a relevant means of increasing the multidisciplinary character of observing systems. This could be motivated by the development and implementation of complementary techniques like ocean regional tomography, life monitoring, thus not only focusing on physical ocean acoustic phenomena.
4. Include the mitigation of anthropogenic noise and monitor its impact on life in the ocean as part of the common strategy. This objective implies to implement a broad multidisciplinary framework where experts from several disciplines should be involved.
5. Develop requirements and procedures for rapid and free exchange of scientific and technical results that are relevant to several communities. This process will imply to define routes to achieve interoperability between the systems, i.e. instrument integration, data exchange, and common data policy procedures for standard sensors.
6. Study and identify the possibilities to implement sensor interoperability concepts, harmonized timing protocols and software-based open standards in order to enhance the hosting capacity of observatories, optimize and reduce costs of instrument operation and exchange.
7. Elucidate how non-research oriented ocean observing systems equipped with hydrophones in open ocean conditions can contribute and open up to the scientific community. Contacting with representatives and involving them in round tables where agreements can be defined and implemented is probably an essential aspect of the process.
Integrated Ocean Observing Systems (IOOS) have been under development by the oceanographic community over the past decade to serve the immediate and long-term needs of society (www.ioos.gov). The overarching goal is to provide practical products and information to society as a return on its long-term investment in oceanographic research. Demand is increasing for information about the state of our oceans to address a myriad of issues ranging from climate variability to fisheries management to public education. Customers for ocean observing systems range from government agencies to commercial shipping companies to the science projects of high school students. The archetypical Argo program (www.argo.ucsd.edu), a component of the Global Ocean Observing System (GOOS), was initiated following the landmark OceanObs'99 conference and reassessed during OceanObs'09. Regional ocean observing systems (www.usnfra.org, e.g., NANOOS www.nanoos.org), purposely distinct from NOAA, began to develop in the early 2000's. The OOSes are not research programs, but sustained monitoring, data-archiving, and information-providing services.

The Ocean Observing Initiative (OOI) developed out of the Deep Earth Observing System (DEOS) idea of the early 2000's to deploy platforms over the world's oceans for geophysical research. Funded by the National Science Foundation, the OOI has three main components: the undersea cabled networks (“Regional Scale Nodes,” e.g., Neptune www.interactiveoceans.washington.edu), five sustained moorings scattered over the world's ocean (“Global Scale Nodes”), and a small set of relocatable “Pioneer” platforms (“Coastal Scale Nodes”) for coastal oceanographic research. These components provide unprecedented, sustained platforms in the ocean for multidisciplinary research.

Acoustical techniques have been minimally represented in the OOS or OOI programs. This unfortunate situation is surprising. The oceans are largely transparent to sound, hence oceanographic, biological, engineering, and signal-processing acoustic techniques are primary tools for ocean observation. (The recent OceanObs'09 conference had no acoustical representation on the science panels, nor was acoustics represented in the initial program.) With the possibility of significant sustained funding for comprehensive oceanic observations, one hallmark of planning conferences has been their political overtones. Successful implementation of acoustical components for the IOOS require the sustained cooperation and encouragement of three factions: the oceanographic community, the national, state and private funding agencies, and the acoustics community. At present, the cultural gaps between these three factions are formidable.

The opportunities and value of acoustical observations and techniques within these systems are boundless, yet incorporation of these techniques has been opportunistic and ad hoc. If deployed instrumentation is to serve several purposes, as it should, coordination of the acoustical applications is essential. Insisting that the design specifications of the generic components of the observing system allow for acoustical applications (e.g., adequate time keeping, power, and data bandwidth capabilities) is also essential. Organizations advocating acoustical observations face
enormous challenges of planning, implementation and data management to bring acoustical tools to fruition for ocean observing systems.

**Existing acoustical elements of the Ocean Observing System** are eclectic and uncoordinated. Examples include, but are not limited to: A nascent acoustical contribution to the Arctic Ocean Observing System is being developed by the “ACoustic technology for OBserving the interior of the ARctic Ocean (ACOBAR http://acobar.nersc.no) consortium, including a small sustained tomographic array spanning Fram Strait. A sustained modest system of hydrophones in Puget Sound by the VENUS, the coastal network of the Ocean Networks Canada Observatory, focusing on marine mammals, ships, and biological sounds (http://venus.uvic.ca/research/ocean-processes/ocean-acoustics/). The eleven hydroacoustic monitoring stations of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), scattered throughout the world's oceans. The Ocean Tracking Network (http://oceantrackingnetwork.org) and the Australian Acoustic Tagging and Monitoring System (http://www.imos.org.au/aatams.html, part of the Australian Integrated Marine Observing System), both used to monitor the behavior and status of a large variety of marine animals. Although the case for monitoring the ocean's temperature variations on regional to basin scales using acoustic tomography is strong (a natural complement to the Argo float system), there are at present no such sustained observations.

**The Challenge of Ocean Noise Prediction and Characterization.**

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In order to address the issue of ambient noise monitoring, an operational global anthropic noise prediction system called Quonops has been designed similarly to weather forecasting systems. Quonops combines real-time environmental data and real-time human information, and assimilates real-time acoustic measurements to produce the resulting 3D ocean noise fields as a function of time. The system has been thought to cover most basins and activities. The initial version of the system aims to deliver a mapping service based on the current technical and scientific possibilities. The long-term goal is to improve the quality of the prediction by implementing emerging technologies, new methodologies, and improved knowledge.

The sound fields needs to be calibrated by means of in-situ acoustic measurements. Although certainly economical considerations have to be taken into considerations, there is a need to discuss the representativeness of ambient noise measurement by the means of punctual hydrophones. As a matter of fact, a hydrophone, by nature, will give a local and punctual knowledge. As long as the measurement is not contaminated with self-noise, mechanical noise from the mooring itself or the water flow around the sensor, measurement present the necessary advantage of providing a ground truth. However, as it is observed for marine mammals, masking effects between numbers of anthropic sources are likely to occur for significant period of times. Hydrophones therefore measure the closest noise events which raise the issue of the representativeness of in-situ measurements, and its assimilation into sound maps.
Sound and noise are changing, highly variable and evanescent by nature. The production of 3D sound fields gives access to the geographical characterization of the noise structure as a function of time for a given volume of water. The characterization of the sound is therefore a challenging task, and only a probabilistic approach should apply.

Experimental Approaches to Understanding Responses of Organisms to Specific Sources
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Experimental approaches are often separated into laboratory and field experiments, with the latter offering several different levels of control of experimental conditions. While laboratory studies will always have limits in their ability to forecast response in the field where animal motivation, attention, sensory abilities, health and social status are less easily known or controlled, there is no rational basis for arguments that laboratory studies have no value in understanding the effects of sound in the open ocean. In field research the development of Controlled Exposure Experiments (CEE) of increasing sophistication has been of immense value. Control of sound source characteristics and movement; use of tagged and photo-identified individuals; mapping of sound fields and prey fields; collection of biosamples for genetic and health information; and both visual and acoustic monitoring are all now possible for field experiments with marine mammals. However, less extensive, and less expensive, efforts involving as little as a controlled source and shore observations of surface behavior can still yield useful data. Experimental controls, a subject often foreign and unnatural feeling to the field observer, are a critical element of successful field experiments. Knowledge of the sound exposure regime brings with it opportunities for data bias, much of it unconscious and unavoidable. This makes control protocols especially important: effort to shield observers from knowledge of the exposure schedule, to conduct overlapping or duplicative observations that are blind to the other observers’ results, and the use of control or ‘false positive’ trials are all important tools in building confidence in the data from field experiments.

There are many areas for advancement, from applications of new tag technologies and acoustic monitoring to systematic manipulation of source characteristics. At present we have only tested a few species with a few sources of interest. What we still lack are carefully controlled tests of the relationship between responsiveness and amplitude. It is equally important to start investigating the role of context in responsiveness to sound: source movement, similarity to signals of interest, and other variables. Since many species of marine mammals are social we should also be very interested in social facilitation and the tendency of individual behavioral responses to converge over the course of an exposure event.

How do these kinds of studies help us meet the IQOE objectives? While the spirit and intent of IQOE as originally formulated is laudable, the logistic challenges and socio-economic costs of lessening existing noise over meaningful areas and time spans simply as an ‘experiment’ will be difficult. Engineering change through practical experiments like moving shipping lanes or closing areas to certain activities may be more feasible, but will still carry socio-economic costs that may be unacceptable. Adding noise is, unfortunately, the more feasible experimental approach.
Most focus thus far has been on short term, acute sound usage and response. But I think we are all equally concerned, if not more concerned, about chronic, ubiquitous, persistent noise sources. It is difficult to get the funding and to sustain the effort needed to adequately monitor noise exposure for months or years, but this is an important aspect of human noise safety regulation and should also be part of our thinking about underwater noise. As someone who has for many years been engaged in the battle to secure and maintain funding for this kind of research I am much concerned with the questions of who has the will, the funds, or the mandate to sustain long term efforts? For shorter studies the proponent of the action of immediate interest may end up shouldering the cost, but that does not solve the long term management of cumulative effects from many different actions. In any case some form of assurance is also needed that the money, public or private, is being well spent: that the research is buffered from political pressures, with proposals and publications independently peer reviewed, and so forth. The training of additional scientists or technical staff is important; stimulating good students to choose this field as a career. Last but not least there remain tools and technologies that need further development. I am thinking mainly of commercial sources of animal tags, hydrophones or recording systems for the non-expert, and acoustic signal processing systems capable of operation by non-experts.

It is often said that “we lack data” or “there are not enough data” [to support difficult decisions about noise management], so often, in fact, that these statements have lost whatever value or impact they may once have had. Decisions get made when they need to get made, with whatever data are available. The past decade has seen amazing advances in our ability to monitor and understand the significance of sound in ocean ecosystems. We are rapidly entering a stage when obtaining “any data” is simply not a good enough reason to do the work. The quality and relevance of scientific effort in this field must continue to set higher standards and demonstrate an underlying comprehension of where a project fits in our overall understanding of the key knowledge areas of: underwater sound, marine animal hearing, hearing-mediated behavior, socio-economic trends in human use of the marine environment, and management practices for the sustained health and productivity of our oceans. This is a challenging goal for ocean acoustics, but one that I think it attainable and, most importantly, is a goal that will provide value to ocean protection and stewardship far beyond the immediate goal of managing anthropogenic sound.

Ocean soundscapes
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The Canadian composer R. Murray Schafer coined the term ‘soundscape’ to denote the assemblage of sounds that "describe a place, a sonic identity, a sonic memory, but always a sound that is pertinent to a place".

On this basis an ocean soundscape would describe the acoustical features of a particular volume of water. As with a terrestrial landscape, which is seen from a viewpoint, a soundscape is audible from a particular position. And it is detected by a specific receiving system, whether a hydrophone or the ear of an animal. The soundscape can be considered in terms of the aggregate
of sounds as received and interpreted by the listener, with those sounds emanating from a variety of sources, only some of which can be located.

The soundscape includes both the natural acoustic environment, consisting of sounds from animals and other natural elements like waves; but it may also include anthropogenic sounds, created through human activities, including those resulting from industrial technology. Disruption of a natural soundscape may be described as noise pollution.

There may be keynote sounds, which form the character of that particular soundscape, emanating from the dominant sources of sound. In ocean noise terms those sounds may characterise the animals living there or reflect the natural topography, oceanography and climate, or even the industrial activities that affect the site. A scientist may describe the spectral, temporal and directional characteristics of a particular soundscape, and may set out to analyse, locate and model the sources contributing to the received soundscape. From a more subjective standpoint the soundscape can be seen as providing information to a human or an animal about the surrounding environment, about which judgements may be made. A soundscape, like a landscape, be described as beautiful or ugly to the ear of an individual listener.

Those interested in the aesthetic experience of listening to sounds have recently tried to appropriate for themselves the concept of the soundscape. See for example the work of the Acoustic Ecology Institute at http://www.acousticecology.org/ and of the World Forum for Acoustic Ecology (WFAE), an international association of affiliated organisations that share a common concern with the state of the world's soundscapes (http://wfae.proscenia.net/). Soundscape: The Journal of Acoustic Ecology has been established as a place of dialogue and debate for those with an interest in acoustic ecology and the description, creation, improvement or modelling of particular soundscapes. In the field of acoustic ecology, emphasis is placed on the role of the listener in the listening environment and often upon improving the acoustic quality of places and the protection and maintenance of ‘acoustically balanced’ soundscapes.

In considering ocean soundscapes one of the main issues therefore is how soundscapes are best treated. Should soundscapes be described solely in terms of objective acoustical metrics or should their description take account of the impact upon human and animal listeners, and be concerned with issues of changing sound quality from a sentient receiver’s perspective? There is a whole community of people out there who support the latter approach.

**Describing ocean soundscapes**
A D Hawkins, Loughine Ltd., Kincraig, Blairs, Aberdeen, UK

Different listeners may perceive and interpret the soundscape in different ways. Some may place emphasis on those sounds that are pleasing; others may be more concerned with those that are not. Listeners may devise their own subjective descriptions. Scientists too may describe soundscapes in terms of their own particular interests, whether these are the sounds of particular animals, or industrial sounds from particular sources. Receiving equipment is tailored to specific requirements, and is often designed to exclude sounds judged to be of lesser importance.
Our task must be to describe soundscapes objectively, in terms of all their acoustical features, taking advantage of the great expansion in the acoustical tools now available.

A soundscape can be described in terms of the overall characteristics of the ambient noise, without attributing sounds to individual sources. But it can also be regarded as an aggregation of separate sources, which can be distinguished from one another. The relative contribution of different sources may be estimated from modelling their propagation and from knowledge of their individual characteristics. Soundscapes, and the contributions from different sources, will also vary with time. Soundscapes can also be examined from different locations, and their directional and spatial attributes examined. The challenge is to provide better representations of soundscapes, which might enable regulators and the general public to understand the implications of any changes that are taking place. There is a particular need to provide more helpful visual representations of acoustical data, set out on paper where they are amenable to discussion and analysis.

However, it is not only a description of each soundscape that is required. We may have to evaluate the effects of anthropogenic noise within a soundscape. Scientists may have the same interest as acoustic ecologists in preserving a high quality acoustical environment. The ecological costs of industrial noise in the ocean must be assessed and objective judgments made on whether the noise is harmful or not.

Much attention has already been directed at identifying the direct effects of sound sources upon the survival, hearing abilities, health and specific behavior patterns of individual animals. Important adverse effects include disruption of behavior, loss of attention, masking of key signals, impaired communication, diversion of time and energy and avoidance of important habitats and resources. But it is the population effects and ecological impacts of the whole soundscape that are really critical. New assessment tools are required, including derived metrics that better express and display effects on both individuals and populations.

One example of a novel paradigm sets out to examine masking by anthropogenic sound, which has an effect upon animals’ abilities to communicate, navigate, avoid predators and capture prey. Clark and others have defined ‘communication space’ as the volume of space surrounding an individual, within which acoustic communication with other conspecifics can be expected to occur. The authors have translated the concept of acoustical space into a series of mathematical expressions based on the sonar equations, and have developed a metric to quantify the potential for masking communication.

We need more derived metrics of this kind, which characterize soundscapes in terms of their implications for living organisms in an objective but holistic way.

**Passive monitoring of marine environment for marine mammal risk mitigation and ocean soundscape modelling**

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In recent years there is increasing concern about the impacts of underwater noises on marine life. Considerable effort has been devoted to relevant research topics, such as the acoustic systems/characteristics of marine organisms, and the long term trends of ocean ambient noise levels. Although we have known much more about marine mammal acoustics than what we did a decade ago, little quantified knowledge is available to address what the limitation of ocean ambient noise levels are that will disturb/damage marine organisms regionally and globally. Hence it is hard to provide scientific basis for establishing corresponding regulations. Inherently, systematic and long term observations are required to fulfill the knowledge gaps for assessing, predicting and understanding the effects of ocean noises on marine organisms.

Due to the regulations at the NATO Undersea Research Center (NURC) about sonar operation related research, NURC has been developing acoustic monitoring systems since 1999. In order to have the least impact on marine life, the acoustic monitoring systems were designed to work at passive mode, and to be operated on relatively low noise platforms. Two typical passive monitoring systems developed at NURC are CPAM (Compact Passive Acoustic Monitor, towed), and HYDRA (High Yield Data Recording acoustic Array, bottom mounted). Glider with CTD and acoustic sensors onboard was also employed in a most recent sea trial for Marine Mammal Risk Mitigation Project, led by Dr. D. Hughes. Some features of the systems are as following:

- Broadband: 0 – (up to) 100 kHz, to cover the most frequency band of the sounds in the ocean;
- Long period of time, self recording and easy to deploy: (HYDRA, few months, can be improved)
- Capable of providing 3D direction information (CPAM and HYDRA)
- Fly along pre-programmed survey routes and at depth of interests (Glider).

The observation systems are expected to measure diurnal/seasonal/annual ambient noise level variations, and daily activity related vocals of marine mammals at the same time. By use of these long term recorded acoustic data, the correlation between the changes in marine mammal behavior and human generated sounds that introduced by industrial/ military activities will be studied.

NURC has a long history of underwater acoustic research and underwater acoustic propagation model development. It is well established that environmental knowledge has great impact on the accuracy of ocean soundscape modelling. The information from NURC acoustic monitoring systems will be used to characterize the ocean environment (oceanographic and geophysical parameters) for better soundscape prediction. Furthermore, the measured data can also be used to validate ocean soundscape models.
The Soundscape of the Southern Ocean – How Quiet and how Loud can Nature be?
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The Southern Ocean around the Antarctic continent provides some of the most extreme environmental conditions on earth which shape also the unique underwater soundscape. The area probably contains the most quiet locations within the world's oceans but is also stage for some of the loudest natural events. It is still relatively void of anthropogenic noise and is one of the most important feeding grounds for great whales. However, comparatively little acoustic data exists from this region so far because the collection of acoustic recordings is hindered by logistic constraints associated with this remote region.

Very Quiet
The large cavities below the giant floating ice shelves of Antarctica are amongst the most isolated areas in the world - but with a window to the open sea. Neither local surface noise nor biological sources are present within hundreds of kilometers radius. Sound levels here should reflect unbiased readings of the long-range acoustic energy field - and yield a lower boundary of how quiet the ocean can get. During much of the year large parts of the polar oceans are covered by sea ice, which has a significant impact on the underwater acoustics. Sea ice isolates the water from the air, impeding the generation of waves, while the snow layer absorbs acoustic energy efficiently, creating an "anechoic chamber" which may serve as a natural lab to test and verify sound propagation models.

Very Loud
But ice is also a major source of noise. Table icebergs, calved from the shelf, are the largest moving objects on earth, spanning areas of 1000 square kilometers with a thickness of several hundred meters. Driven by the ocean currents, billions of tons of ice can gain terajoules of kinetic energy, equaling that of a nuclear bomb. This energy can be released within a brief period of time when the iceberg touches ground or collides with other bergs or the ice shelf. These events produce some of the loudest natural broadband sounds in the ocean, rivaled only by earthquakes and can be recorded in distances as far as other continents. They would probably make perfect test signals to measure long range broadband sound propagation. However, their occurrence is relatively sparse, we detect about one or two such events in the vicinity of our Antarctic observatory per year. Additionally, smaller but frequent iceberg calving events, reaming of ice floes, exploding little bubbles of high pressure gas occlusions in melting glacier ice combine to a most diverse abiotic soundscape.

Relevant Biology
However, it is the biology that produces the major contribution to the overall sound budget here. Despite the reduction of the blue whale population to a small fraction of their pre whaling size, the chorus of blue whales is the predominant acoustic source in the Southern Ocean, present on 365 days per year. Together with about ten other marine mammal species occupying this ocean area, they fill the whole audible frequency range with relatively little spatio-temporal overlap, suggesting that acoustic bandwidth is an important natural resource that different species compete for. Here we have the unique chance to study the acoustic ecology of a large ecosystem which is not yet significantly influenced by anthropogenic sound and resides in an extremely rich
natural soundscape. And as many of its acoustic ingredients compare to anthropogenic emissions in other areas of the world, one could derive reference models of the interaction of sound and biology from here.

Data Acquisition
All this is based on long term, wide area and high quality passive acoustic data. Our current effort builds on an established network of oceanographic moorings in the Weddell sea, which is fitted with long term acoustic recorders capable of recording broad band audio continuously for several years. Along with the permanent acoustic observatory on the ice shelf, PALAOA, which features a hydrophone array protected under a 100 m thick ice shield, this covers a significant part of the Weddell basin from the shore to the deep sea. Sea ice coverage and ice berg movement is captured by high resolution satellite images and local ship traffic is monitored by AIS receivers. Our acoustic record spans 6 years by now will be continued to be able to characterize typical annual fluctuations and long term trends in both the acoustic background and animal behavior and set them in relation to abiotic factors. We believe that this dataset will serve as a valuable reference for many ocean noise related questions and encourage to set up a similar networks in other polar seas.

Ocean Soundscapes
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One of the keys to quantifying soundscapes is to identify the sounds produced by different animals, including invertebrates, fishes, and marine mammals.

Acoustic recordings in the ocean often reveal biological sounds produced by unknown sources. These unknown sound sources can be the dominant sound sources in an area. Recent recordings from the Gulf of Mexico show that we only know the identity of two of the top ten most common sound producing fishes. This includes sounds that are recorded over hundreds of kilometers for hours each night, and are the dominant sound sources at low frequencies (below 1000 Hz).

While sound is commonly used for communication in the deep sea, there are no confirmed recordings of sound production by deep-sea fishes, despite the identification of sound producing muscles in deep-sea fishes 40 years ago. This is no doubt due to the difficulty of working in the deep-sea. The deep-sea typically has very low background noise levels, and is thus potentially at higher risk to increases in anthropogenic noise. Many of the deep-sea fishes with sonic muscles are commercially important species, such as grenadiers.

For fishes most identifications of species-specific sounds comes from either laboratory recordings or field recordings with video. The earliest comprehensive work in this field comes from Fish and Mowbray who surveyed many fish species. Most of their recordings were made in captivity with disturbed (poked, prodded, shocked) fish. Many of the sounds recorded in the field, are different from those made in response to disturbance, because they are produced during courtship or spawning. It is important that recordings be made in natural situations to document
sound production by a given species and to determine the context in which sound is used. If acoustic communication is critical for successful spawning, then increased levels of noise could impair reproduction.

Finally, it is important that we don’t assume all the sounds produced by different animals are known. For example, in bottlenose dolphins, much attention has been given to signature whistles and echolocation signals. However, they make a wide variety of other sounds in lower frequency ranges in different contexts, such as feeding and reproduction. It is important that the behavioral context in which sound is used is determined.

Ocean Noise Budgets
Many animals are capable of detecting sound close to the natural noise floor at frequencies where their hearing is most sensitive. One way to understand the potential impact of noise over large temporal and spatial scales is to determine the fraction of time that the noise floor in different frequency ranges is dominated by natural noise versus anthropogenic sound.

Recommendations

- Identify the most common biological sound sources in the ocean. This research should be conducted globally from shallow estuaries to the deep ocean.
- The context in which animals produce sounds needs to be determined.
- Develop new techniques for identifying sounds produced by different animals, such as attachable or implantable recording tags.
- Develop automated techniques to determine whether the background noise floor is dominated by natural or anthropogenic sound sources.

Opportunistic studies of changes in underwater soundscapes related to ship traffic patterns
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Simultaneous long-term monitoring of commercial ship traffic and underwater noise provides an opportunity to study fluctuations in low-frequency ambient noise. Examples are drawn from regions off the coast of southern California and the Gulf of Mexico. Between 2007 and 2010, two events occurred that resulted in a decrease in ship traffic in the Santa Barbara Channel, a coastal basin in southern CA: the economic recession and a coastal air-quality improvement rule. Monthly statistics of low-frequency ambient noise during this time period at a site 3 km from a major shipping route were compared to regional traffic levels. Two different metrics of ship traffic (number of ships per day from the Automatic Identification System and container traffic from port statistics) showed that on average a 1 dB reduction in low-frequency noise levels resulted from a decrease in traffic by 1 ship per day.

During the 2010 Gulf of Mexico oil spill a large number of vessels were involved in the spill response and cleanup. The high density of vessels resulted in high levels of ambient noise in the northern Gulf of Mexico. Tropical Storm Bonnie passed near the spill area and as a safety
precaution, most of the oil spill response ships were evacuated from the area for several days, resulting in a \( \sim 15 \) dB decrease in regional ambient noise. Combining ambient noise data and ship tracking data will allow estimation of the contribution of oil service, drillship and other vessel types to the ambient noise field.

These decreases in ocean noise provide direct evidence for the impact on the ecosystem from human activity and present a unique opportunity to understand the magnitude of change necessary to improve acoustic habitat quality. Furthermore, the behavioral response of animals to dynamic soundscapes can be examined. We investigated the vocal behavior of endangered northeast Pacific blue whales (*Balaenoptera musculus*) in the different background noise levels within the Santa Barbara Channel. Despite the high levels of ship traffic in the region and subsequent increased background noise level, blue whales continued to call; therefore, we developed techniques to investigate calling rate and call amplitude to provide additional insight into the potential vocal responses to ship noise. When ships were present, we found evidence for modifications in call interval, type, and amplitude related to the increase in noise from transiting ships. The similar results of song calling patterns in 2008 and 2009 support the hypothesis that blue whales are compensating for increases in background noise with short-term vocal adjustments - instead of modifications specific to the average noise levels of a region. These findings add to a growing body of literature identifying how animals are adjusting to the increased background noise from the urbanization of their habitats and highlight the importance of developing meaningful statistics for underwater soundscapes.

**Discussion points for developing a Ocean Acoustical Observing System in support of the International Quiet Ocean Experiment (IQOE)**

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The design and development of a Global Ocean Acoustical Observing System in support of the International Quiet Ocean Experiment (IQOE) is an opportunity to design an observation system around the acquisition of acoustic data instead of trying to integrate acoustic sensors into already established ocean monitoring systems. For the purposes of discussion during the IQOE open science meeting, I’d like to start with a blank slate in considering the optimal acoustic and ancillary sensors as well as mechanisms for data transfer, as this is an opportunity to think “outside the box” in creating sensors and a system to meet the specific objective of coordinating the international research community to both quantify the ocean soundscape and examine the functional relationship between sound and the viability of key marine organisms.

I feel one of the most difficult challenges in meeting the stated objective is to develop a strategy and associated observation system for being able to measure and define the relationship between sound, animals, and the environment. There is not only a large amount of spatial and temporal variability of noise in the ocean, but also in ocean productivity and physical processes that influence marine animal distribution and behavior. We need to be able to effectively address these confounding variables when teasing out the observed response of animals to sound. To do this we need to be making the necessary measurement of ocean processes to correctly interpret observations related to noise. What are ocean parameters that need to be measured to provide adequate context for interpreting marine animal response to sound?
The initial concept of the IQOE includes both an experimental and comparative approach in examining the interaction of marine organisms and sound. Both of these approaches requires knowledge of the animals’ environment from an acoustical, biological, and physical perspective in order to most effective and accurately interpret observed patterns in relation to sound levels and changes. Is one observation system appropriate for both approaches?

Over the course of the ocean observation system discussion, there will be a need to discuss present sensor technology, technological development of sensors, data transfer logistics, and potential integration of new sensors into already established observation systems. I encourage participants to not limit themselves to what is currently available but to aim high in designing the optimal system to meet the experiment objectives, which may require the design and implementation of a new type of observation infrastructure.

Guiding discussion topics include:

1. What are ocean parameters that need to be measured to provide adequate context for interpreting marine animal response to sound?
   a. Sensor requirements
   b. Data transfer requirements
   c. Observation node placement
   d. Potential use of existing systems
2. Is one observation system appropriate for both the experimental and comparative approaches?
   a. Requirements for each approach
   b. Factors (from the perspective of ocean observation) to consider when selecting an experimental region

An idea for collecting data for creating and/or validating Soundscapes
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Given the rapid development of relatively high quality acoustic recording devices and the ready access to hydrophones, I suggest that IQOE consider investing in a large set of ‘Field-Ready acoustic recOrding packaGes’ (FROGs). The FROGs could be provided to researchers, fishers, managers, recreational boaters, etc., and with little instruction these folks could make recordings around the globe. The data collectors could then upload the raw files to an IQOE hosted site, which could then be analyzed by persons working on the IQOE project. This system would not be appropriate for recording very low frequencies, but for much of the band of interest these systems could provide useful data. How would the system work? Here’s an example: the U.S. Antarctic research vessels transit the Drake Passage several times/year, as well as sailing through many areas of the Southern Ocean. One of these ships, the ASRV LM Gould makes XBT
measurements as it transits the Drake Passage, and they could be asked to stop for a short time (weather permitting) and make short acoustic recordings.

Equipment to be included in the FROGs:

- Handheld digital recording device (e.g., Microtrack, Tascam DR-07 mkii)
- General purpose hydrophone (e.g., Hi-Tech SSQ-min)
- Handheld GPS for logging locations of recordings
- Small waterproof case that contains all equipment
- Estimated cost: $400

Ocean soundscapes from low-duty cycle, broadband, adaptive recorders
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Low duty cycle recorders have the capacity to make long-deployment acoustic measurements that can be used to describe ocean soundscapes and sound budgets without the need to store large quantities of temporal acoustic recordings.

The key to formulating a soundscape is identifying the unique characteristics of different marine sound sources. If this can be done from spectral components alone, then massive post-process analysis of the recorded data can be avoided. The soundscape and sound budget can be described from spectra alone.

This classification of the sound source is essential before quantification of physical processes such as wind and precipitation can be attempted from the ambient sound.

This classification of the sound source also allows adaptive sampling strategies for different sound sources to be implemented.

Specific sounds, for example, clicking from beaked whales, can be targeted, allowing selective temporal acoustic recordings to be saved for further analysis. This allows focused collection of sounds of interest on the recorder.

A low-duty cycle recorder is an acoustic event detector. Different physical processes have different time scales that can be used to aid identification. The recorder needs to sample several times during an event to detect that event. Events also include non-physical processes including calling bouts from animals and anthropogenic activities including for example, ship passages or industrial activity.

Geophysical signals are often stationary over the duration of a single sample, only a few seconds long. Biological signals (calls and clicks) are often non-stationary over the single sample, allowing click detectors or other software to find these signals.
Low-duty cycle, broadband, passive acoustic monitoring technology is being implemented on Argo floats to support the NASA Aquarius/SAC-D satellite mission. Up to 70 acoustically equipped Argo floats will be deployed in the next two years. These data include absolute sound levels, and are reported by satellite link every 5-10 days.

**Global Ocean Soundscapes**
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The International Quiet Ocean Experiment seeks to define global ocean soundscapes as prerequisites to appropriate design, planning, and implementation of human activities that introduce noise in the ocean. Models that can accurately estimate such soundscapes are needed to set standards for noise production in the ocean, while avoiding excessive precaution and over-regulation. However, modeling ocean soundscapes is difficult because of the inherent spatial and temporal variability of sound fields in the ocean.

A preliminary capability has been set up to model and visualize global ocean soundscapes. This involves a sound propagation model with inputs from sound sources (global shipping data) and environmental information (bottom hardness, oceanography, and bathymetry). The output consists of global images of ship-induced soundscapes.

We envision that such soundscapes could be provided and updated several times per day using global oceanographic forecasts such as those of the HYbrid Coordinate Ocean Model (HYCOM). Further, they could incorporate real-time information on storms, ship locations, air guns, etc. The acoustic simulations are rapid enough to keep up with these inputs.

The modeling work described brings up several scientific discussion topics because accurate predictions of these soundscapes require accurate knowledge of the bottom hardness for which knowledge is notably sparse in global databases. Could we overcome this deficiency by using observations of the sound field to learn about the bottom hardness, which in turn improves our ability to forecast the soundscapes? Can we use measurements at one frequency to improve the environmental knowledge, to help predictions at another? For instance, wave-wave interaction produces a ubiquitous 'lighting' of the ocean bottom. Further, can we incorporate in real time the information from sound sensors (underwater acoustic arrays) to track ships at sea and estimate their levels, further improving the accuracy of the soundscape forecasts?

**Small but powerful automatic underwater sound monitoring system (AUSOMS) for possible used in IQOE**
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An International Quite Ocean Experiment (IQOE) requires multiple calibrated fixed hydrophone systems to monitor present noise condition in the ocean. An AUSOMS (Automatic Underwater
Sound Monitoring System) designed for passive acoustic surveys of phonating marine organisms, can be used for the noise monitoring as well. The AUSOMS products have been applied for the survey of dugong in Thailand, humpback whales and dolphins in Okinawa Island as well as the monitoring of underwater construction noise in Tokyo Bay.

The AUSOMS records underwater sound of frequency range between 20 Hz to 20 kHz by monaural (1 ch) or stereo (2 ch) hydrophones at sampling frequency of 44.1 kHz (variable at latest version, maximum sampling frequency is 192 kHz) with 16 bits resolution. This instrument can record up to 15 days (at 2 ch, 44.1 kHz) continuously with 16 alkaline D cells. Flexible scheduled operation such as the start time, duration and recording mode are programable. Underwater sound data are stored in 1.8 inch hard disk without compression (WAV format), which avoid any distortion of data storing especially broadband noises. The AUSOMS can be selected 2 type hydrophones. One is for low frequency band (20 Hz to 20 kHz) and the other is for high frequency (20 Hz to 100 kHz) underwater sound. The receiving sensibility of low frequency hydrophone and high frequency hydrophone are -193 dB and -210 dB (1V/μPa), respectively. Both are omnidirectional hydrophones. Frequency response of the low frequency hydrophone is flat within 5 dB between 20 Hz - 20 kHz and the high frequency hydrophone is flat within 5 dB between 20 Hz - 100 kHz. The amplifier (40 dB to 70 dB, 10 dB steps) and the high pass filters (thru, 200 Hz, 1 kHz and 4 kHz) are available. It is 7 kg in weight in the air including 16 alkaline D cells, 900 mm in diameter and 530 mm in length. This compact size system enables smooth installation and recovery by a human diver using a small boat. The water proof case up to 100 m is made by stainless steel.

The AUSOMS is small and light underwater sound recording device. The AUSOMS can be installed on sea bed or moored at a rope. The AUSOMS series will be useful tools for IQOE’s range wide and long term monitoring with cost effective benefit.

**IQOE – One-Page Discussion Paper**
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My observations ahead of the IQOE discussions in Paris will likely be redundant of others, and are in some ways to points made in our Oceanography article from earlier this year, but I will make them anyway. These perspectives presume that a sustained, strategic, and international collaboration for acoustic monitoring of the oceans is needed.

(1) Acoustic monitoring capabilities as part of regional and basin-scale systems should be leveraged in large part on existing or future ocean observing systems. Additional dedicated deployments may be necessary or logical in some areas of more intense local emphasis. However, most effort should be made to integrate acoustics into traditional observing/monitoring systems that lack but could reasonably accommodate passive acoustic capabilities.

(2) There is a temptation to get as much acoustic data as possible through the integration of passive acoustics into ocean observing systems, but efforts must be coordinated and strategic. The overarching approach should assess differences, similarities, or trends in
acoustic conditions in different areas according to several important contrasts. These
include:

a. Areas of variable biological diversity and abundance;
b. Areas of variable anthropogenic footprint;
c. Areas of anticipated variance in climate, biology, or anthropogenic activity; this
should obviously include the Arctic, but also some areas where changes are occurring
along fewer dimensions.

(3) Of equal importance to a strategic deployment strategy for acoustic monitoring is the
need for a systematic and standardized data management structure. The volume of
information coming from the unintegrated smattering of deployments and systems is
already overwhelming. Information and potentially important trends and observations are
likely to be lost or unutilized unless an explicit strategy is implemented for how data will
be archived, analyzed, and shared for analysis. Data standards in acquisition and
reporting are an important part of this, as are the development of data-sharing agreements
that ensure the rights of individual data holders.

Signal characteristics, masking models, and sensory systems of marine animals.
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The majority of study cases used to determine auditory thresholds, masking properties, and
behavioral responses to sounds use tightly controlled sound sources such as sinusoids and
sinusoidal-derived broad-band noise. While these sources are easy to control and thus yield more
predictable responses (and are easier to model), they are a poor proxy for the many types of
sounds that are increasingly being used in ocean technologies, and not representative of habitat
conditions.

Additionally, our models of impacts such as masking and auditory thresholds are often based on
terrestrial hearing priorities and may not accurately reflect the way that marine animals inhabit
their particular sound scenes.

1) Signal characteristics
One area that would yield much needed data include an understanding of the effects of the types
of sounds being introduced. Digital communication signals or constantly operating machinery
(for example) introduce sounds into marine habitat that are entirely new to the environment.
Characteristics such as fast rise-time, high kurtosis, “unlikely” harmonic combinations, and
constant, very broad-band noise may have behavioral impacts that are not revealed in more
typical sound exposure protocols used in the lab.

2) Masking models
Some of the assumptions made about masking for marine animals are predicated on terrestrial
animal hearing system priorities. Sensory systems of marine animals may have adapted to
potentially interfering noise by using sensory integrations which do not have terrestrial analogies
– such as signal discrimination in the time-domain. This might include the ability of fish to
discriminate useful particle/pressure gradient phase information in the near field while not being
sensitive to “phase-aligned” far-field noise. It is possible that bio-sonar receive signals are time-correlated to the send signal, allowing echo-locating animals to filter out returning signals outside of the range of “likely” reflections.

3) Sensory systems
Consistent with some of the above, sensory system information of marine animals need to be examined in the context of the particular species habitat needs. For example auditory threshold tests using operant conditioning may overlook the possibility that there may be a signal characteristic or frequency sensory transitions between voluntary and autonomic nervous system responses to acoustical stimulus.

Three key points to the IQOE discussion - noise exposure criteria, ability of numerical modeling of ocean soundscapes and new technologies for monitoring and mitigation of impact of manmade noise on Marine Mammals

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We would like to suggest three key points of studies in which our Institute has been involved for discussion to plan investigations and collaborations in frame IQOE for forthcoming years. These proposals probably should be considered in different Working Groups of the IQOI meeting.

- The first problem (may be highest priority) is absence of real international regulation and guidelines for the Noise Exposure Criterion giving thresholds for adverse behavioral response at assessing impacts of anthropogenic sound on marine mammals and fish. Since publishing "Marine mammal noise exposure criteria: initial scientific recommendations" (Southel et al., 2007) we don't see any essential updating. As it was reported in 2010 on the 2nd International Conference “The Effects of Noise on Aquatic Life” in Cork, Ireland neither NOAA Guidelines (see Scholik-Schlomer conf. paper) nor in MSFD (EC Marine Strategy Framework Directive, presented by Tasker on Cork conf.) have any essential progress and actual changes yet. We vitally need guidelines and quantitative thresholds for SEL metric (Sound Exposure Level) to use it right now e.g. in today's acoustic monitoring of huge industrial activity off the Sakhalin island (Russia) close to feeding area of critically endangered Western Gray Whales population. We already proposed a SEL based Criteria for continuous noise (Nowacek et al., Cork conf.) but oil companies only partially adopt them because of lack of appropriate scientific data, international regulation and national legislation.

- We strongly support one of the IQOE ideas to provide predicting sound fields across the global ocean by sound propagation modeling. Recently in frame of the European Commission Seventh Framework Programme (Project “ACCESS”) we have done estimation of the noise pollution in the Arctic for the site of future location of the Shtokman Gas-Condensate Field in Barents Sea. For TL calculation we used PDPE model (also known as “split-step Pade technique”). Estimated noise budget includes 77 fishing ships really distributed in Barents Sea in
May and sea surface noise at wind velocity 10m/s and 20 m/s. The results for sea depth 100 m in frequency bend up to 500 Hz showed full dominating of the sea surface noise. Integral noise level in this bend was estimated for ships as 92 dB re µPa while noise from surface -105 dB re µPa at 10 m/s and 113 dB re µPa at 20 m/s. We are sure this approach is very appropriate to provide a general view of the sound fields across the global ocean by sound propagation modeling but need new steps in cooperation and sharing database of oceanic environmental parameters.

- We propose to discuss a mechanism for coordinating of existing activity on developing fully functional system for acoustic monitoring of noise impact on marine mammals. Today we participate in joined Russian-French Project “Satellite buoy for acoustical detection and classification of marine mammals at monitoring industrial noise impact on them”. Our concept based on construction three-in-one tool for passive acoustic measurements of industrial noise levels, synchronous detection of the presence of vocal marine mammals species by using new algorithms and transmission of this data and/or decision on shutdown of sound sources directly to Internet in real time. This tools could be not only the means for acoustic monitoring of impact on marine organism but instrument for conducting innovative experimental studies on the effects of sound and real time acquisition of the physical parameters of the ocean environment too.

Understanding Biologically Significant Responses of Organisms to Specific Sound Sources
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Sound in the oceans is generated by a variety of natural and anthropogenic sources, and may affect marine life at multiple levels from behavioral disruption to population level effects. Numerous scientific and government panels and task forces have called for directed behavioral response studies to identify the causal link between sound exposure and behavioral responses that could lead to strandings. Recent federally funded behavioral response studies are designed to obtain direct measurements of responses to simulated sonar and other sound exposure that indicate onset of behavioral disruption in different contexts. Ultimately, the goal of BRS studies is to provide a scientific basis for estimating risk and supporting and/or improving environmental assessments and science-based mitigation measures for future operations. There is a need, however, to differentiate between disturbance resulting in minor behavioral changes and the disruption of biologically significant activities, including but not limited to, migration, breeding, care of young, predator avoidance or defense, and feeding.

In 2005, the National Resource Council (NRC) set out to clarify the term ‘biologically significant’. In the broadest sense, any action or activity becomes biologically significant in an individual animal when it affects the ability of the animal to grow, survive, and reproduce. The committee provided a conceptual framework to structure future 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 issued its report, and advances in research that were not considered explicitly by the committee,
have made it possible to transform this conceptual framework into a more formal model structure.

Research sponsored by the Office of Naval Research (ONR) and the Chief of Naval Operations Energy and the Environment Readiness Division (N45) is addressing the potential behavioral response of animals to sound exposure through controlled-exposure experiments and opportunistic studies on Navy ranges. Knowledge of how effects transfer between behavior and life functions, and between life functions and vital rates, is limited. Improved understanding of these transfer functions, whether theoretical or empirical, will help guide research and management efforts, and project how marine mammals may respond to alternative future scenarios of anthropogenic sound. In 2009, ONR has convened a collaborative group of researchers who cooperate and meet regularly to examine the population-level effects of sound exposure on marine mammals. Recent theoretical and empirical work has substantially improved understanding of the population-level effects of multiple sources of disturbance, including sound, on marine mammals.

In discussing and developing experimental approaches to understanding responses of organisms to sound it might be instructive to draw from recent theoretical and empirical work on population-level effects of sound to focus future efforts on understanding the responses that might be biologically significant for the individual and population.

**Approaches to Evaluating the Physiological Responses of Organisms to Specific Sound Sources**

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Marine mammals are exposed to a variety of potentially stressful anthropogenic and natural environmental inputs in both the wild and captive environments. Potential stressors include noise, pollutants, threatening stimuli such as fishing gear, habitat disruption, ecosystem changes in free-ranging animals, and transport/restraint, novel environments, and social interactions for animals maintained under human care. Previous and recently federally funded behavioral response studies have sought to identify and characterize behavioral changes associated with exposure to anthropogenic sound and effects on the auditory system; however, there is a lack of scientific data and knowledge of the physiological effects of sound exposure on marine mammals. Behavioral responses are an overt and observable response to anthropogenic sound, but population level effects of this sound will be modulated through physiological stress response.

The stress response in marine mammals has been shown to conform to the classical definition of the generalized stress response, which is defined by activation of the hypothalamic–pituitary–adrenal (HPA) axis in response to an internal or external stimuli (or stressor) resulting in elevated levels of glucocorticoid (GC) hormones (i.e. cortisol and corticosterone). The involvement of the sympathetic nervous system (SNS) in the stress response is immediate and acute in terrestrial and marine mammals and is characterized by the release of the neurohormones norepinephrine and epinephrine (i.e., the catecholamines). Whether the response
is beneficial or deleterious depends on the magnitude and duration of the response and the condition of the animal exposed to the stressor.

Interpreting point measures of endocrine responses to a stressor requires a good understanding of the natural variation in hormones associated with the generalized stress response. In wild animals, where blood is difficult or impossible to sample, this understanding must extend to matrices (i.e. biological samples such as blubber or hair) which are more likely to be sampled. Although levels of stress hormones such as cortisol in the bloodstream provide relevant information and are the “gold standard” in stress physiology, accumulation in non-blood matrices such as blubber, hair, feces, and blow may provide superior measures of chronic stress since they are integrated measures of the magnitude and duration of physiological stress responses. Thus, to use stress hormones from non-blood matrices as indices of stress, the relationship between the levels and dynamics of hormones in blood and nonblood matrices must be determined.

Little is known about long-term effects of stress on individuals and populations in marine mammals. Prolonged exposure to stress may result in immune system suppression, reproductive failure, accelerated aging, and slowed growth. If GCs are not the primary mechanism, they and other biomarkers may well be indicators of the cascade of effects leading from behavioral changes to alterations in reproduction and survival.

**Integrated Acoustic Systems for Ocean Observations**

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Ocean acoustic observing systems can and should do far more than simply make measurements of the global ocean sound field to assess the possible impacts of anthropogenic sound on marine organisms.

*Passive acoustic systems.* Passive systems can be used for many purposes in addition to providing information to help assess possible environmental impacts of human activities, including for example, (1) tracking, counting, and studying the behavior of vocalizing marine mammals and fish; (2) assessing and monitoring the impacts of ocean warming and acidification on marine ecosystems and biodiversity; (3) detecting undersea explosions such as blast fishing or nuclear tests; (4) detecting and quantifying tsunamis; (5) measuring wind and rainfall; (6) measuring the properties of undersea earthquakes and volcanoes; (7) monitoring the sound produced by high-latitude sea ice; (8) monitoring anthropogenic activities in marine protected areas.

*Active acoustic systems.* Active systems, employing the same receiving systems used for passive acoustic measurements, can be used for remote sensing of ocean temperatures and currents on regional and global scales (ocean acoustic tomography). In addition to contributing to our understanding of how global climate change is affecting the ocean, measurements of the physical
environment in which marine organisms live and how it is changing are important to properly interpret changes in marine populations and understand ecosystem variability. Acoustic travel times have a number of attractive features for this purpose. They are inherently spatially integrating, naturally suppressing mesoscale variability, and providing precise range-averaged temperature. Acoustic measurements can be made without risk of calibration drift - time is the fundamental measurement – making them ideal for long-term monitoring of ocean temperatures.

**Navigation.** The acoustic sources used to measure ocean temperatures and currents can also be used to implement an underwater global position system (UGPS), enabling precision tracking of floats, gliders, and AUVs for long-term sustained operation beneath the ocean surface and under ice to make ocean measurements. Small, active acoustic tags that transmit to the passive acoustic receiving systems also used for other purposes can be employed to track marine organisms that do not vocalize, e.g., the Ocean Tracking Network (OTN).

**Education.** The sounds of the ocean offer a diverse and lively introduction to oceanography and the motivations for ocean observation (c.f., Discovery of Sound in the Sea - http://www.dosits.org/).

**Summary.** In order to justify and maximize the return on the investment required to implement and maintain a global ocean acoustical observation system, it is important to develop integrated acoustic systems for ocean observations, incorporating multipurpose passive and active components. Such integrated acoustic systems can make sustained observations of not only the ocean soundscape, but also biological, physical, chemical, and geological processes at time and space scales previously unexplored. Sound in the sea is not just noise. It is used for a wide variety of valuable and important purposes.
NOTES FOR VISITORS TO PARIS – BY ELIZABETH GROSS

Getting around:

The Paris Metro is very easy to use and, given the traffic congestion in Paris, is often much faster than taking a taxi. Pick up a Metro map at your hotel. The various lines are numbered and color-coded. You need to identify the number of the line and name of the station at the end of the line in the direction you wish to go so that you know which way to go in the station.

If you are going to be in Paris more than a few days, or are going to be traveling around the city for sightseeing, it is much cheaper to buy a “carnet” (pronounced car-nay), which is a set of 10 tickets, than to buy a single ticket each time you use the Metro.

When you go through the turnstiles, insert your ticket into a slot and it comes out on the other side. Be sure to take your ticket back and keep it with you until you leave the station at your destination – inspectors occasionally check riders for tickets.

The standard tip to taxi drivers is generally one to two Euros, unless you have received unusual service – say with luggage.

Personal safety:

As in any large city, be aware of situations where pickpockets may be a problem, especially in crowded places like some of the major Metro stations. In general, Paris is a very safe city.

Eating in Paris:

Unless you want to eat surrounded by tourists, do not expect to eat dinner in France before 8:00 p.m. at the earliest. Many restaurants do not even open before 7:30. If you want to eat early, a café is your best bet. They are also the best choice if you want to have lunch within the time allowed at most meetings.

In a café, if you only want a coffee, drink and/or a light meal (e.g., sandwich), be sure to sit at a bare table or one with paper placemats. If you sit at a table with a cloth and more formal place settings, you will be expected to order a full meal.

A café is a great place to watch Parisian life go by. Order a coffee, beer (“pression” = draft) or wine and relax. The house wine in cafés is called “vin de la maison”, or “vin du patron” (literally, the owner’s wine). In a café, this is usually sold in 0.5 (“demi”) or 0.25 (“quart”) liter jugs, called “pichets” (pronounced pee-shay). Similarly, draft beer (see “pression” above) comes in the same sizes.

In almost all cases, the tip or service charge is included in your bill in cafes and restaurants in France. In rare cases (or with large groups) you may see “service non compris” (service not included) on your bill. In this case, use the same guidelines as you would at home. Even when the tip is included in the bill, it is customary to leave a small amount of change as a bonus to your waiter if you have been well served.

A French menu is called “la carte”. Almost all restaurants offer you 2 options. You can order off the menu (“à la carte”), but you should always look at the front or back for “le menu”, the daily fixed-price offerings. For much less money you will get several choices for each course: an
appetizer (called the entrée) main course (“le plat”) and a dessert or cheese. Sometimes wine is even included – “boisson compris”. The menu of the day is sure to include the specialties of the chef and to be made with the freshest ingredients.

Menus must be posted outside all restaurants, and many include rough English translations, so it is possible to check it out before you make a commitment and enter the place! See the following list for some personal favorites.

RESTAURANTS AND CAFES IN THE AREA CLOSE TO UNESCO AND LOCAL HOTELS
Personal selections offered by Elizabeth Gross

Note: this list has not been updated recently, but most of the restaurants are still open. There are several small cafes and brasseries near the UNESCO building for those who want to leave the building for lunches.

De la Garde
83, av de Segur, 15th arrondissement. Tel: 01-40-65-99-10
A very nice restaurant – the place to go for a bit of a splurge in the area near UNESCO. Reservations are advisable.

Le Sept-Quinze
29, av de Lowendal, 15th arrondissement, Tel: 01-43-06-23-06
Named because it sits near the boundary between the 7th and 15th arrondissements of Paris. Meals are consistently good here.

Swann et Vincent
32 Boulevard Garibaldi, Tel: 01-42-73-30-44
West side of Bd. de Garibaldi between the Place de Cambronne and the rue Miollis.
A small, popular bistro featuring Italian and French cuisine.

La Fontana Rosa
28 bd Garibaldi, Tel: 01-45-66-97-84
Within a few doors of Swann et Vincent.
Has a nice outdoor courtyard and a lovely antipasto buffet. Classic Italian/Sicilian.

Auberge du Champs de Mars
18, rue de l'Exposition, Tel: 01-45-51-78-08
On the rue de l’Exposition, which also is home to several other nice little restaurants, especially around the courtyard and fountain where the rue de l’Exposition intersects the rue St. Dominique. The Auberge has always had one of the most affordable and enjoyable daily menus in this area of Paris.

Le Fontaine de Mars
129, Rue Saint-Dominique, Tel: 01-47-05-46-44
To be found on the courtyard mentioned above. French country cooking.
**Café du Commerce**

51 rue du Commerce, 15th arrondissement Tel: 01-45-03-27.
This is an historic Paris restaurant, over a century old; it was a former workingman’s soup kitchen. Renovations have retained most of the old fittings and the waiters still wear the classic uniforms. Many dishes feature very traditional items.

**Le Petit Niçois**

10, rue Amélie, 7th arrondissement. Tel: 01-45-51-83-65.
This is a seafood restaurant. It’s a longish walk from the UNESCO area, but you can work up an appetite! The “soupe de poisson” (fish soup), paella and the bouillabaisse are classics.

**Bistro de Papa**

81 Av. Bosquet, 7th arrondissement. Tel: 01 47 05 36 15.
A casual brasserie, open most of the time. Warm atmosphere and reasonably priced.

**Le Troquet**

21 rue François Bonvin – go out the back door of the IOC building and up about one block. Basque regional cuisine. Open for lunch and dinner, except Sunday and Monday. Owner/chef.

**Le Suffren**

At the corner of Aves de Suffren and Motte-Piquet. A “brasserie” - a good bet on a Sunday when many places are closed. If you are brave, try a “degustation” (sampling of various shellfish).
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