OCEAN NOISE
Making Sense of Sounds

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The Problem
A Possible Response
A Required Expertise
The Problem:

CALIBAN

Be not afeard. The isle is full of noises,
Sounds and sweet airs that give delight and hurt not.
Sometimes a thousand twangling instruments
Will hum about mine ears, and sometime voices
That, if I then had waked after long sleep,
Will make me sleep again; and then, in dreaming,
The clouds methought would open, and show riches
Ready to drop upon me, that when I waked,
I cried to dream again.

*The Tempest (Shakespeare)* 3.2.148-156
The Problem:

SOURCES OF ARTIFICIAL NOISE
- Shipping
- Exploration and production of offshore fossil energy,
  - Navy and industrial sonar
    - Experimental acoustics
    - Underwater explosions
      - Engineering activities
      - Supersonic airplanes
      - Offshore windmills
- Anthropic activities
  - industrial, navy sonar
  - seismic surveys
  - shipping
  - nuclear testing

Marine organisms: cetaceans, crustaceans, etc.

Anthropogenic activities:
- breaking waves
- sismic activities
- waves, wind
- bubbles
- wave interactions
- turbulences
- storms
- rain, snow

Intensity (dB re 1 μPa² Hz⁻¹ m⁻¹)

Frequency (Hz)
The Problem:

Yes.... but what do we really know?

Anthropogenic activities:
- industrial, navy sonar
- seismic surveys
- shipping
- nuclear testing

Sismic activities:
- breaking waves
- bubbles

Tides

Marine organisms:
- cetaceans, crustaceans, etc.

Turbulences

Waves, wind

Storms

Rain, snow

Intensité dB re 1 μPa².Hz.a.1m

Frequency
The Problem:

UNCERTAINTIES:
- species affected
- behaviour concerned
- sound characteristics
- cumulative effects
- available tools for monitoring, mitigation, modelling, stranding response, environment impact assessment

The Problem

The Problem

A Possible Response

A Required Expertise
The Problem:

- Ocean Noise will increase in the next decades
- A Global Problem: A Global Solution
- Increasing Pressure from Society
- Environmental Laws to come
- Offshore Economical Interests at Risk
- Need to provide the Industry and the Administration with Predictive and Mitigation Tools
Response:

THE APPROACH

- Additional scientific knowledge and stronger political resolve
- Mathematical and physical sciences MUST converge with biology and biotechnological engineering
- Integration of 3D models that describe and project natural, biological & artificial sound processes in real environments
- Development of passive acoustic technologies that combine the development of offshore interests with the conservation of marine ecosystems
- Analysis of lesions in marine receptors, understanding noise effects
Expertise:

- Regulation and International Initiatives
- Biological Sensory Systems
- Passive Acoustic Monitoring
- Modeling

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THE APPROACH
- EU Marine Strategy Framework Directive
- Cetacean and Sound Mapping http://www.st.nmfs.noaa.gov/cetsound/
- BOEM Effects of Noise on Fish, Fisheries and Invertebrates http://www.boemsoundworkshop.com/
  - The effects of Noise on Aquatic Life http://www.aquaticnoise.org/
- E&P Sound and Marine Life Program http://www.soundandmarinelife.org/
- The Office of Naval Research (ONR), Marine Mammal Biology Program (MMB), http://www.onr.navy.mil/
- Several EU funded programmes: SILENV, ACCESS, AQUO, SONIC, PERSEUS, COCONET
- EU Initiatives: ASCOBANS, ACCOBAMS
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THE APPROACH

-EU Marine Strategy Framework Directive

INDICATORS OF GOOD ENVIRONMENTAL STATUS FOR UNDERWATER NOISE AND OTHER FORMS OF ENERGY

- 10 Hz-10kz impulsive sounds
- 1/3 bands centred at 63 Hz and 125 Hz
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Auditory Evoked Potentials


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Assessment of Acoustic Trauma in Marine Mammals


Low Frequency Noise induces Acoustic Trauma in Cephalopods

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Noise Measurement & Trends


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Real-Time DCL


The Problem  A Possible Response  A Required Expertise
Effects of Noise

Mitigation actions & Long-term monitoring

Automated, Real-time and Statistical Analysis

The Problem  A Possible Response  A Required Expertise

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The Problem  A Possible Response  A Required Expertise

**Stage 1**
- Measure noise
- Discard segment with no acoustic event
- Assign acoustic events to broad categories
  - FM-tonal sounds
  - Impulses...

**Stage 2**
- Classifier 1
- Classifier 2
- Sperm whales
- Beaked whales
- Pilot whales
- Dolphins
- Explosions
- Ships
- Sonar
- Tracking
- Density
- Estimation
- Bearing, Position
- Trajectory, ...

**Stage 3**
- Real-Time Mitigation
- Long term assessment and control of the effects of noise sources on marine organisms
- Public outreach
Expertise:

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RT Acoustic Software Development
Acoustic Data Management

**Pre-Processing Server**
- Segments & tags data
- Encodes 1 channel into mp3
- No data storage – we rely on the MADS

**Analysis Server**
- Source identification
- Localisation and tracking of sources

**ADS**
- Transmission analysis results and mp3 channel
- Transmission of analysis results and mp3 data to Web Server

**MADS**
- X-channel multi-cast data stream

The Problem   A Possible Response   A Required Expertise
<table>
<thead>
<tr>
<th>Country/Location</th>
<th>Platform</th>
<th>Data stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRANCE</td>
<td>ANTARES</td>
<td>36 x 250 kHz</td>
</tr>
<tr>
<td>NEPTUNE CANADA</td>
<td>Folger Passage</td>
<td>1 x 96 kHz</td>
</tr>
<tr>
<td>NEPTUNE CANADA</td>
<td>Barkley Canyon</td>
<td>1 x 96 kHz</td>
</tr>
<tr>
<td>NEPTUNE CANADA</td>
<td>Barkley Slope</td>
<td>1 x 96 kHz</td>
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<tr>
<td>SPAIN (MED SEA)</td>
<td>OBSEA</td>
<td>1 x 96 kHz</td>
</tr>
<tr>
<td>JAPAN (JAMSTEC)</td>
<td>Hatsushima</td>
<td>1 x 100 Hz</td>
</tr>
<tr>
<td>JAPAN (JAMSTEC)</td>
<td>Kushiro</td>
<td>3 x 100 Hz</td>
</tr>
<tr>
<td>ITALY (ESONET)</td>
<td>NEMO TSS/TSN</td>
<td>2x 4 x 96 kHz</td>
</tr>
<tr>
<td>SPAIN (ATLANTIC)</td>
<td>BIMEP</td>
<td>1 x 96 kHz</td>
</tr>
<tr>
<td>CTBTO</td>
<td>11 HA</td>
<td>11 x 200 Hz</td>
</tr>
<tr>
<td>IRELAND</td>
<td>Shannon Estuary</td>
<td>1 x 96 kHz</td>
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**Expertise:**

- Regulation and International Initiatives
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- Passive Acoustic Monitoring
- Modeling

**Live Data Flow**
Detection of short tonal sounds in the band 0.2-16 kHz. Acoustic data from Neptune, 3-24 March 2010, 10 min recorded every 3.5 hour.

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<tr>
<td>Deep-sea or shallow water cabled observatories</td>
<td>Towed arrays</td>
<td>Integrated Systems</td>
</tr>
<tr>
<td>Radio-linked, expandable or moored stand-alone buoys</td>
<td>Underwater vehicles, e.g. gliders</td>
<td></td>
</tr>
<tr>
<td>Geophysics sensors</td>
<td>Offline recordings</td>
<td></td>
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Offshore Mitigation Systems


Acoustic data is stored in many different ways and formats. For best performance, both the data format and the data sampling frequency should be fixed. A Matlab script is delivered that can read a large number of different types of input files, making use of Matlab’s extensive options to read raw data and wav files, and that resamples the data to the sampling frequency expected by the software.
Because the effects of noise on the hearing capabilities of most species are still not yet understood and can change with behaviour (foraging, breeding, etc.), we chose here to concentrate the noise assessment on the physical parameters involved in the noise and biological sources interactions, and look at the masking effects due to shipping noise, without necessarily including physiological damages.
LIDO is designed to be modular and dynamic (allows the choice of detectors/classifiers) depending on the objectives and geographical areas

The system successfully allows:
- the real-time detection and classification of acoustic events
- the real-time and long-term monitoring of noise
- immediate mitigation actions
- the online display of the audio stream and the statistical analysis

The modular system can be implemented on:
- cabled observatories,
- autonomous radio-linked buoys, moored antennas
- autonomous vehicles (e.g. gliders),
- towed arrays
- existing data sets,
- etc.
Expertise:
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LIDO can be applied to:

**Industry & Ocean Users**
- during offshore operations, seismic surveys (expandable buoys), windmills/wave energy (autonomous buoys during construction, cabled observatory during operation), shipping lines, coastal operations (e.g. harbour construction), navy manoeuvres, etc.

**Science**
- in existing and future acoustic observatories
- during CEE and tagging to understand the acoustic ecology of the individual

LIDO is implemented with:
- an alert procedure that allows to automatically target acoustic events of interest and receive it live (e.g. mitigation or research)
- automatic display of AIS data and correlation with noise measurements to determine the acoustic signature of ships cruising over the observatories

The Problem  A Possible Response  A Required Expertise
The system can be operated by a non-expert

The analysis is performed automatically and doesn’t require post-processing

LIDO is immediately available to be applied to any acoustics observatories or any operation at sea