Underwater Noise in the marine Environment - Introduction to the issues

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IOA workshop on underwater noise
…organised by :

…supported by :

Aims

- increase awareness of the issues relating to underwater radiated noise
- provide a forum transfer of knowledge to wider community
- illustrate current best practice
- exchange views and opinions on approaches to the challenges ahead

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Introducing the rest of the day…

Topics covered

- Noise impact on marine life
- Noise measurement methodology and analogies to air acoustics
- Experiences of measuring noise from various sources
- Quantifying exposure of marine species
- Mitigation measures
- Acoustic monitoring
- UK policy regarding off-shore operations

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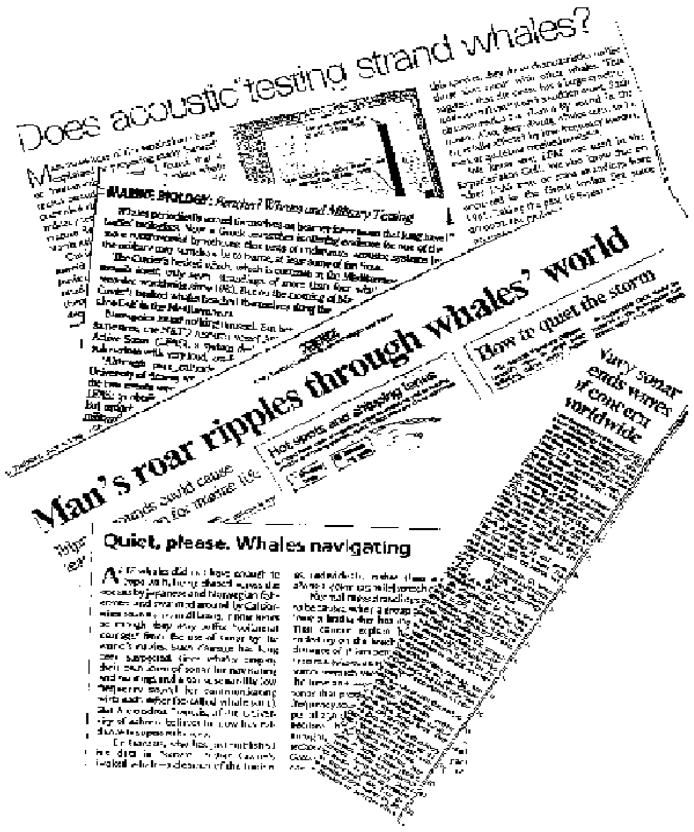
Background

Impact on marine life:
highlighted by events

- Ship Shock Tests 1994
- ATOC 1995
- NATO Greek Strandings 1996
- Bahamas Strandings 2000
- Seismic Research 2002
- US Navy LF sonar 2003



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Easily made mistakes

- misunderstanding of decibel notation
- incorrect reference levels used
- source level versus sound pressure level
- confusion between air and underwater acoustics

Quotes

- “for the whale, it’s like being strapped to the engine of a Saturn five rocket at take off”
- “the sound is 200,000 times louder than that allowed by law for factory workers”
- “people may not be interested in acoustic thermometry, but they are interested in whales”
- “the navy’s new sonar is the loudest noise ever made by man”

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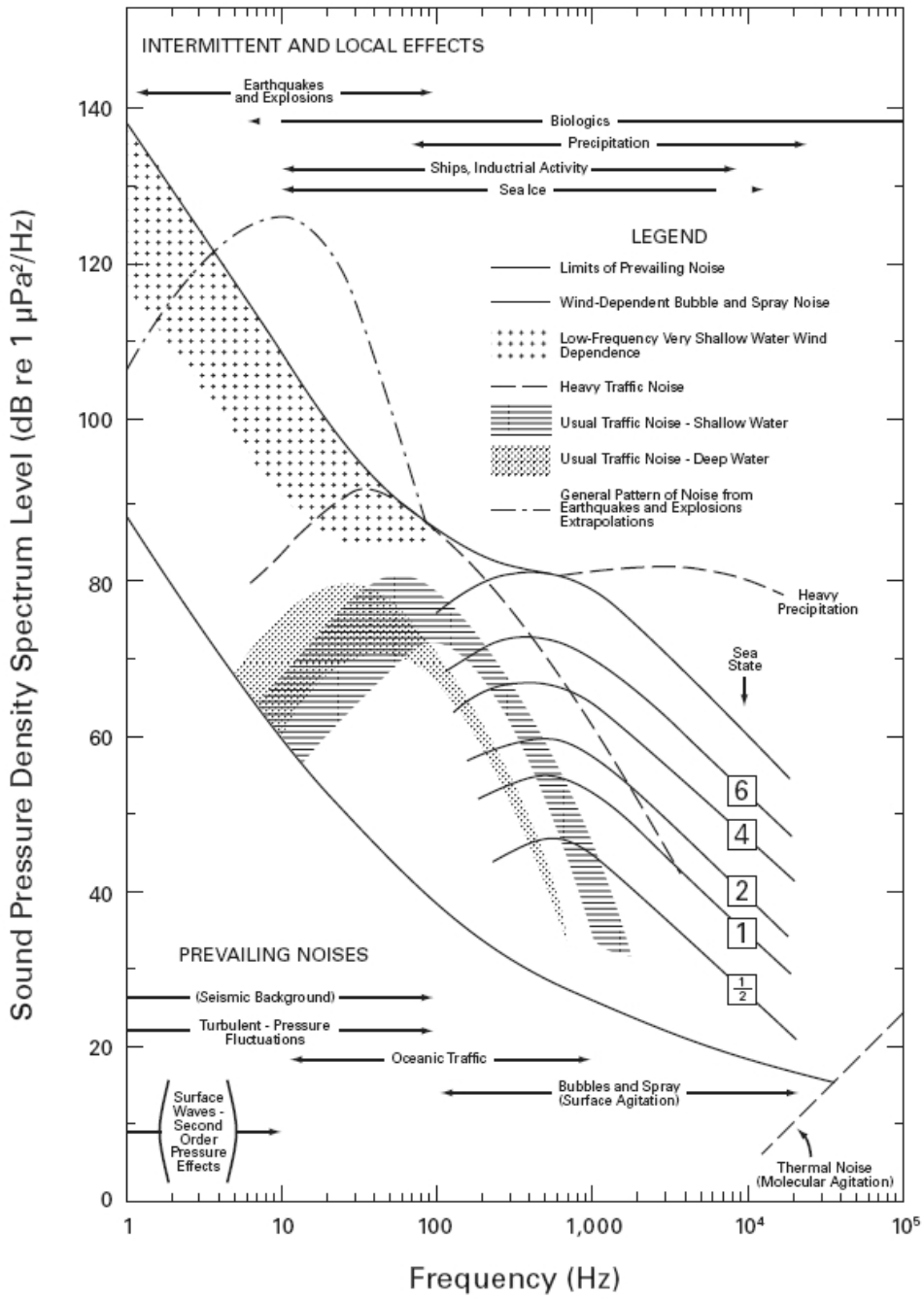
Natural sound sources: ocean ambient noise

- Wenz (1962)
- seismic (LF)
- “distant” shipping
- rain
- waves
  - depends on sea state and wind speed
- biological
  - snapping shrimp, mammals, etc



after Richardson W *et al,* Marine Mammals and Noise. Academic Press, 1995.

Anthropogenic sound sources

- Shipping
- Geophysical surveying
- Drilling, piling, dredging
- Explosions
- Underwater vehicles
- SONAR
- Acoustic communication and positioning transducers
- Echo sounders
- *Equipment usage has increased over time, although some reduction in acoustic leakage has been achieved*

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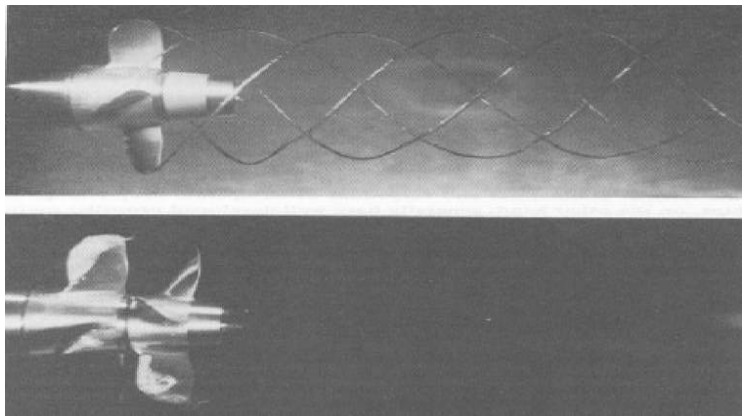
Examples: vessel and platform noise

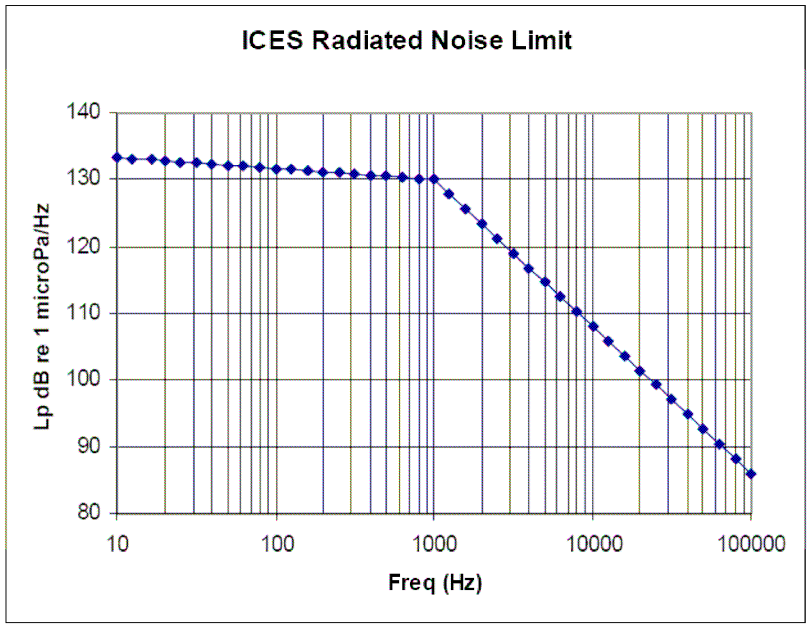
Noise mechanisms on vessels

- Propulsion system (propellers)
  - cavitation, flow noise, “singing”
- Engine noise
- Machinery

- Thrusters
  - dynamically positioned vessels

- Hydraulics power packs
  - ROVs



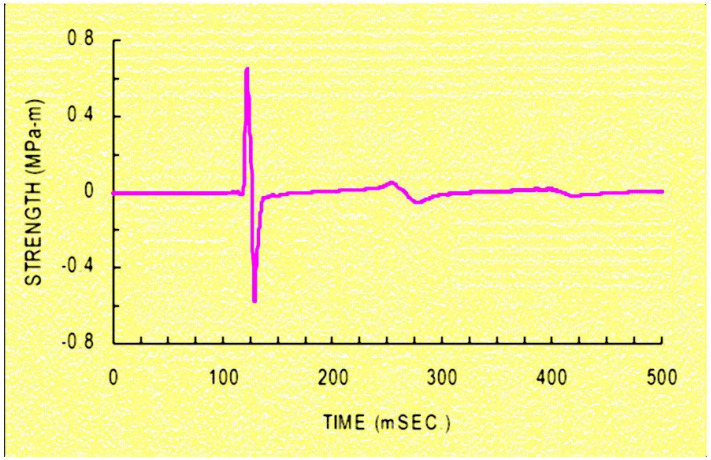


ICES rpt 209 noise limit for fisheries research vessels

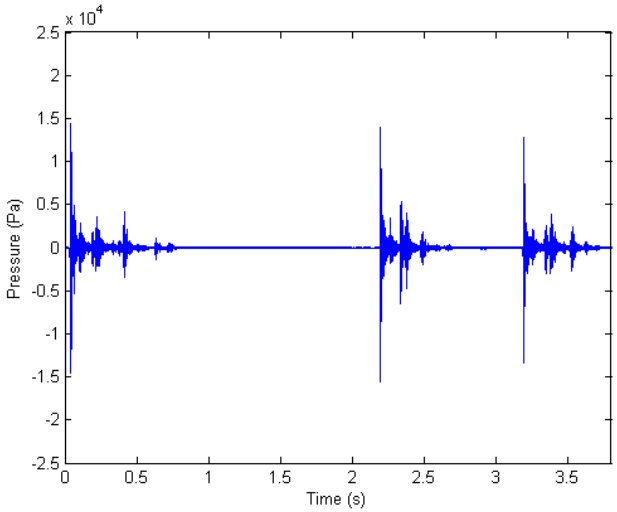
Examples: geophysical surveying and marine piling

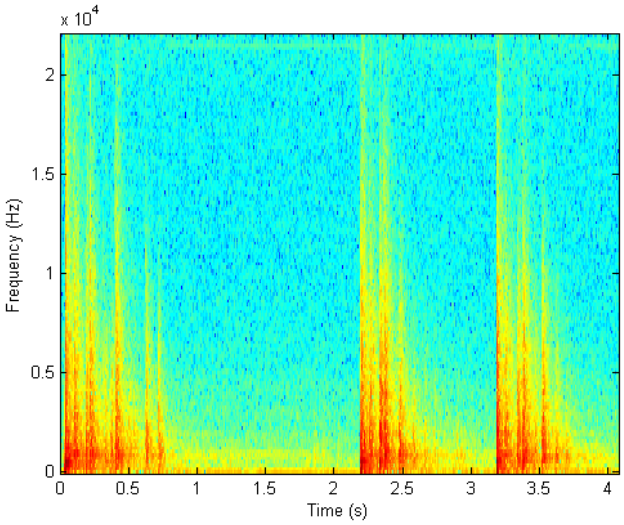
- Loud impulsive sources of noise
- Source levels in excess of 230 dB re 1 µPa•m reported

Typical airgun pulse



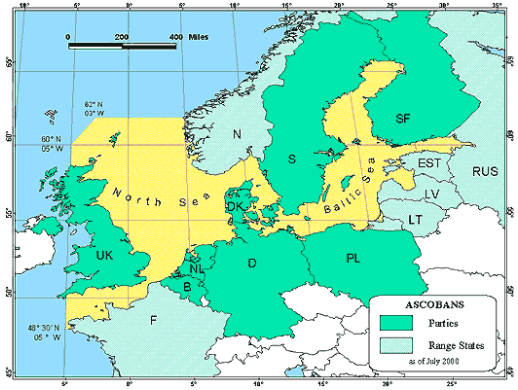
Piling noise pulses



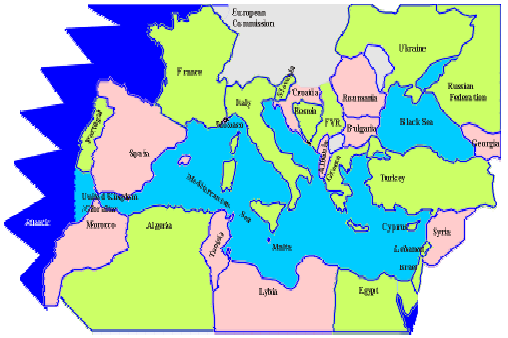


International agreements

ASCOBANS – Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas



ACCOBAMS - Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea & Contiguous Atlantic Area



Marine Protected Areas

UNCLOS 1992 & Rio Declaration

– precautionary principle adopted

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Regulation

- Habitats' Directive 92/43/EEC

- DTI Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (PON 14)
  - covers drilling and seismic surveys

... "assessment of any possible interactions between the survey vessel activities and marine mammals, fish spawning, relevant sites etc"

..."where possible, for surveys using acoustic techniques the **source level** (dB re 1 μPa·m) and **dominant frequencies** generated should be used to assess effects on marine mammals"...

- Licences/consents granted by DEFRA for offshore activities
  - eg windfarm construction

EIAs routinely required

Examples of species under consideration in one recent licence/consent

- common seal
- grey seal
- harbour porpoise
- sea bass
- herring
- salmon
- lemon sole
- crab
- lobster

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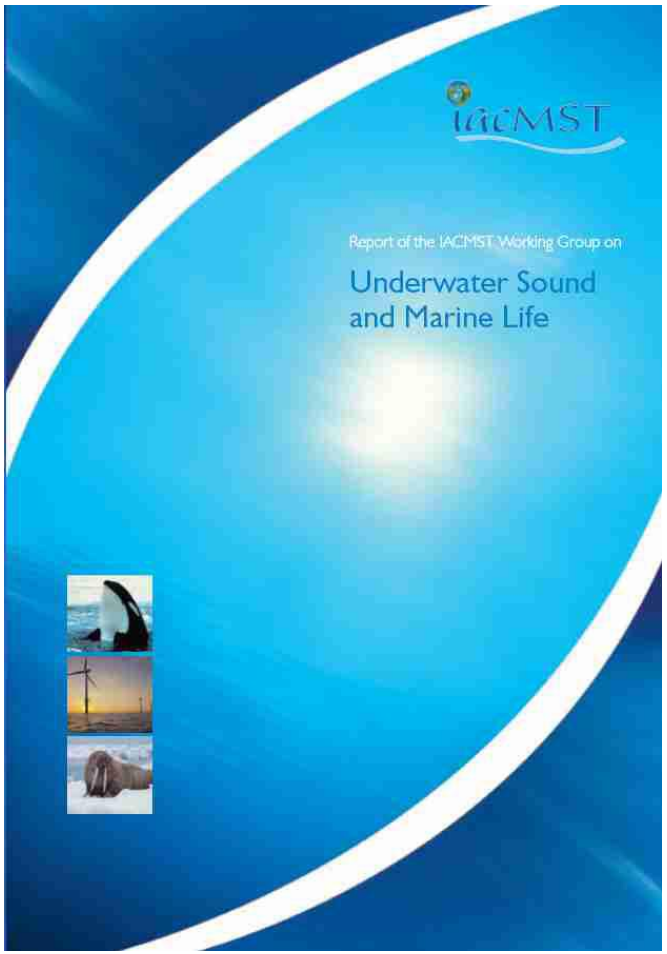
Committees…

- UK **I**nter-**A**gency **C**ommittee on **M**arine **S**cience & **T**echnology (IACMST) Working Group
- Scientific Committee on Antarctic Research (SCAR) Workshop
- US Office Naval Research (ONR) / UK Defence Science Technology Laboratory (DSTL) Workshop
- NOAA working groups
- ASA working groups



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Assessing impact

Impact of underwater noise

- Effect on marine life
- Effect on humans (divers)
- Effect on other acoustic systems

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Underwater noise assessment

Divide the assessment of noise into stages:

- noise emission from sources
  - requires source to be characterised
  - as detailed **source levels** or overall **sound power**
- sound transmission - the **transmission loss**
  - propagation can be highly complex
  - depends on boundary conditions and environmental conditions
- background noise – the **spectral distribution**
  - the ambient noise level in the ocean
- sound reception
  - the sensitivity of the receiver (or animal) at the location where the sound is detected – the **audiometry thresholds**

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Noise measurement methods

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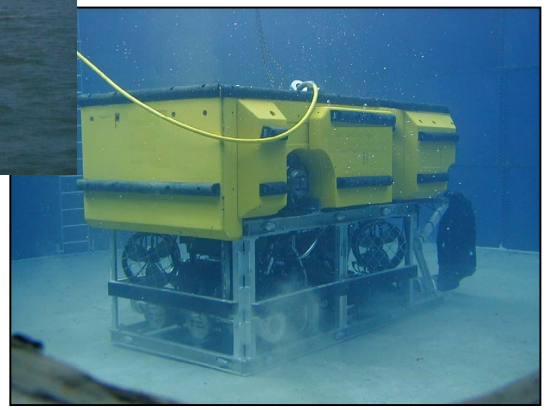
Type of source affects method used

- Vessels

- Vehicles and platforms
  - ROVs, AUVs
- Machinery

- Drilling and piling sites
- Dredging sites
- Off-shore wind farms
- Wave power generators



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Noise ranges

- Located in deep lakes or sea-lochs
- Provide full characterisation
- Provide directivity information
- Can measure large vessels
- Expensive and not always available
- The source must go to the range!
- NATO STANAG 1136 standard

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Portable ranges – *in situ* tests

- Rapid mobile deployment
- Can deploy off-shore for *in-situ* measurement
- Difficult to achieve free-field
  - need to understand propagation or make assumptions
- Accuracy difficult to assess
  - no “standard” method

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Sound propagation underwater

- sound speed varies with **temperature**, **depth**, **salinity**
- sound speed profile important – governs **refraction**
- also important: **reflection** from **surface** and **bottom**

- simple spreading assumptions:
  - spherical (deep water)
  - cylindrical (shallow channel)
- propagation models:
  - normal modes approach
  - ray tracing

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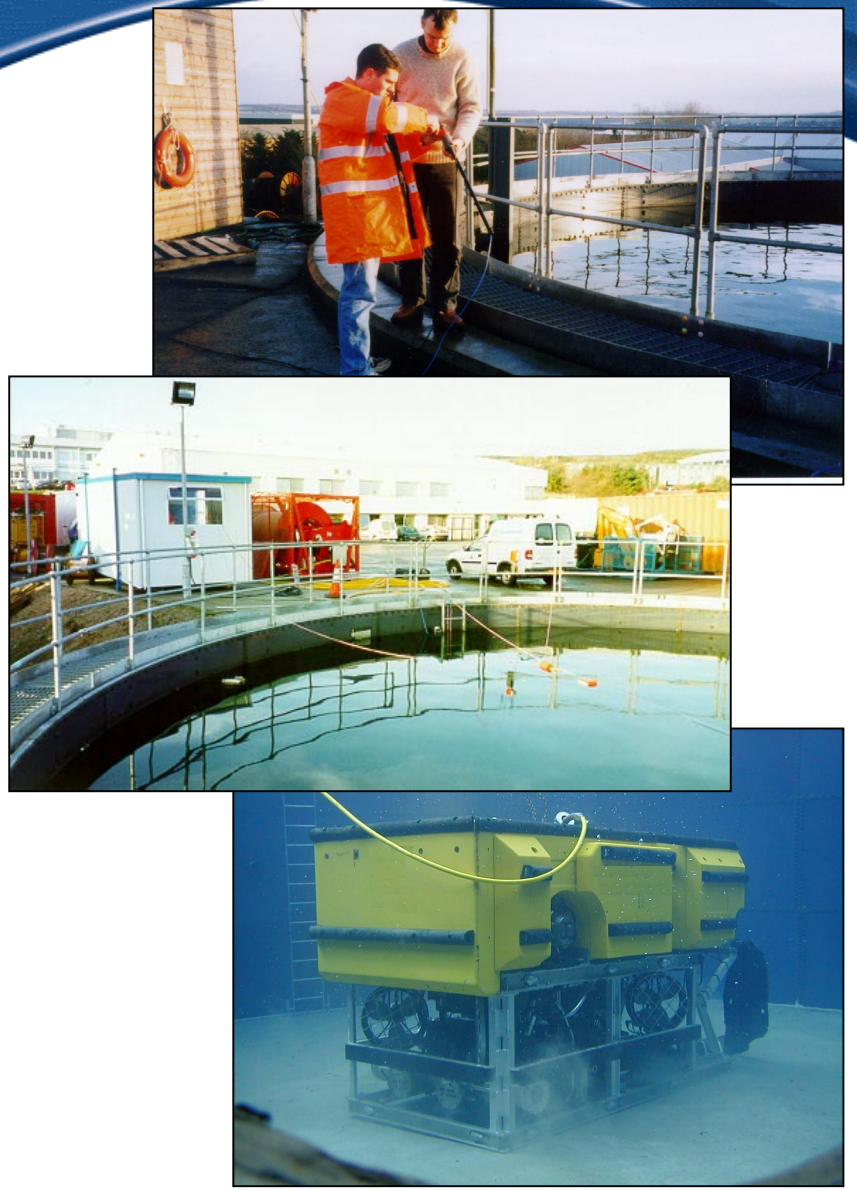
Reverberant test tanks



- convenient for portable sources (eg ROVs)
- test tanks cheaper than *in-situ* tests
- rapid assessment for noise power

- But…

- no directional information possible
- need to calibrate the test tank
- difficult to make highly reverberant tanks

R A Hazelwood and S P Robinson Acoustic power calibration in reverberant tanks. *Proceedings of the IOA*, **20**, 103-110, 1998.

N Cochard, P Arzelies, J L Lacoume, Y Gabrillet. Underwater Acoustic Noise Measurement in Test Tanks. *IEEE Journal of Oceanic Engineering*, **25**, 516-522, 2000.

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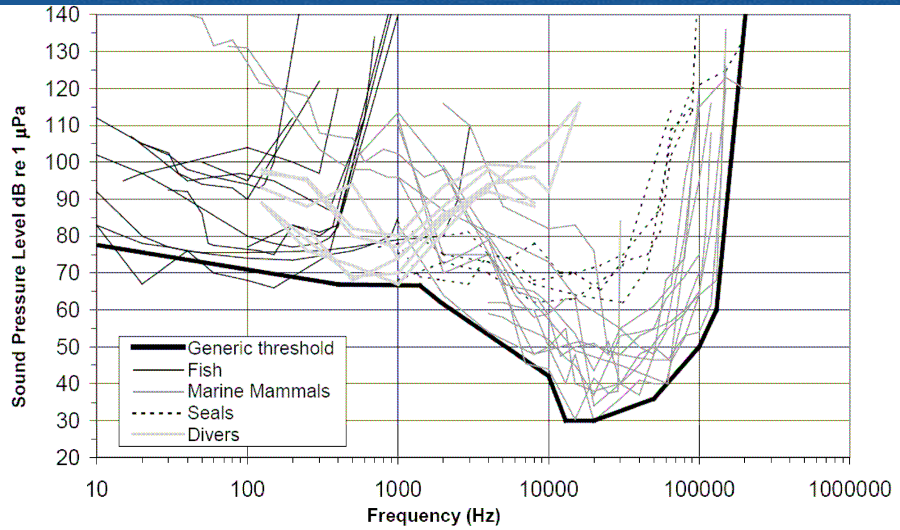
Impact on marine life

Impact on marine life



…from A. D. Heathershaw, P. D. Ward, A. M. David

Proc. I.O.A Vol 23 Part 4 (2001)

Physiological effects:

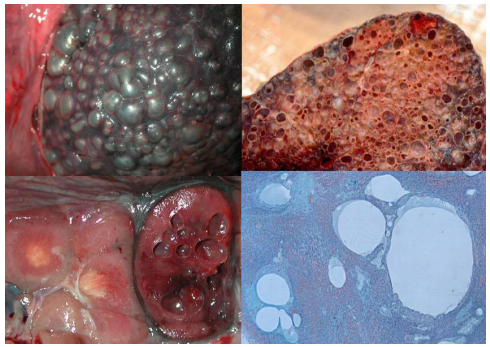
- damage observed to mammal internal organs
- hearing threshold shift (temporary or permanent)

Reference work:
Richardson, W *et al,* Marine Mammals and Noise.

Academic Press, 1995.

Behavioural effects:

- behavioural changes claimed for both mammals and fish
- may affect breeding or feeding patterns
- masking effect important



Gas bubble lesions in organs from a stranded beaked whale, from Jepson *et al*, in *Nature*, vol 425, October 2003.

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Mitigation

Mitigation measures

Mitigation measures

- use of spotters (MMOs)
- cease operations if mammals are observed sufficiently close by
- minimise repeated surveying of high risk areas
- care should be exercised to minimise impacts in known biologically sensitive areas and times

- use of minimum level needed and to ‘soft starts’ or ‘slow’ starts
- use of acoustic “deterrents”

But…

- Costs and complications
- MMOs hindered by poor visibility (night, fog, sea state)
- Only surface animals spotted
- More subtle behavioural effects may be significant
- Not certain how well mitigation measures work

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Acoustic monitoring

Passive acoustic monitoring (PAM)

- Hardware systems: *towed arrays, individual hydrophones…*
- Software: *eg Rainbow Click, PAMGUARD…*
- Operation: ideally automated detection, classification, localisation
- BUT: difficult to detect animals that do not vocalise

Active acoustic monitoring proposed

- similar in principle to fish finding sonar
- enables silent animals to be detected
- BUT introduces more sound into the marine environment !

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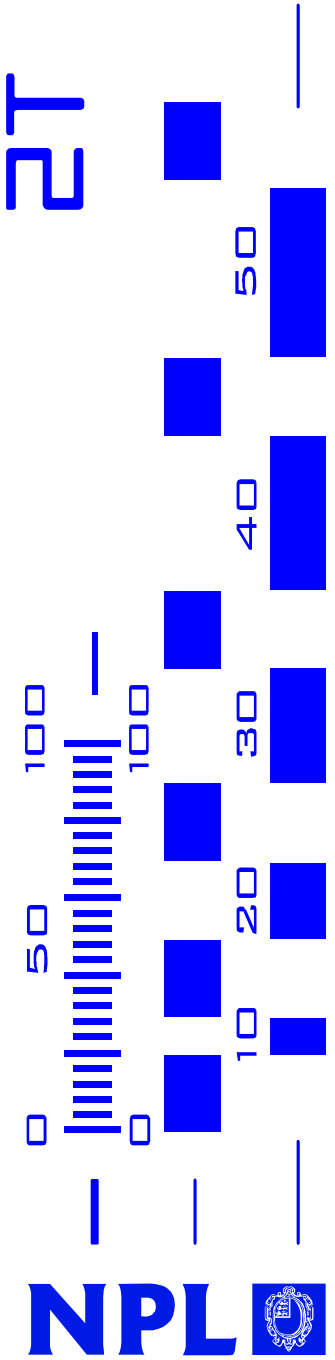
National Physical Laboratory



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