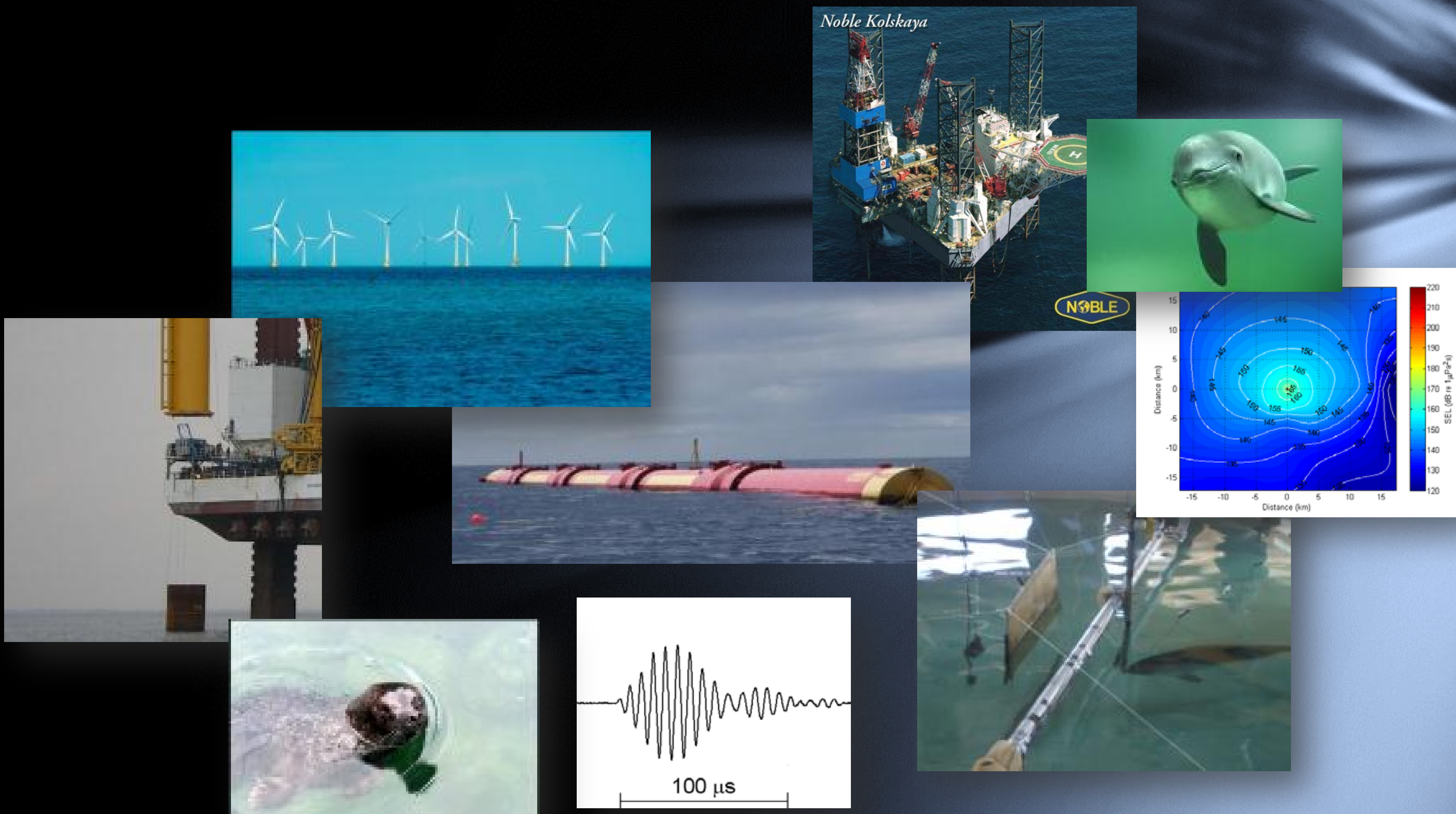
Bioacoustics Research

Dr Paul Lepper - Loughborough University

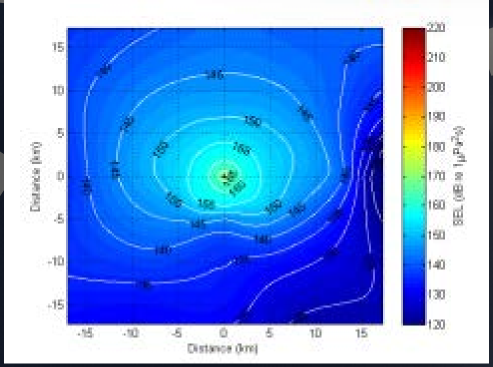


Underwater noise and impact research

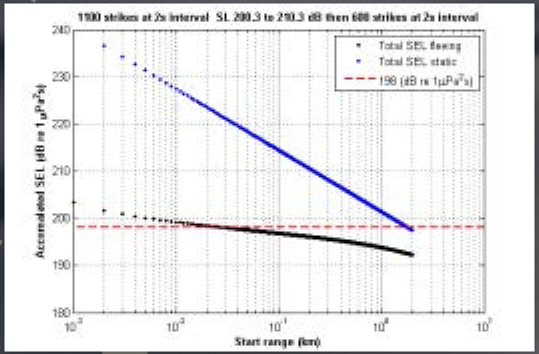
“In relation to the underwater energy, Good Environmental Status certainly occurs when there is no adverse effect of energy inputs on any component of the marine environment.”
EU Marine Strategy Framework Directive: Underwater noise and other forms of energy, 2010.

Physiological / behavioural response research

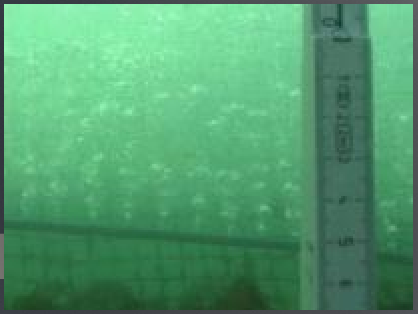
Source / noise field measurements



Acoustic field modelling



Impact prediction



Mitigation technologies / processes

Sources of man-made noise

- Shipping (Commercial, military and leisure)

- Offshore renewables (constructions/operation/decommissioning)
  - Wind (dry)
  - Sub-surface (Wave / Tidal) (wet)

- Sonar systems
  - Military
  - Commercial (Navigation) / Fisheries (Fish finders)
  - Leisure

- Urban / industrial coastal development
  - Harbour and bridge building

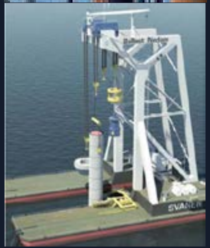
- Dredging (land reclamation / aggregate extraction)

- Petroleum and gas exploration / extraction
  - Seismic explorations (air guns)
  - Drilling / FPSO platforms

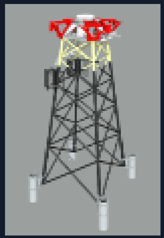
- Fisheries and aquaculture (Fish finder sonar / Acoustic deterrents)
- and more ....

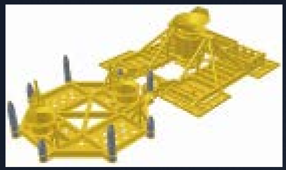
Installation Options

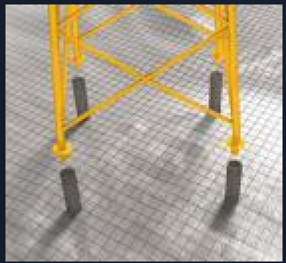
Monopile



Jacket



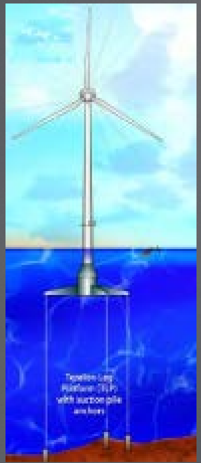




Tripod / Tripile

GBS / Multiple rakers + Pile-cap

Floating



Marine piling for offshore wind

Sherringham Shoal OWF

Vessel: Svanen

4.7m diameter piles.

Max energy: 1073 kJ

Resolution

(max power used 1900 kJ)

Jumping Jack

(max. power used 800 kJ)

Vessel: Stanislav Udin

Piles: 6.0 – 6.5 m diameter

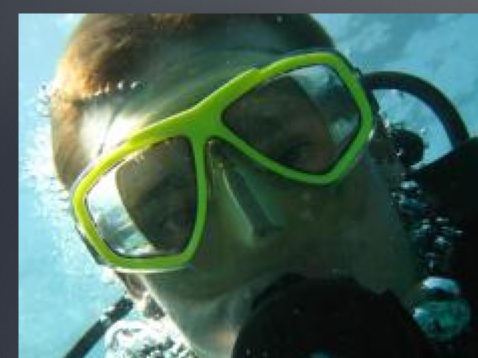
Max hammer energy 1070 kJ

NPL

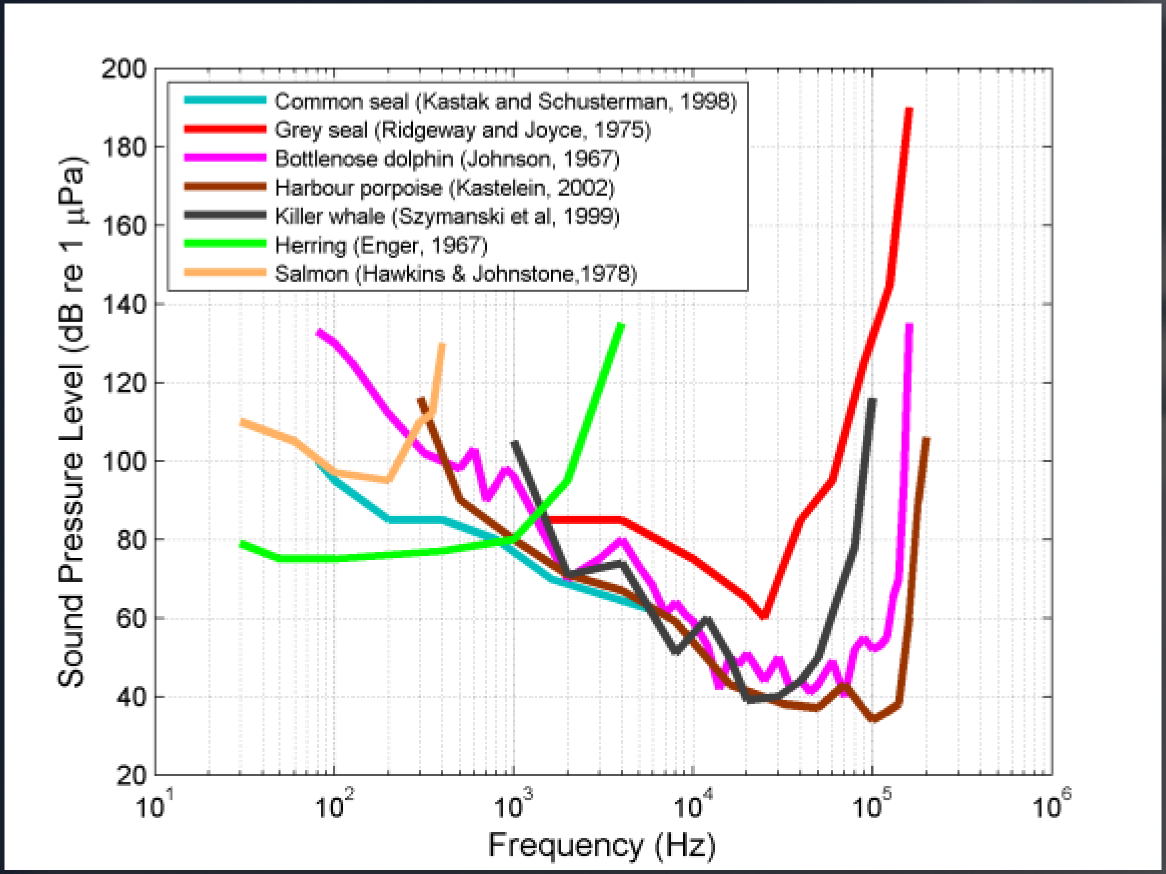
Loughborough University

Potential receptors

- Marine mammals
- Fish (adult / lava)
- Crustacean/shell fish
- Diving birds
- Others (polar bears, ott
- Humans
(Divers / Sonar operators)



Potential receptors



Physiological and behavioural impacts

Physiological responses

- Hearing damage

  Temporary Threshold Shift / Permanent Threshold Shift

- Mortality

  Direct (physiological damage)

  Indirect (stranding, evoked decompression injury)

Behavioural response

- Avoidance

  Habitat exclusion long term / short term

- Masking

  Ability to find prey

  Breeding (finding partner / care for young)

  Predator avoidance

Key Research Areas

Marine Mammals hearing and TTS

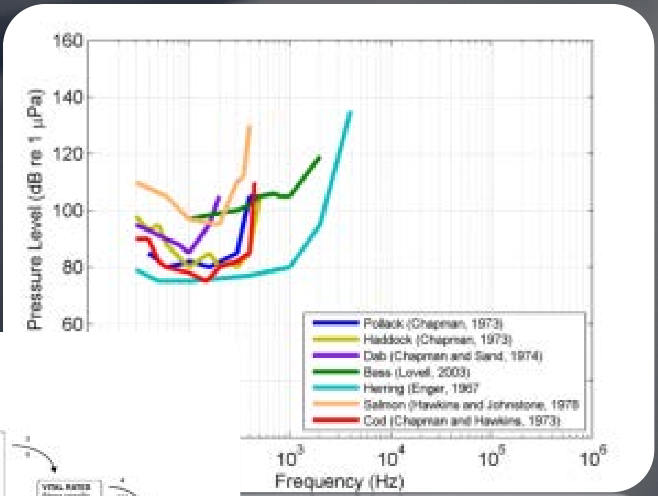
- Bottle nosed dolphins and belugas
  (Finneran *et al.*, 2000-2010, Nactigall *et al.*, 2003, 2004 Mooney *et al.*, 2009)
- Harbour porpoise
  (Lucke *et al.*, 2009, Popov *et al., 2011,* Kastelein *et al.*, 2012)
- Pinnipeds
  (Kastak *et al.*, 1996, 2005, 2007, Sclundt *et al.*, 2000, Finneran *et al.*, 2010)
- Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations
  (Southall *et al.*, 2007)

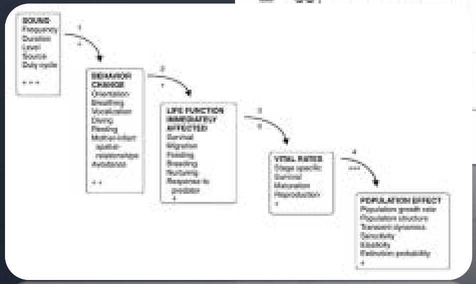
Fish:

- FHWG interim criteria (Popper *et al.*, 2006)
- COWRIE (Mueller-Blenkle *et al.*, 2010)
- Other guidance provided by Cefas in the UK

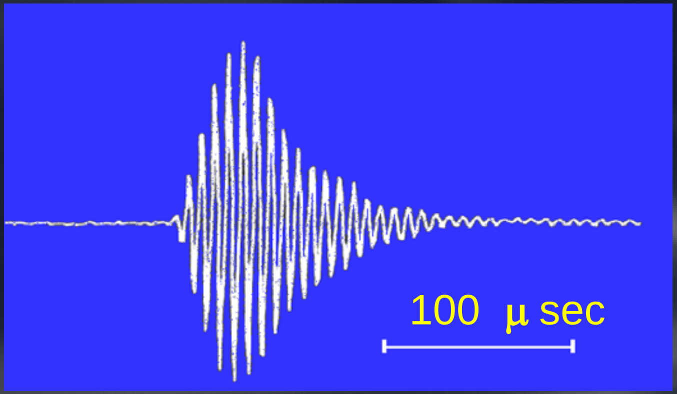
Impact models:

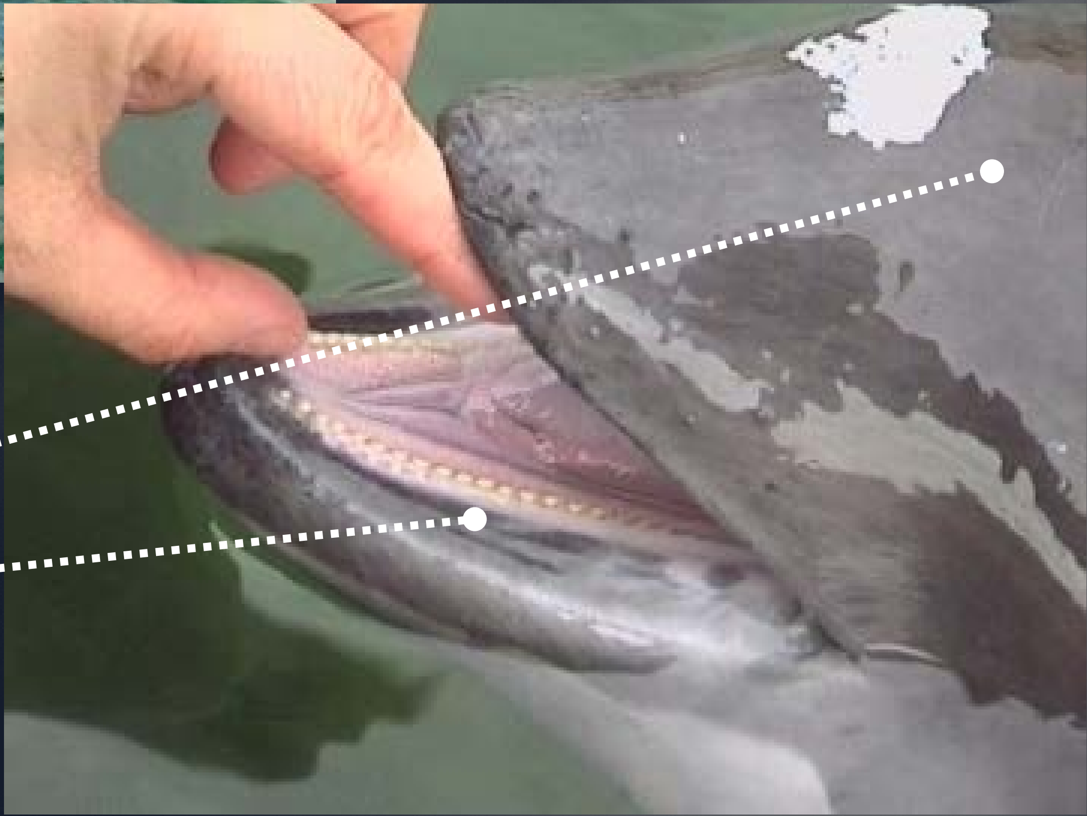
- Cumulative exposure
- Individual animal based models
- Population level consequences (PCAD / PCoD)





Harbour porpoise hearing





ACTIVE SONAR

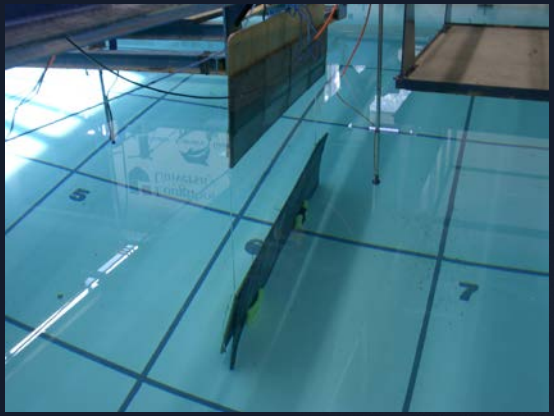
Transmit path via ‘Melon’

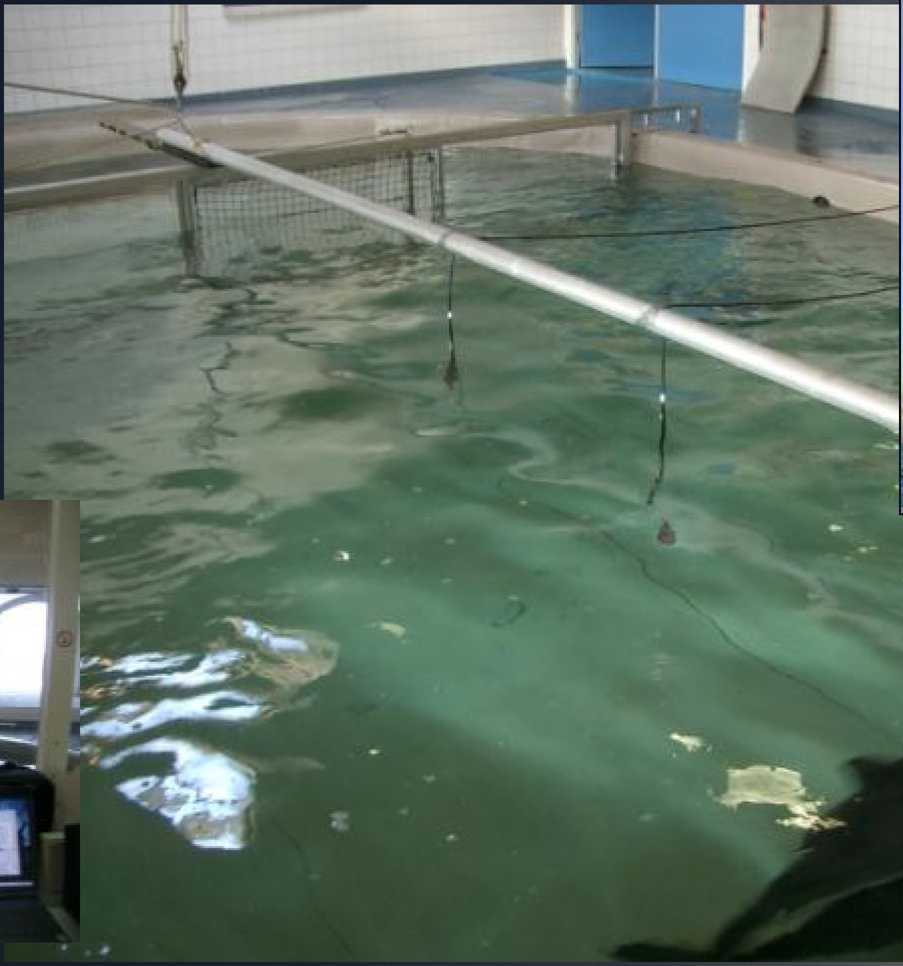
Echo reception related to

lower jaw

Harbour porpoise hearing

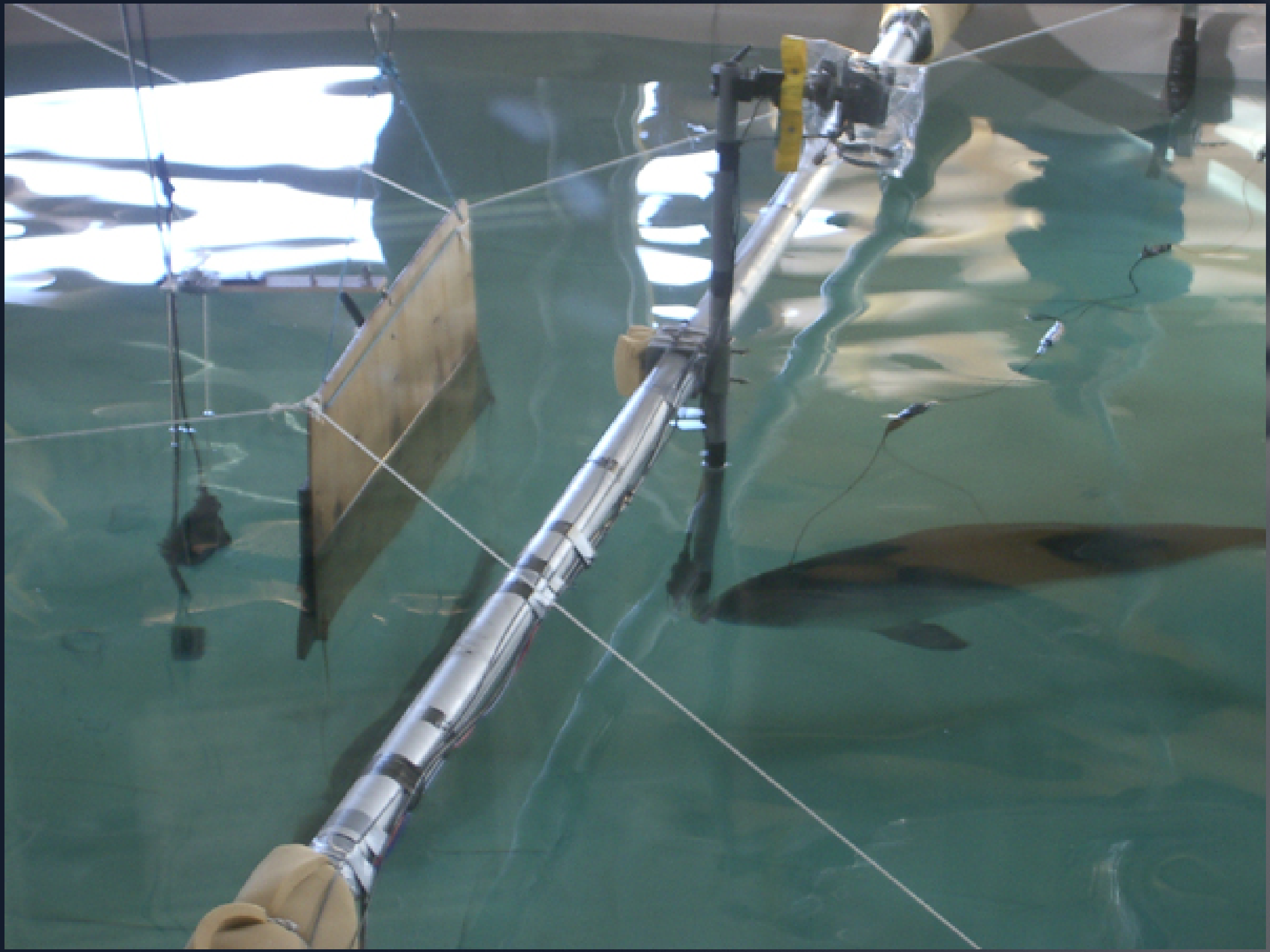
Harderwijk, Netherlands





Environmental impacts of off-shore windmills construction

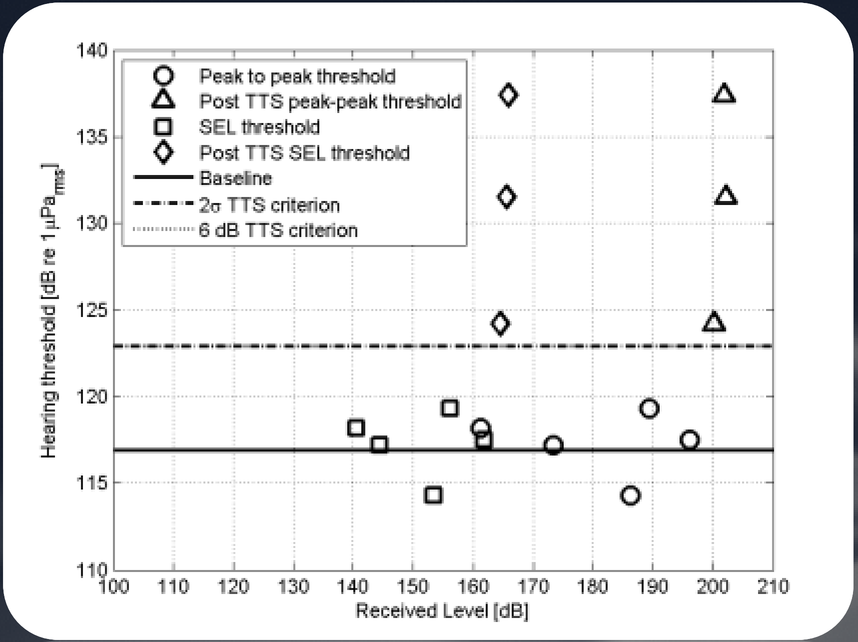
Harbour porpoise hearing

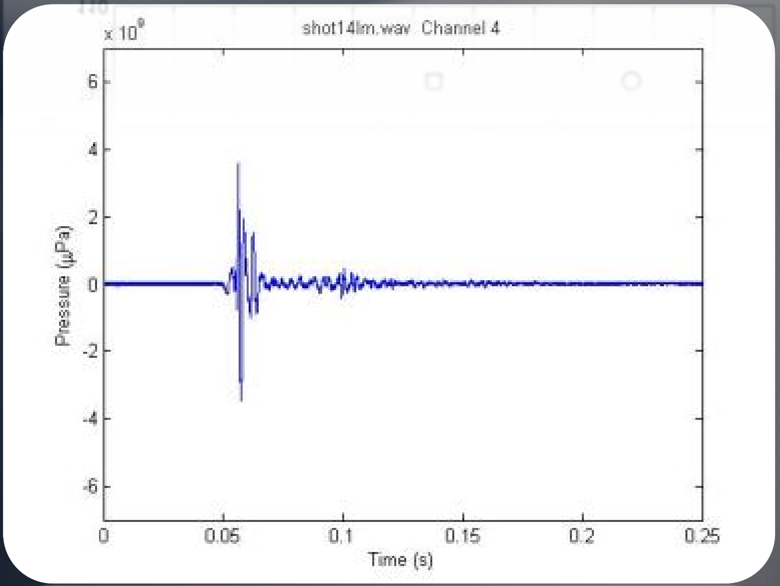


TTS in harbour porpoise

Lucke *et al*., 2009

Kastelein *et al*., 2012

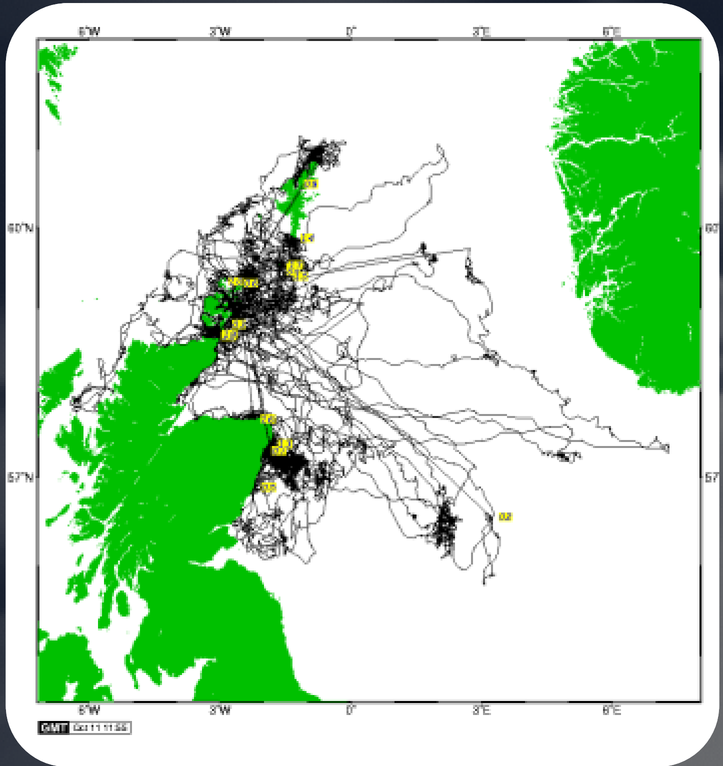




Large scale observation of behaviour

Acoustic detectors
(T-Pod / C-Pod)

GPS tags



D-tag and controlled exposure experiments

«Woods Hole Oceanographic Institution

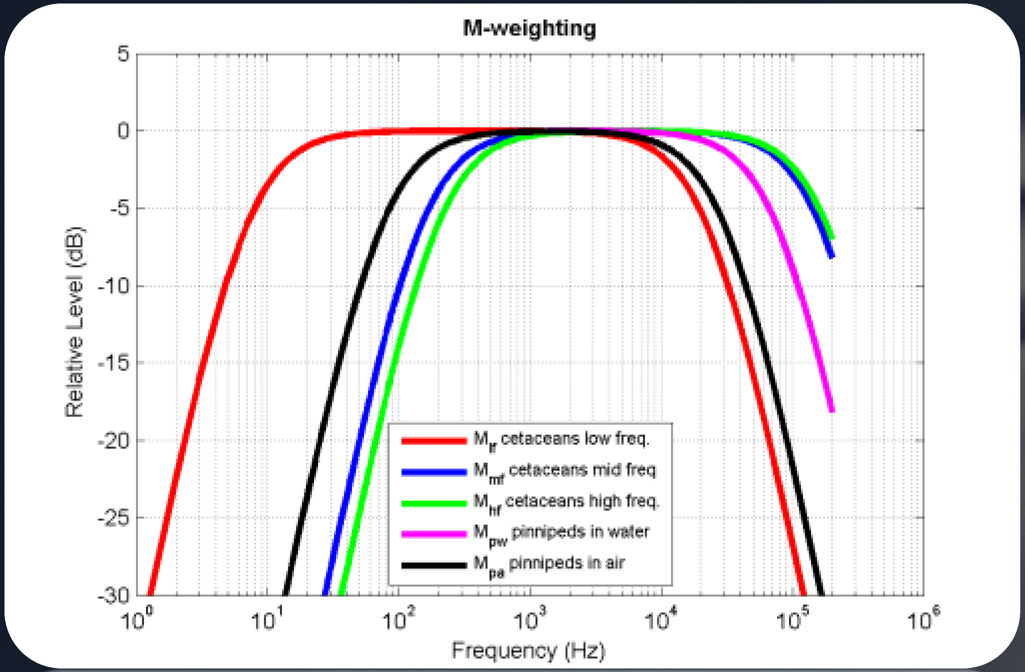
SMRU

Chelonia Limited
Cetacean Monitoring Systems

Assessing the impact

Marine Mammal Impact Criteria:

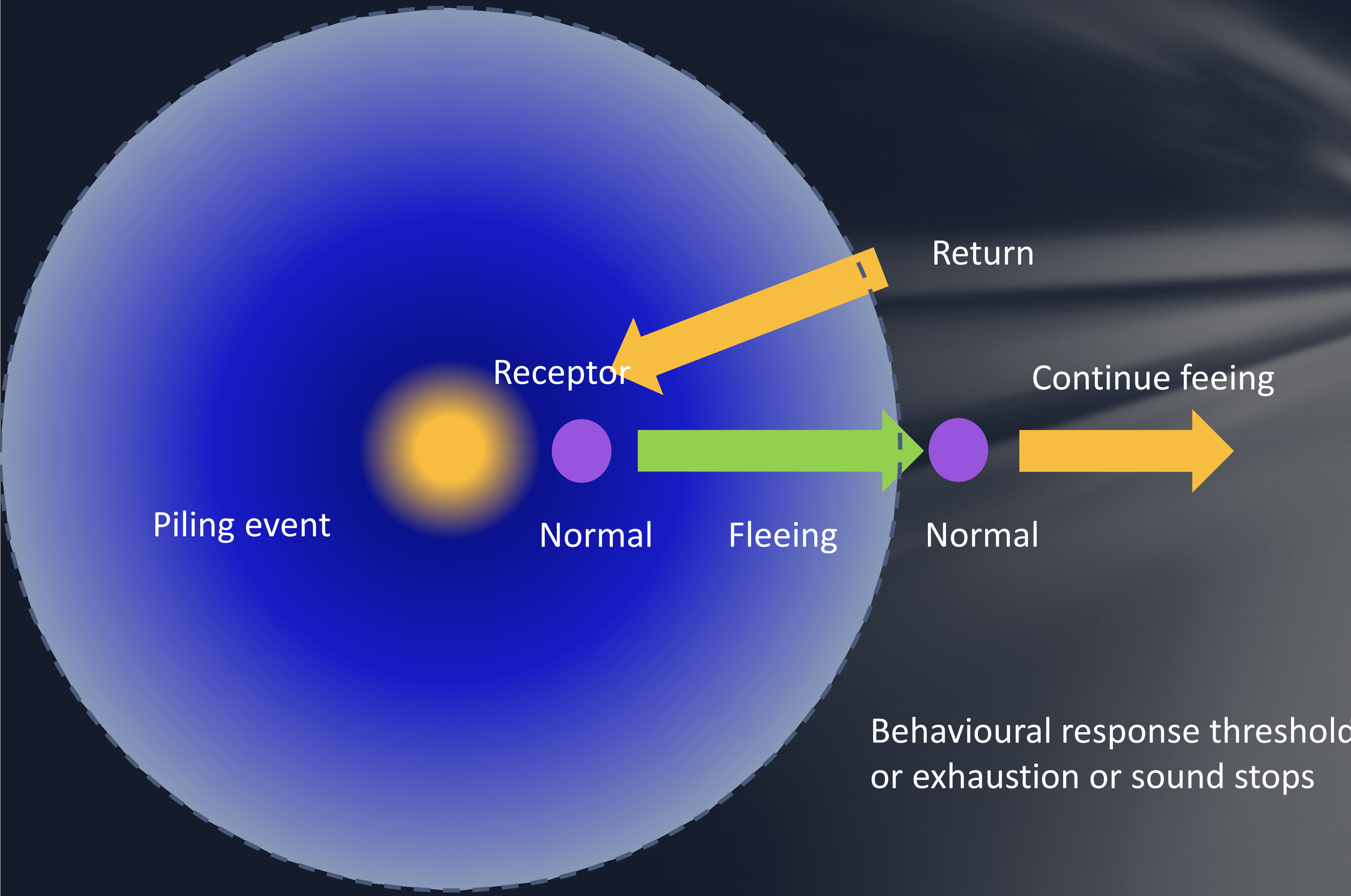
- Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations (Southall *et al*, 2007)



Dual criteria a peak exposure level (un-weighted) and frequency weighted (M-weighted) Sound Exposure Levels for different functional hearing groups

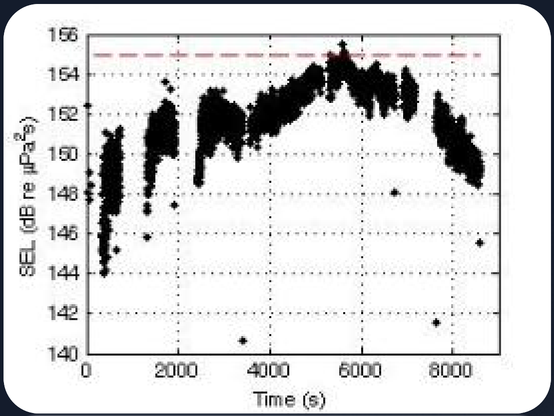
- 164 dB re 1 μPa²s in harbour porpoise (Lucke *et al*, 2009)

Behavioural response

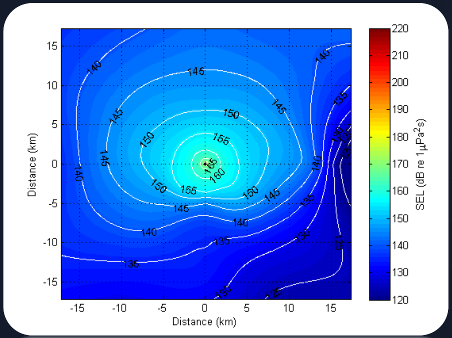


Impact modelling

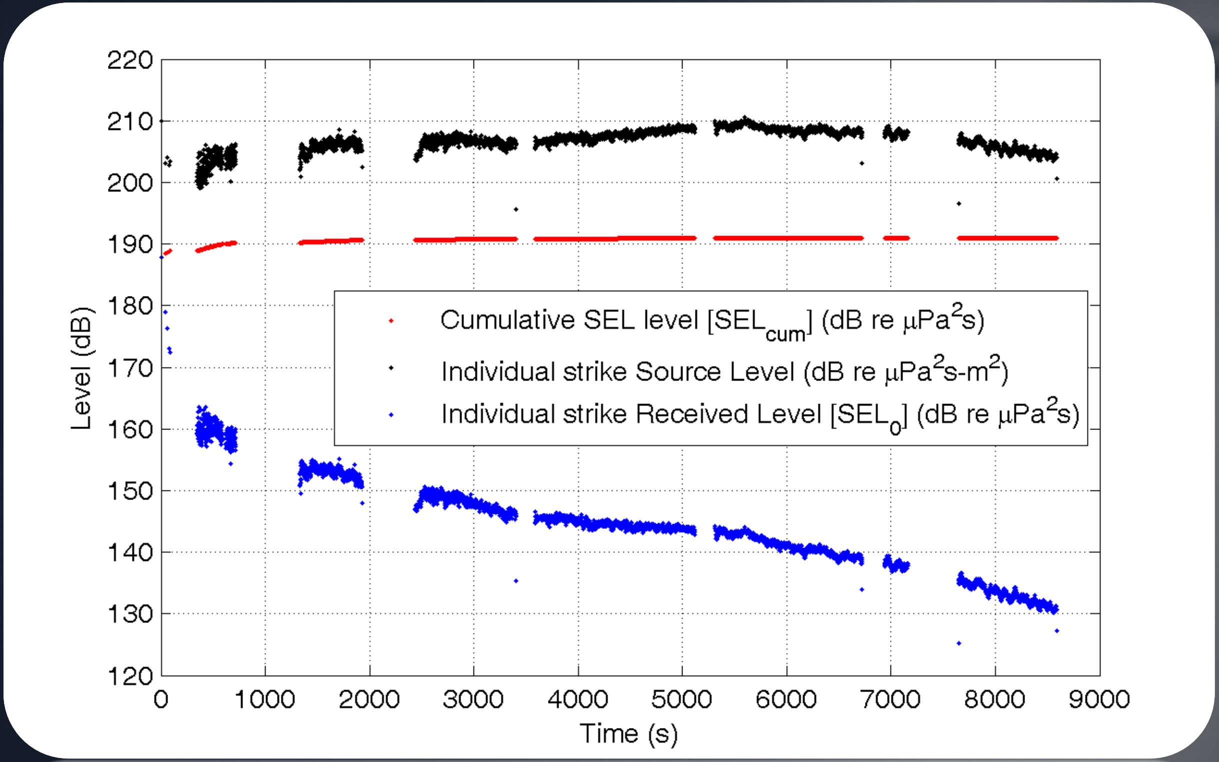
SEL received level



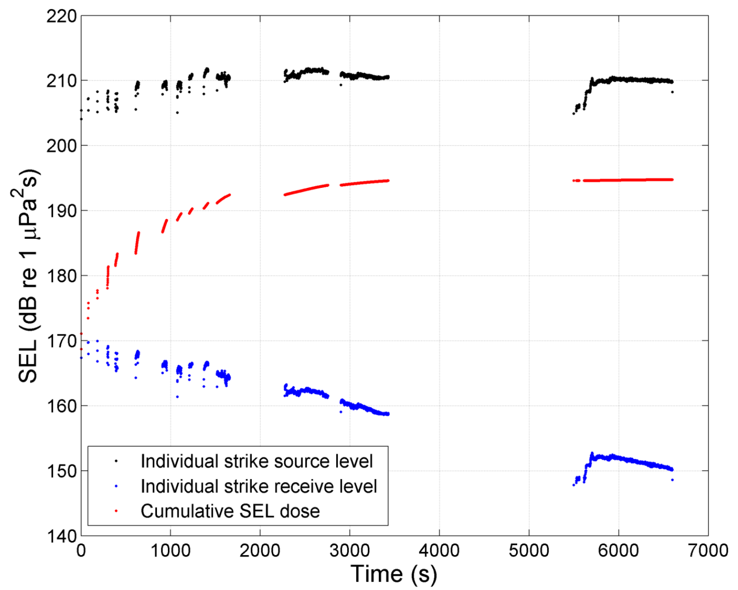
Propagation loss modelling

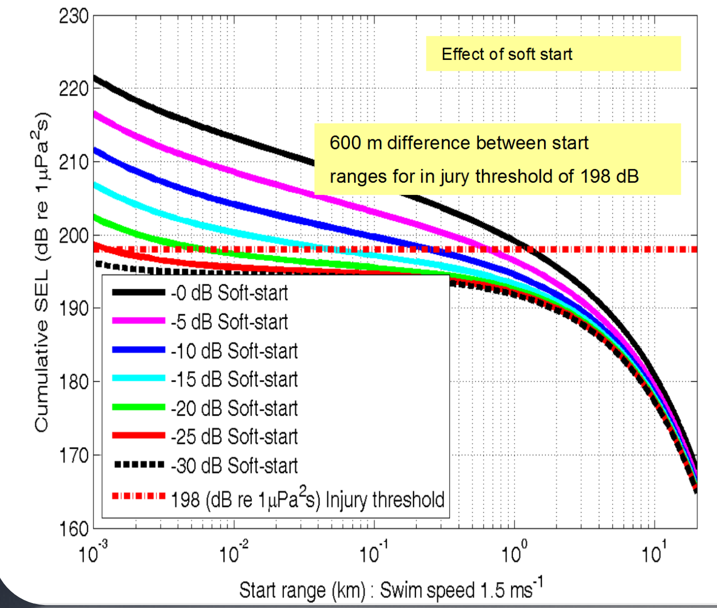


Cumulative exposure for a fleeing animal Scenario (start range 100m / swim speed 1.5ms^{-1})



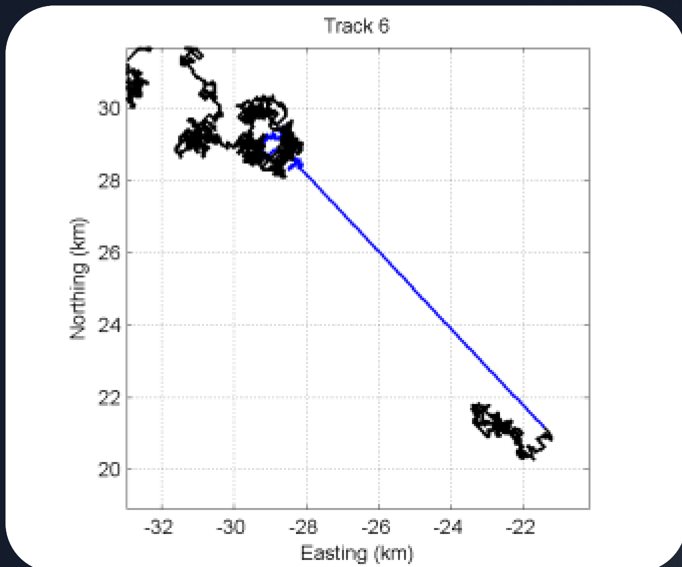
Soft-start = reduced exposure

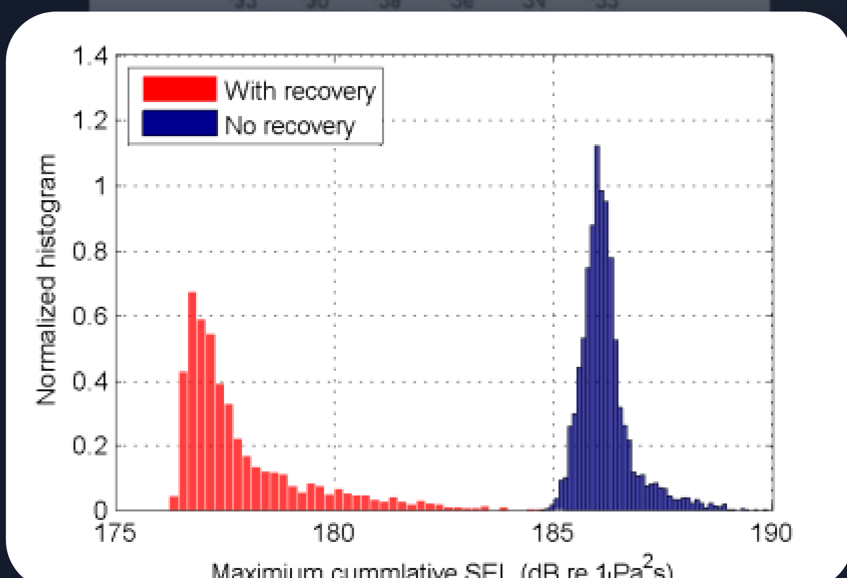




Cumulative SEL (red) received by a fleeing animal (un-weighted) for a start range of 1 km, with a swim speed swim speed of 1.5 m/s and with the I4 measured energy source level of 205 dB re 1µPa²s.m². Also shown is the source level (black) and received SEL (blue).

Whole windfarm construction example (Monte Carlo approach)

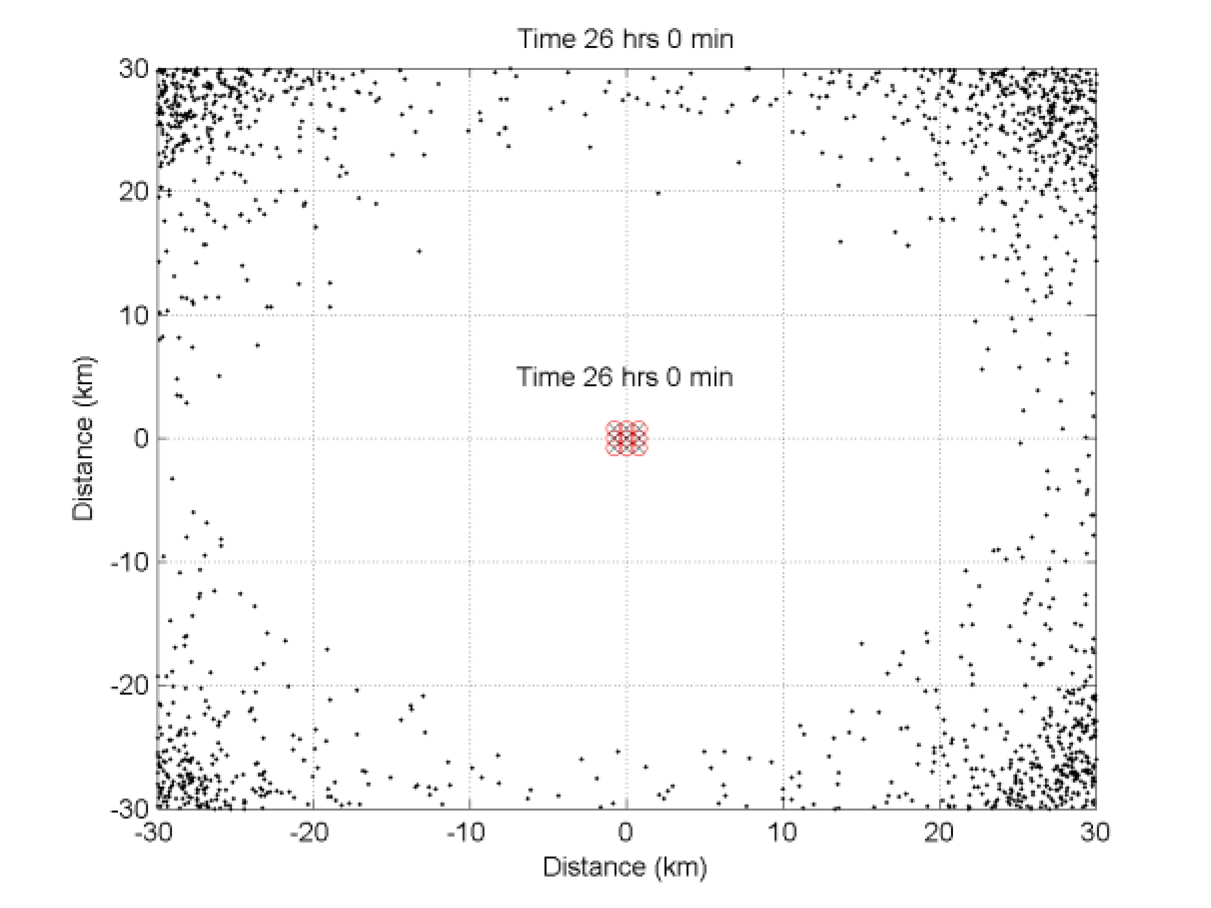




- 9 Foundation construction
- 800 m spacing
- >4000 hammer strikes in around 2.5 hours
- 36 hours between piling events
- 6 hour lead in before piling
- 24 hours after piling
- Simple propagation loss model

Distribution of Exposure Risk

Spatial and temporal distribution



NERC – DEFRA Marine Renewable Energy Research Programme

DEFRA

RESPONSE: Understanding How Marine Renewable Device Operations Influence Fine Scale Habitat Use And Behaviour Of Marine Vertebrates

EBAO: Optimising Array Form for Energy Extraction and Environmental Benefit

FLOWBEC: Flow, Water column & Benthic Ecology in 4D (involves co-location of a variety of sensors to better understand physical and biological interactions

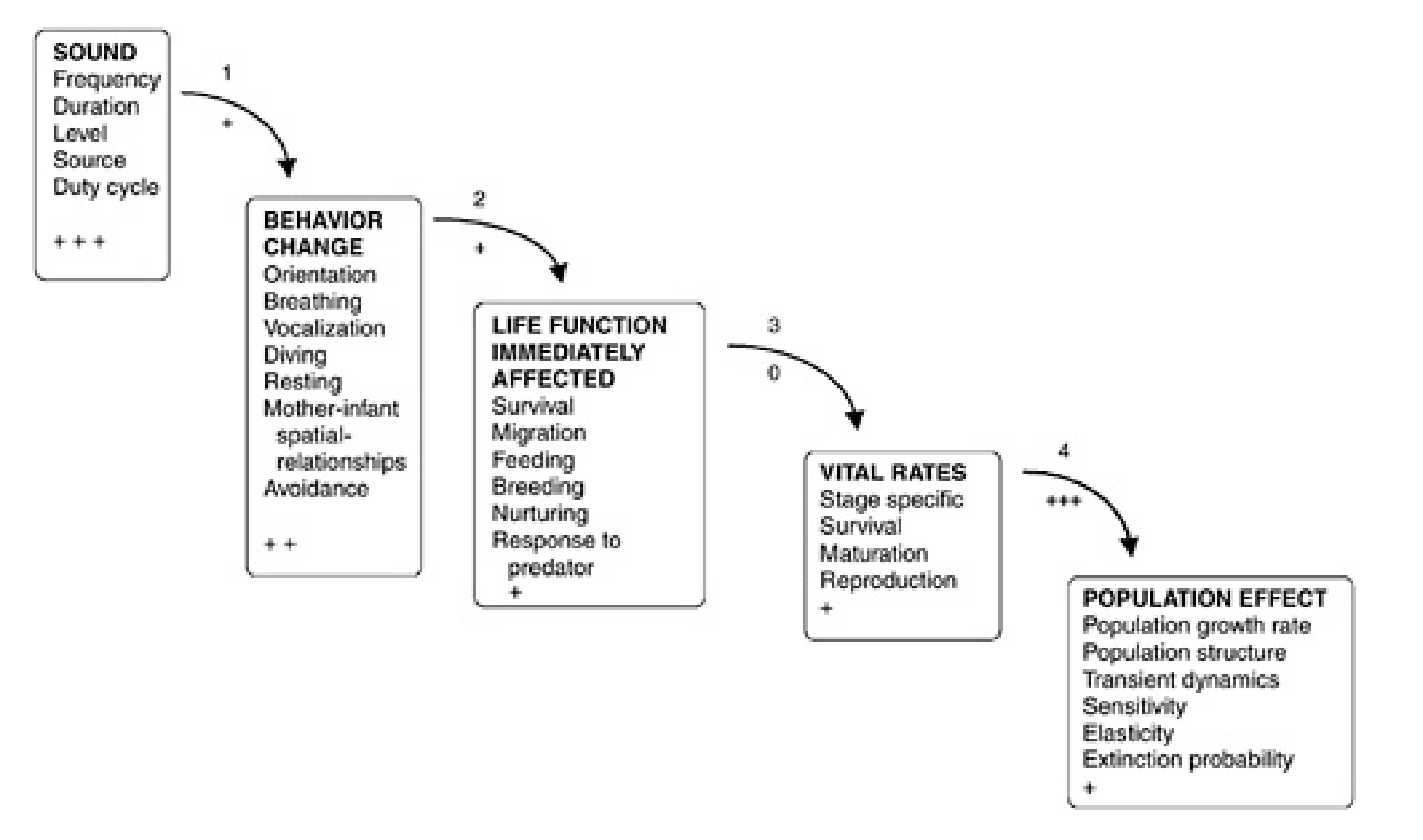
QBEX : Quantifying benefits and impacts of fishing exclusion zones on bio-resources at energy sites

Summary

- Physiological and behavioural studies on some marine species is taking place on a limited number of key species of cetaceans and fish. Large knowledge gaps exist.
- Characterization of many offshore activities is beginning to take place however very little data exists on new and emerging technologies.
- Measurement standards are being developed ANSI / ISO / BSI (shipping, deep, shallow water, piling, wave energy devices, etc.) More needed, quicker.
- Key Knowledge gaps have been identified by industry and government on the effects of noise on the marine environment. These uncertainties are seen as one of the major risk barriers to many on going renewable energy developments.
- There is therefore a major driver for collaborative, multidisciplinary research to help answer these questions to support these developing industries.


Thank you

Population Consequences of Acoustic Disturbance (PCAD) model



How to Get from Acoustic Disturbance to Population Effects