Determination of noise exposure criteria – the German approach

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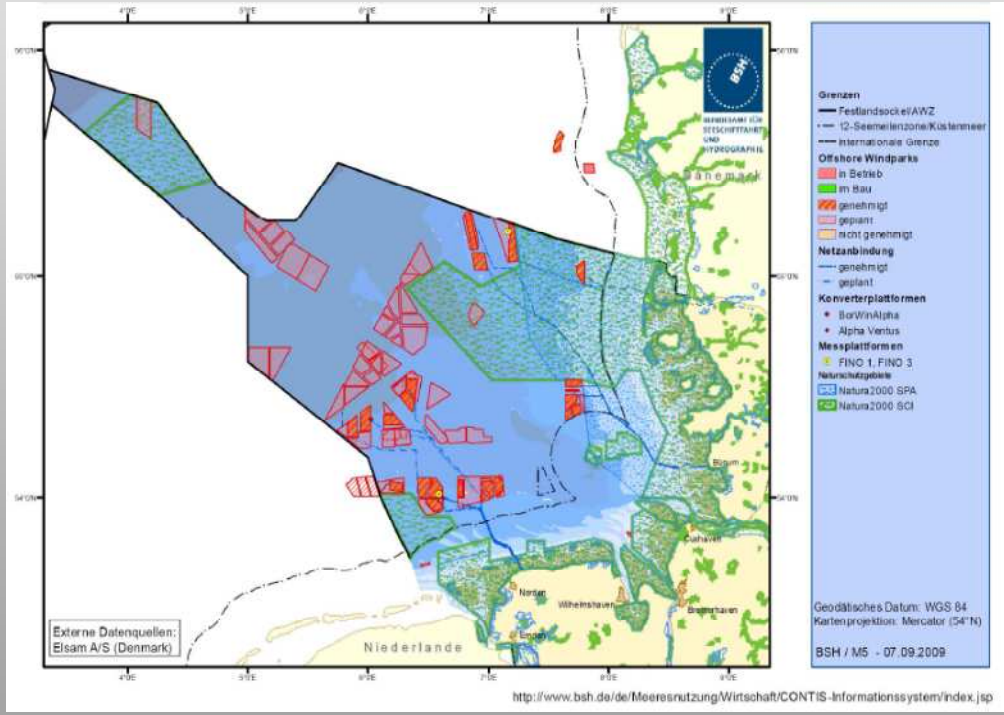
Offshore development Germany

NORTH SEA
- Test farm „Alpha-ventus“ in operation (12 turbines)
- Bard Offshore I (in construction, 15 turbines aready operating)
- In total 25 licences for owfs in EEZ (1787 turbines)

BALTIC
- Baltic I in operation (21 turbines)
- In total 3 licences for owfs in EEZ (240 turbines)

GOALS
- 25-37 GW installed in 2025-2030
- Proportion of renewables on gross electricity consumption: 18% in 2020 (35% in 2030, 60% in 2050)



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Life cycle of a wind farm

(i) Pre-construction phase (1-5 years)

(i) Construction phase (around 1 year)

(i) Operational phase (20-25 years)

(i) Decommissioning phase (around 1 year)

- Due to short duration of impulses and dominant low frequencies mainly consideration about direct damage to marine mammals close to piling site (alteration in hearing-threshold shifts) & large-scale disturbances /displacement are of relevance
- 2.000-3.000 strokes per turbine with strong Sound Pressure Levels:

Pile Diam	Sound Pressure Level (Peak to Peak)	Sound Pressure Level (RMS)	Energy Flux Density (single pulse)
4.7 m	252 dB re 1µPa	234 dB re 1µPa	220 dB re 1µPa^{2}s
6.5 m	258 dB re 1µPa	240 dB re 1µPa	226 dB re 1µPa^{2}s

@ COWRIE 2007

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Legal concerns

Marine Strategy Framework Directive: Annex I, Descriptor 11: „Introduction of energy, including underwater noise is at levels that do not adversily affect the marine environment.“

***Commission Decision on criteria and methodological standards* (2010/477/EU):**
Indicator 11.1 (Distribution in time and place of loud, low and mid frequency impulsive sounds): “Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1µPa 2·s) or as peak sound pressure level (in dB re 1µPa peak) at one meter, measured over the frequency band 10 Hz to 10 kHz.”

→ Pile driving activities in German waters within next years probably main contributor to 11.1

UNEP/CMS
Res.9.19 (2008): Resolution on adverse anthropogenic marine/ocean noise impacts on cetacean and other biota & **Res. 10.24 (2011):** Resolution on further steps to abate underwater noise pollution for the protection of cetaceans and other migratory species

ASCOBANS

MOP6/Doc.7-04 (P) (2009): Draft Resolution on Adverse Effects of Underwater Noise on Marine Mammals during Offshore Construction Activities for Renewable Energy Production

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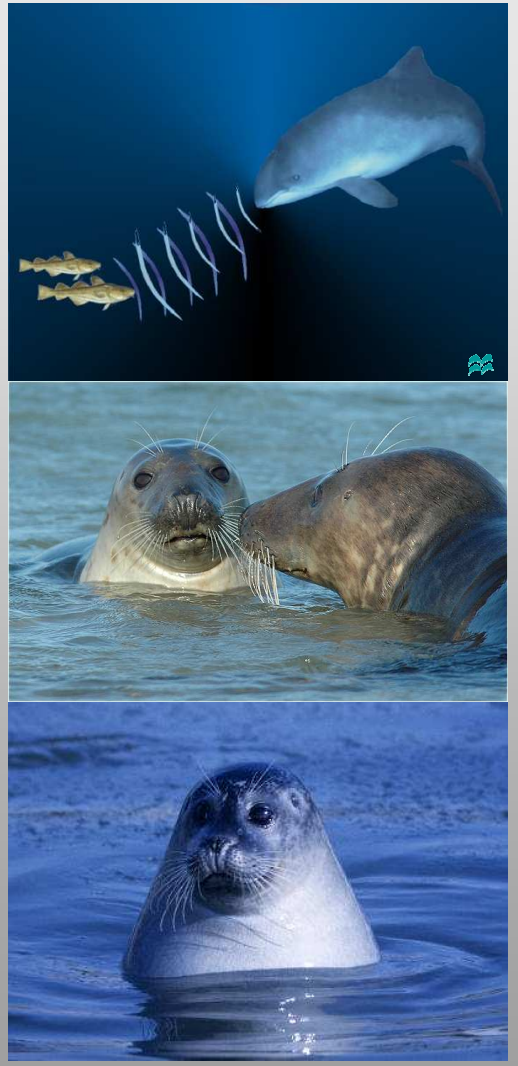
Marine mammals in German EEZs

- German Baltic & North Sea: three species of marine mammals on regular basis
- Harbour porpoise = most abundant mammal in German EEZ of North Sea – in summer around 50.000 animals (4-5 individuals/km²), start to calve in June, only 10-20% of these numbers in Baltic, genetic different
- Both grey and harbour seal are more abundant in coastal waters – far less contact with offshore construction sites than harbour porpoises
- Healthy hearing of vital importance for marine mammals, use sound for communication, orientation, finding food, predator avoidance, obstacle avoidance
- Most sensitive hearing of h.p. beween 16 kHz and 140 kHz, captive to detect frequencies between 200 Hz-180 kHz



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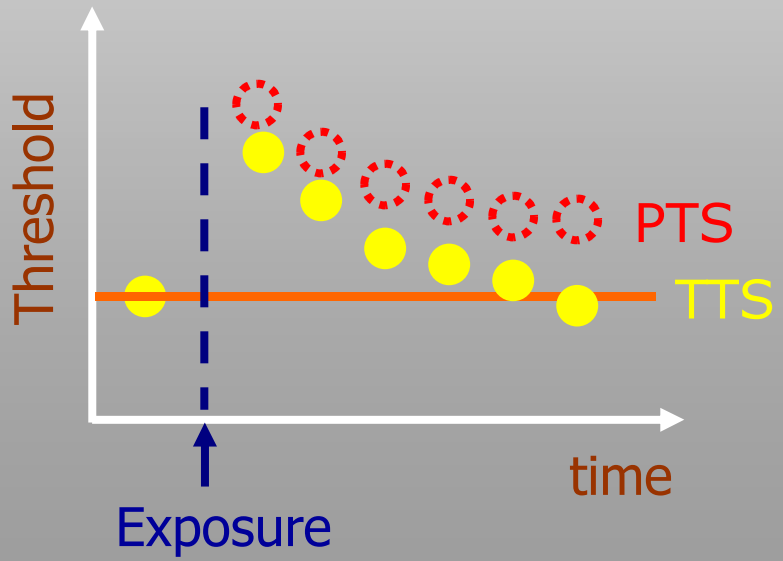
Noise induced hearing loss

- Noise exposure can lead to a shift in hearing sensitivity (Threshold Shift, TS), this effect can be temporary (TTS) or permanent (PTS)
- TTS is defined as the difference between hearing thresholds measured before and after intense sound exposure
- Even though the hearing sensitivity of h.p. is low at the frequency at which most of the sound energy of pile driving occurs (under 5 kHz), TTS can be induced in higher frequencies
- Multiple exposures at levels inducing TTS can lead to prolong recovery periods and eventually the possibility for PTS onset, new findings refer to irreversible long term impacts as the animal ages



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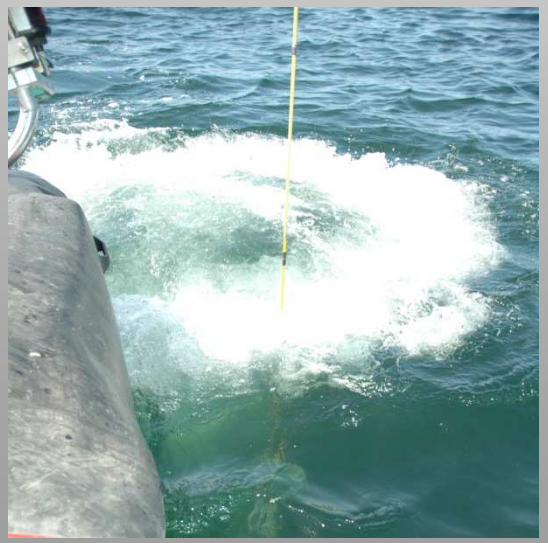
TTS-tests on a harbour porpoise using an impulsive sound source



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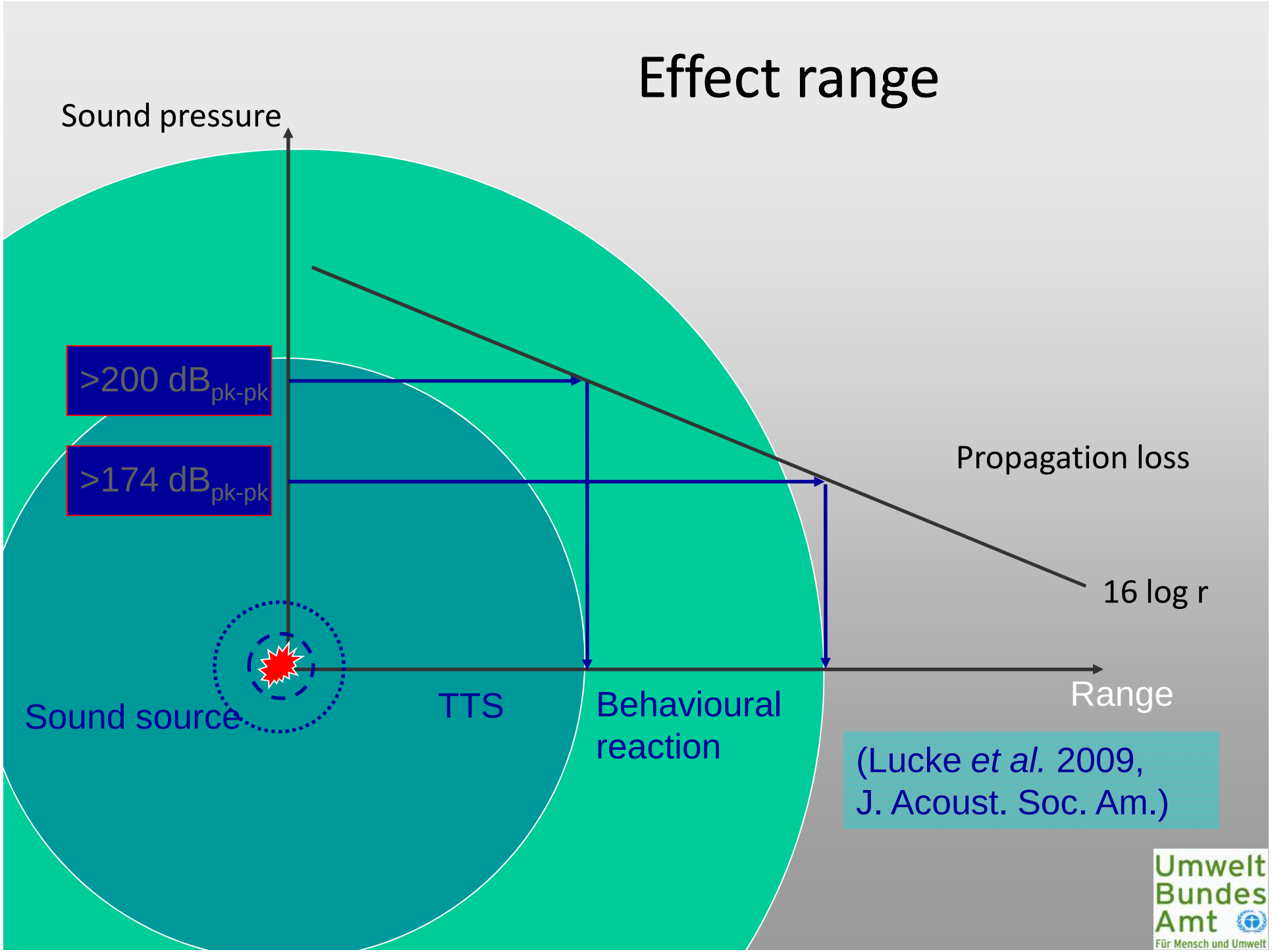
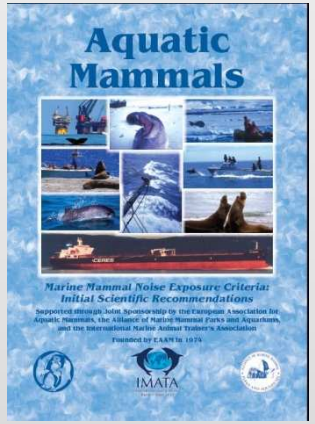
Effect range



Results



- Threshold by Southall et al. (2007) for TTS in „high-frequency cetacean“:

➢ SEL = 183 dB dB re 1 µPa^2·s
➢ SPL = 224 dB re 1 µPa

- But: values were investigated in mid-frequency-species (*Tursiops truncatus & Delphinapterus leucas)* & extrapolated to high-frequency cetaceans

- Findings by Lucke et al. (2009) indicate much higher hearing sensitivity of harbour porpoises

- Study by Popov et al. (2011) in finless porpoises found even higher sensitivity (circa 6 dB TTS @ 158 dB SEL & circa 25 dB TTS @ 163 dB)

- Studie by Finneran (2010): TTS in the range of 3-40 kHz was derived @ 4 kHz; TTS already occured at low exposure levels, but increased more rapidely with increasing exposure level - as frequency increase beyond 3 kHz

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UBA - Recommendation on safety values for noise protection in offshore wind farm construction

- In 2003 the German Federal Maritime and Hydrographic Agency (BSH) introduced standard threshold values for piling noise based on a first advise by UBA; since 2008 the recommended safety values (based on new findings) are part of the licenses

- Porpose: to prevent auditorial impairment (TTS) in harbour porpoises

- Sound duration as well as the sound level important in estimating the damage to organism that may be caused by a impulsive sound (Report of EC TG 11; Southall et al. 2007)

- A dual criteria is applied considering these two measures by combining information of the Sound Exposure Level (SEL) that integrates received sound energy over time and the Sound Peak (Pressure) Level (SPL) of the sound source

- UBA safety values (dual criteria):
  → SEL = 160dB re 1 $mPa^2 \cdot s$
  → SPL (peak-peak) = 190 dB re 1 µPa
  Both measures should not be exceeded at a distance of 750 m from the piling site. It has to be ensured, that no animals are left within this exclusion zone.

- Observed exceedances: „alpha ventus“: regular 10 dB, max. 14 dB (SEL);
  BARD Offshore 1: max.19,1 dB (SEL) in 750m, still circa 5 dB (SEL) in 5000 m distance

http://www.umweltbundesamt.de/uba-info-medien/4118.html

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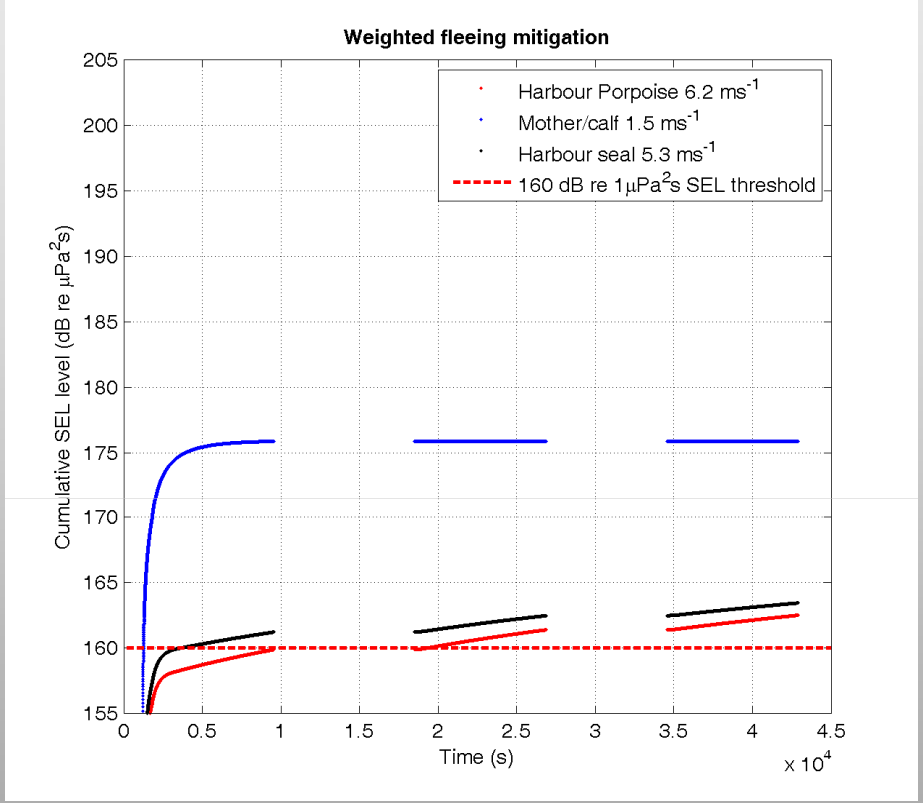
Values include some safety adjustment for cumulative exposure



Harbour porpoise = 162,5 dB
Mother-calf-pair = 189,5dB
Harbour seal = 163,4 dB

Modelling of cumulative sound levels for a) an adult harbour porpoise, b) a mother/calf pair and c) a harbour seal during pile driving of a tripod given the safety value of 160 dB SEL have been matched at 750m (scenario: escape from the area where acoustic deterrent devises have been applied under construction conditions similar to the „alpha ventus“)
@ P. Lepper (2011)

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Further work

- Threshold-validation on more individuals and other frequencies
- Effects of TTS on echolocation or foraging ability of h.p.
- Species specific weighting functions
- Hearing recovery times,
- Better knowledge on seasonal migration and abundances
- Considerations on severe behavioural responses/ large scale displacement
- Other species (fishes (specialists), invertebrates) & life stages, also in relation to possible other forms of damage than auditorial (damage to other tissues)
- Consideration of cumulative impacts (cumulative exposure of mulitiple strokes, different building sites, noise input from other anthropogenic sources)
- Etc.

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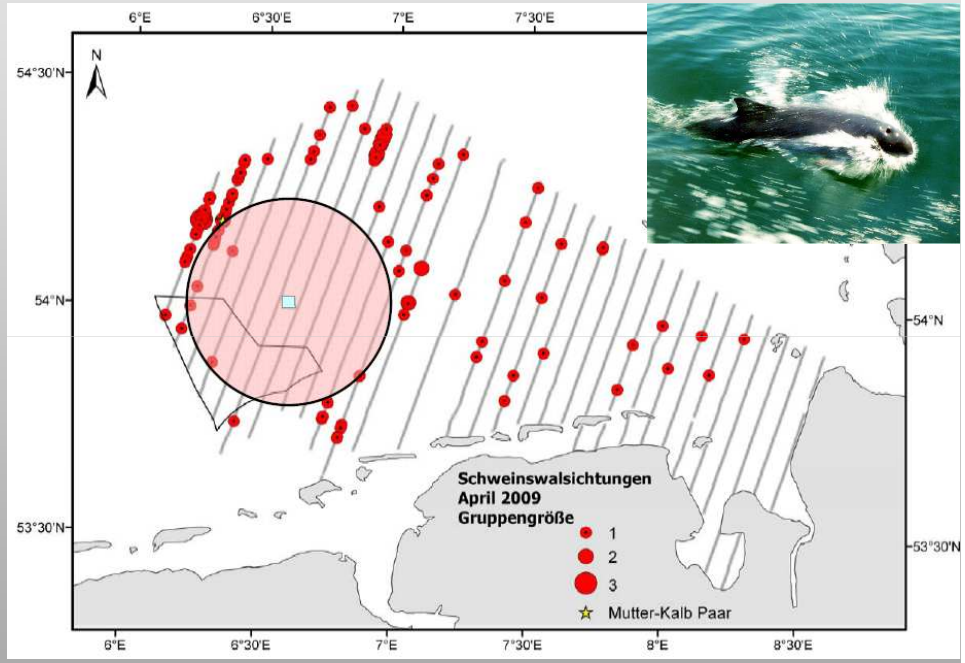
Behavioural responses/displacement

- **Gilles et al. 2009b, 2010 & Lucke et. 2010:** construction of „Alpha-Ventus“ – almost complete avoidance of around 25 km around construction site - data from airial surveys backed up by parallel derived POD data

- **Tougaard et al. 2011 & Kastelein 2011:** playback of pile driving sounds – avoidance behaviour at received levels of 140 dB/115 dB

- **Diederichs et al. 2010 & Betke and Matuschek 2010:** “alpha-ventus: significant effects (waiting times) in 16,4 km (SEL 140 dB), no more in 21 km distance (SEL 134 dB)



- **Ecological consequences:** likely to be ecologically significant, h.p. forage by using echolocation – requires acute hearing, h.p. have a high digestive rate – TTS or temporal or permanent displacement from ecologically important areas can negatively influence physiological state

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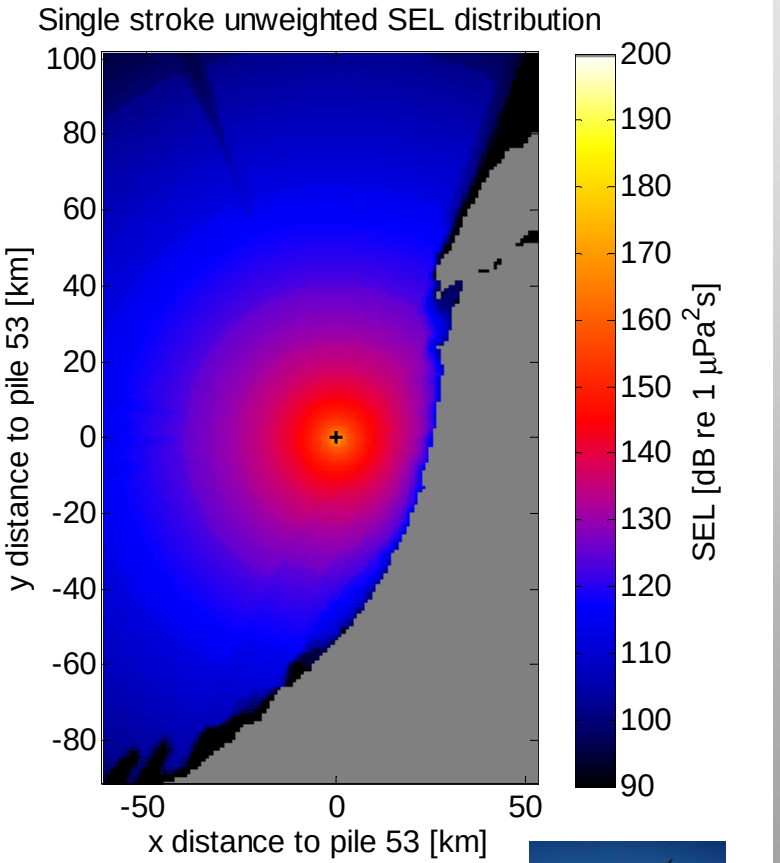
Noise mapping

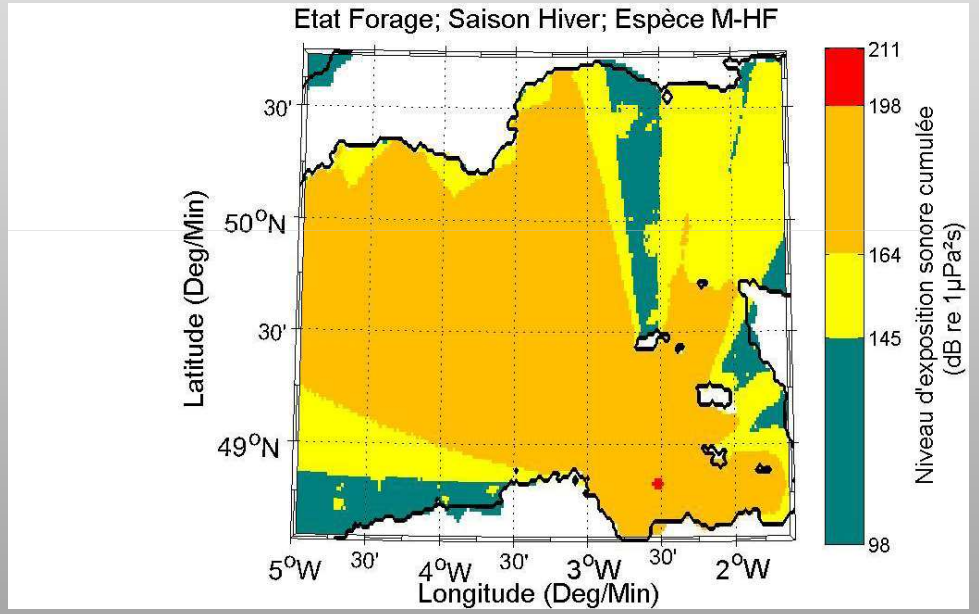
- Tool to predict for cumulative effects -



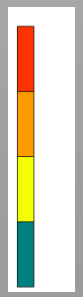
@ TNO

Emissions

Immissons (Harbour porpoise)



@ Quiet oceans



PTS (Permanent threshold shift)

TTS (Temporal threshold shift)

Behavioural change

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Technical feasability – example dewatered telescopic cofferdam

- **Offshore test** conducted at december 19th in Denmark, Mejlflak
- **Sea Energy Offshore** together with Siemens & TENET
- **Water depth**: 14m
- **Hammer**: Menck S 800 (kJ)
- **Pile diameter**: 2,13 m
- **Cofferdam diameter**: 3m
- **Length of monopile**: 35m, 11 m piled into ground with around 60 strokes (100 % energy)
- **Measurements**: at 750 m North and South of piling site with and without cofferdam, different depths
- **Without cofferdam**: in average 175 dB SEL (SPLpeak 197 dB)
- **With cofferdam**: in average 152 db SEL (SPLpeak 180 dB)
- **Mitigation** of 23 dB (SEL) at 4 kHz in 750 m
- **Application in 2012**: converter platforms BORWIN II, HELWIN I
- **Equipment** can be adapted to any existing contruction logistic

@ SeaRenergy Offshore

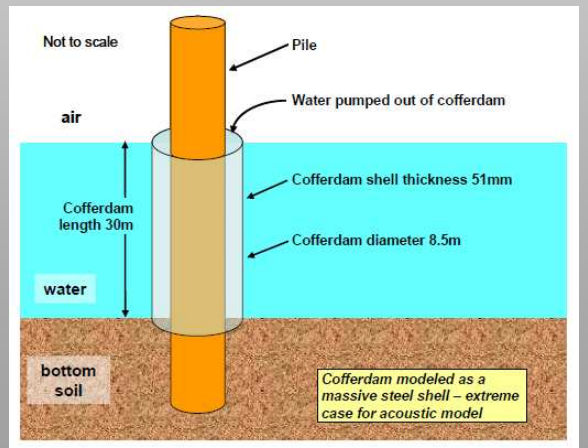

Figure 7: Cofferdam details for 30m deep ocean.

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Many thanks for your attention!

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