Effects of underwater sound from impact piling for wind farms on harbour porpoises

Monitoring at Borssele and Gemini

Christ de Jong. de Jong | TNO Acoustics & Sonar

C.A.F. de Jong, F.P.A. Lam, A.M. von Benda-Beckmann, T.S. Oud (TNO);
S.C.V. Geelhoed, T. Vallina, T. Wilkes (Wageningen Marine Research),
J. Brinkkemper, R. Snoek (WaterProof BV)

14 February 2023

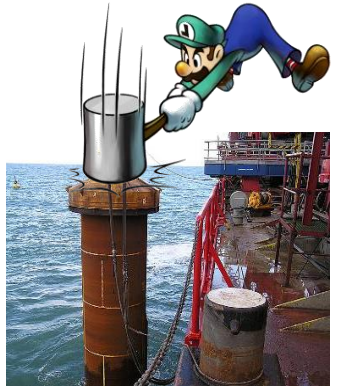
WOZEP
DUTCH GOVERNMENTAL OFFSHORE WIND ECOLOGICAL PROGRAMME

TNO innovation for life

WAGENINGEN UNIVERSITY & RESEARCH

WATER PROOF

Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0)

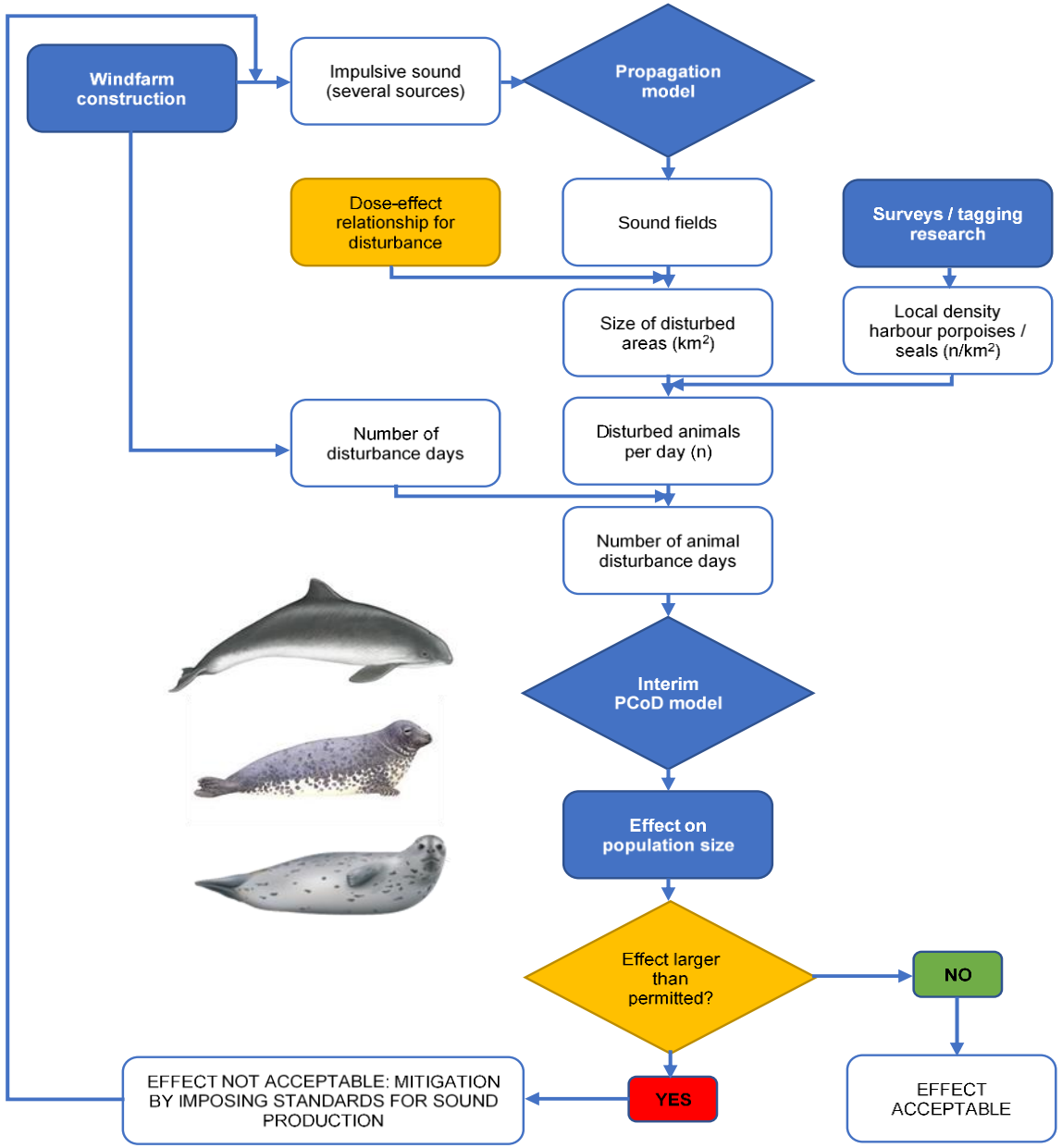


- Piling sound disturbs marine mammals
- KEC 4.0 describes the methodology for assessing the impact of this disturbance on marine mammal populations (porpoises and seals).
- Ecological standard:
  the populations of harbour porpoises, harbour seals and grey seals on the Dutch Continental Shelf (DCS) must be maintained at a minimum of 95% of the present level with a high degree of certainty (>95%) .
- This leads to underwater noise limits in the permits, such as:
  the underwater sound from each piling stroke, observed at 750 m from the pile, shall not exceed SELss = 168 dB re 1 µPa^{2}s (*broadband, unweighted*).

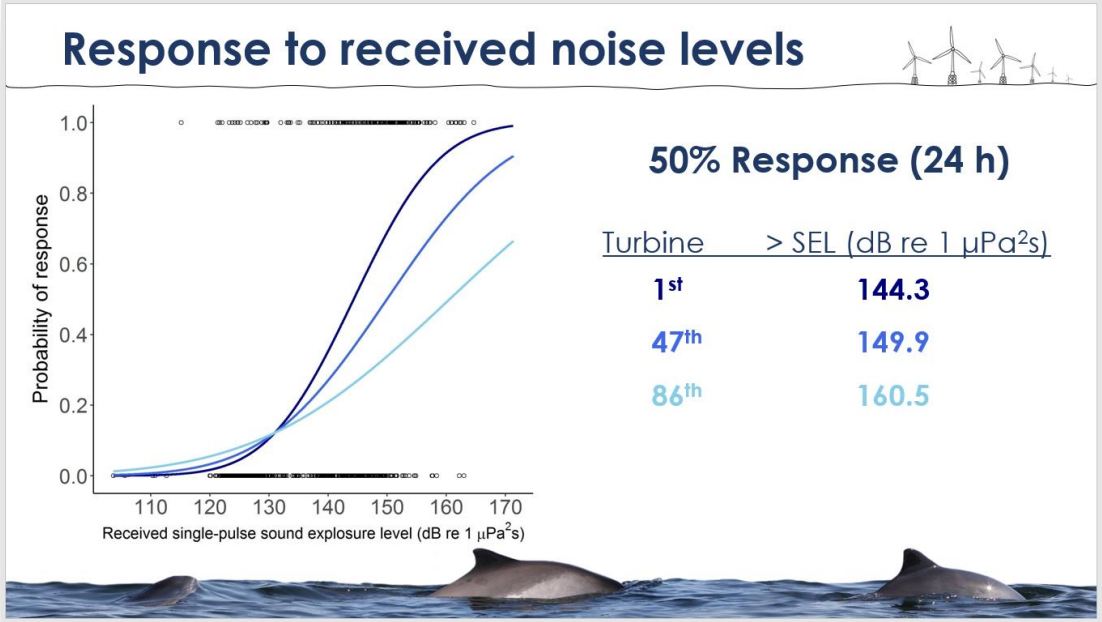
KEC 4.0 procedure:

1. Calculate underwater sound distribution
2. Use dose-effect relationship and animal density estimate to calculate number of disturbed animals per day
3. Calculate number of 'animal disturbance days'
4. Use the interim PCoD model to estimate the population effect
5. Compare with ecological standard:

high degree of certainty (> 95%) that disturbance by piling sound does not reduce populations with more than 5%



Dose-effect relationship



- Based on data from construction of Beatrice wind farm (Graham et al, 2019)
- Dose = broadband unweighted SELss
- Effect = reduced detection of porpoises (CPODs)

WOZEP: reduce uncertainties in KEC

DUTCH GOVERNMENTAL OFFSHORE WIND ECOLOGICAL PROGRAMME

1. Is the unweighted broadband SELss the appropriate dose ?

   Should the dose account for frequency sensitivity of porpoise hearing ?

2. Can the assumed dose-effect relationship be experimentally validated ?

⇨ Study data from the construction of Borssele and Gemini wind farms

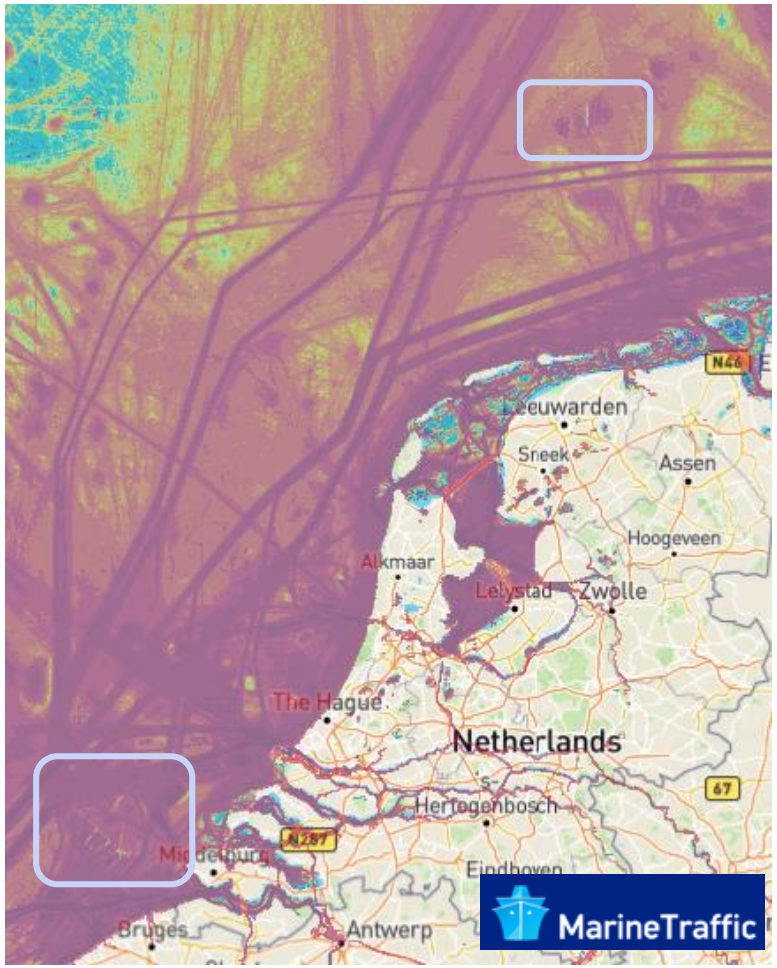
Borssele & Gemini wind farms

Borssele:

- Built 2019-2020
- Noise mitigation:
  - AdBm, HSD, DBBC
- High shipping density

Gemini:

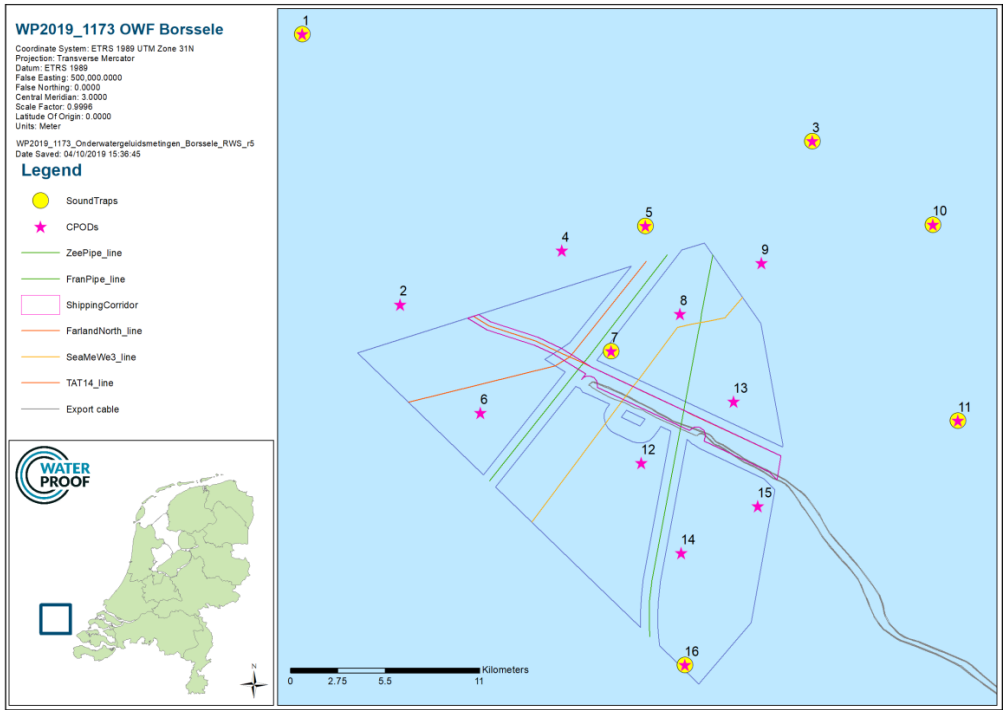
- Built 2015-2016
- No noise mitigation
- Lower shipping density



Borssele monitoring

- 17 Oktober 2019 – 16 September 2020
- 7 SoundTrap sound recorders

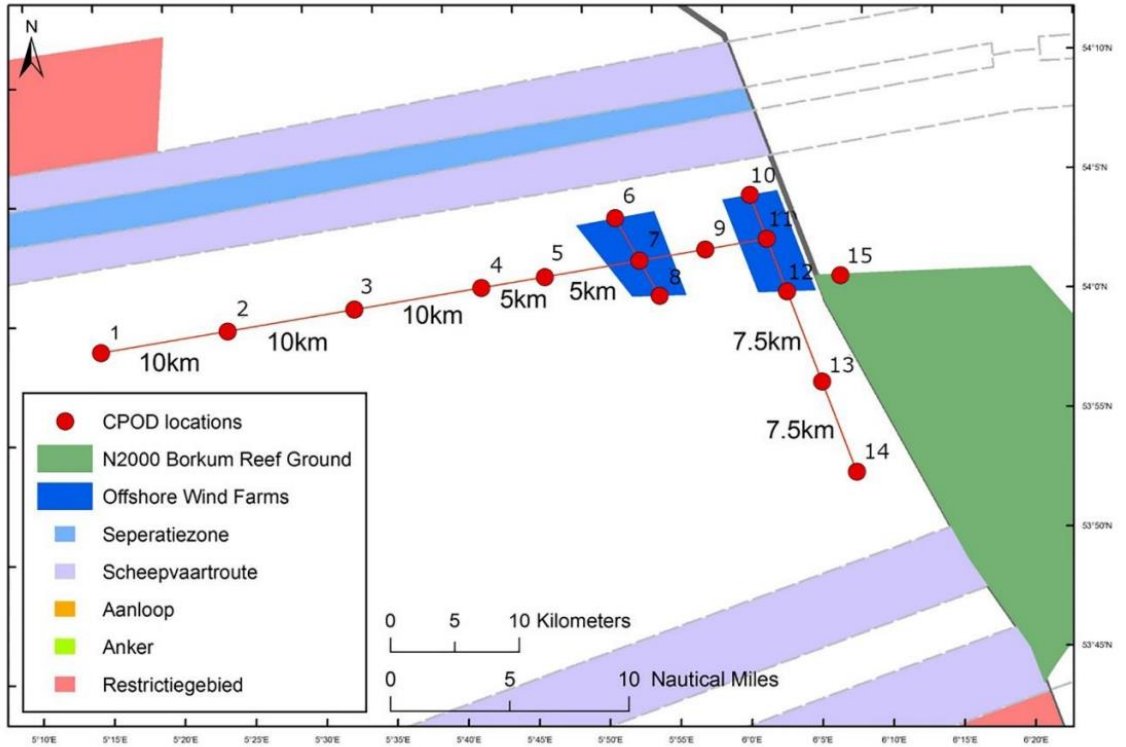
- 16 Continuous Porpoise Detectors (CPODs)



Gemini monitoring

- T-0: juli 2011 – juli 2014
- T-C: juni 2015 – januari 2016

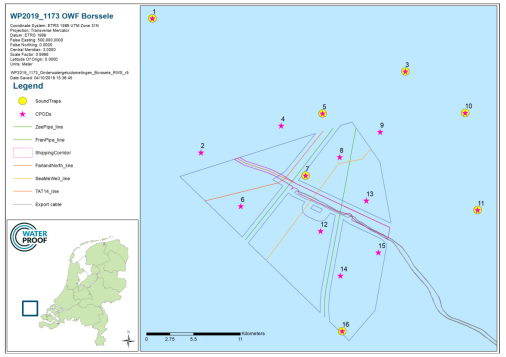
- 2 AMAR sound recorders
  - T-0 only; 2013/2014

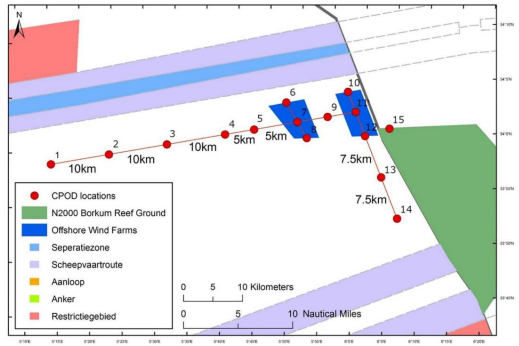


- 15 Continuous Porpoise Detectors (CPODs)

Data analysis

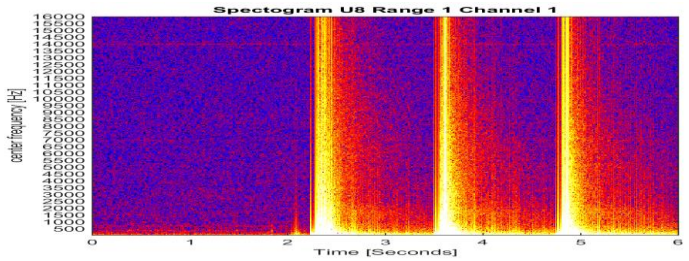
- WaterProof: Sound recording and processing
- TNO: Aquarius modelling and calibration to quantify sound at all CPOD locations:
  - Unweighted broadband SELss
  - Porpoise-weighted broadband SELss,w
- WMR: Quantify porpoise detections (PPM/h)
- WMR: Statistical modelling (Bernoulli GAMM)
  - PPM/h versus either SELss/h or SELss,w/h
  - Incorporating time of day, CPOD location, water temperature, tide & wind



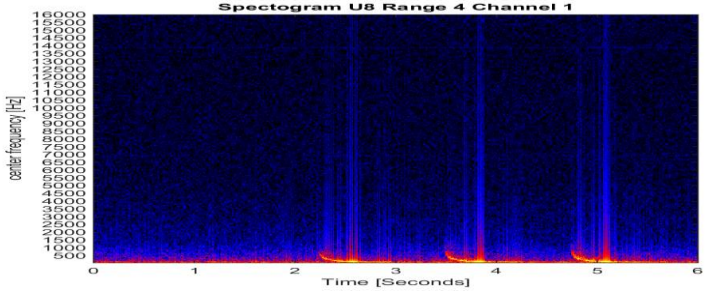


Piling sound

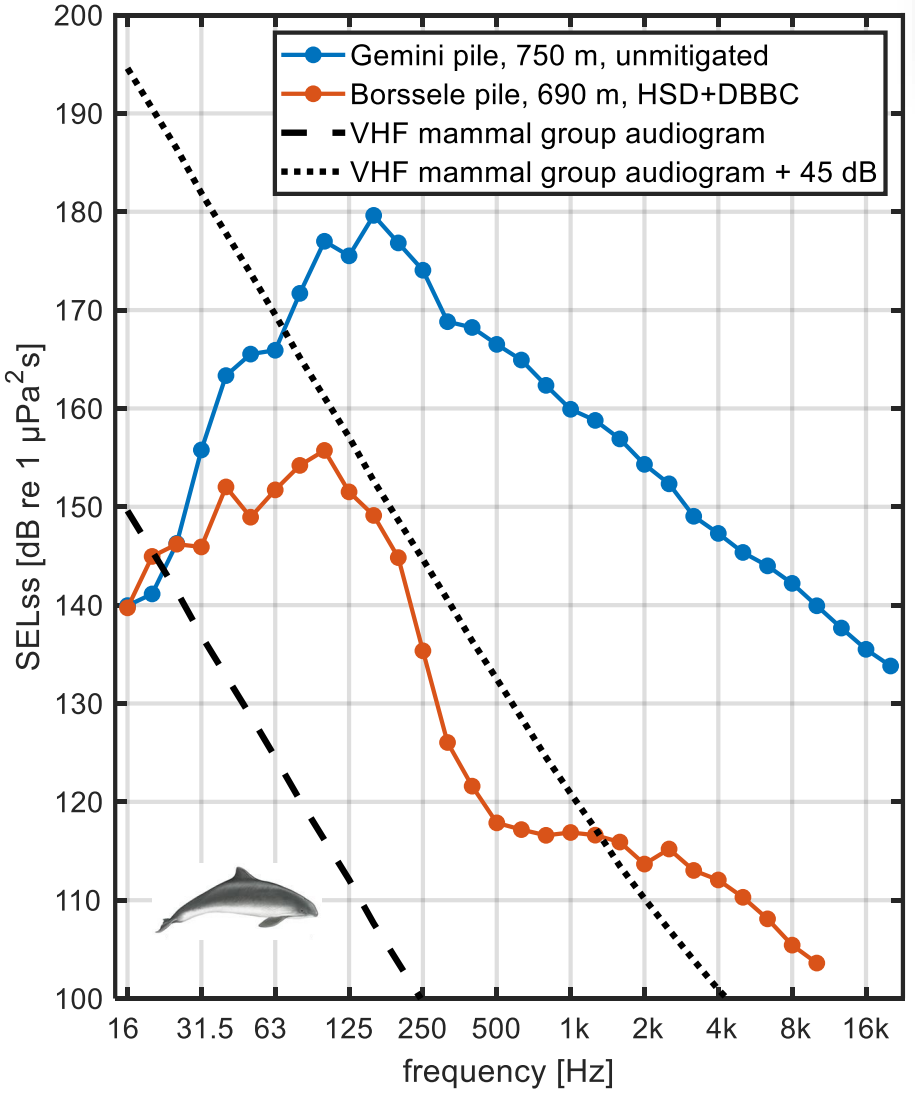
Gemini - 750 m



Gemini - 66 km



Borssele I - 3 km
HSD & DBBC




Marine Pollution Bulletin 90 (2015) 196–208

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

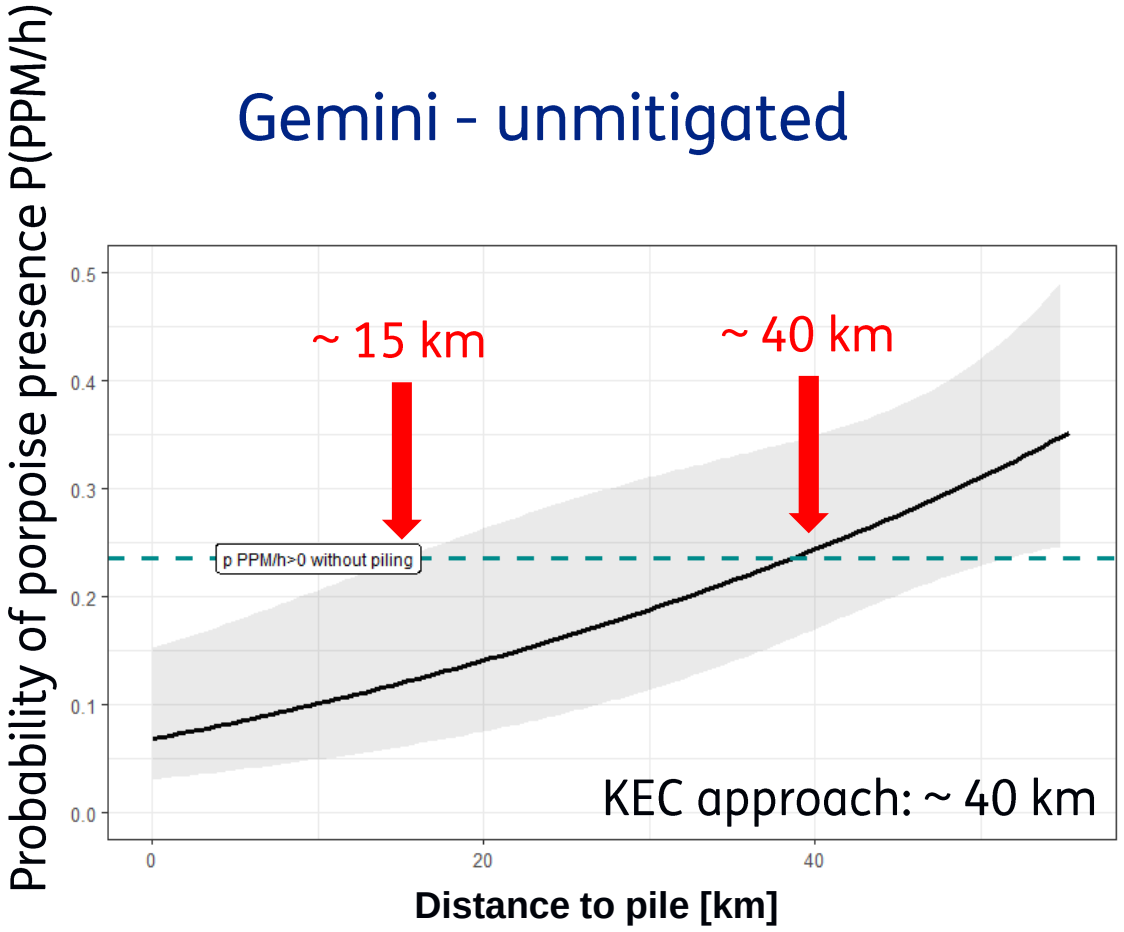
Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises

Jakob Tougaard [a,*], Andrew J. Wright [a,b], Peter T. Madsen [c,d]

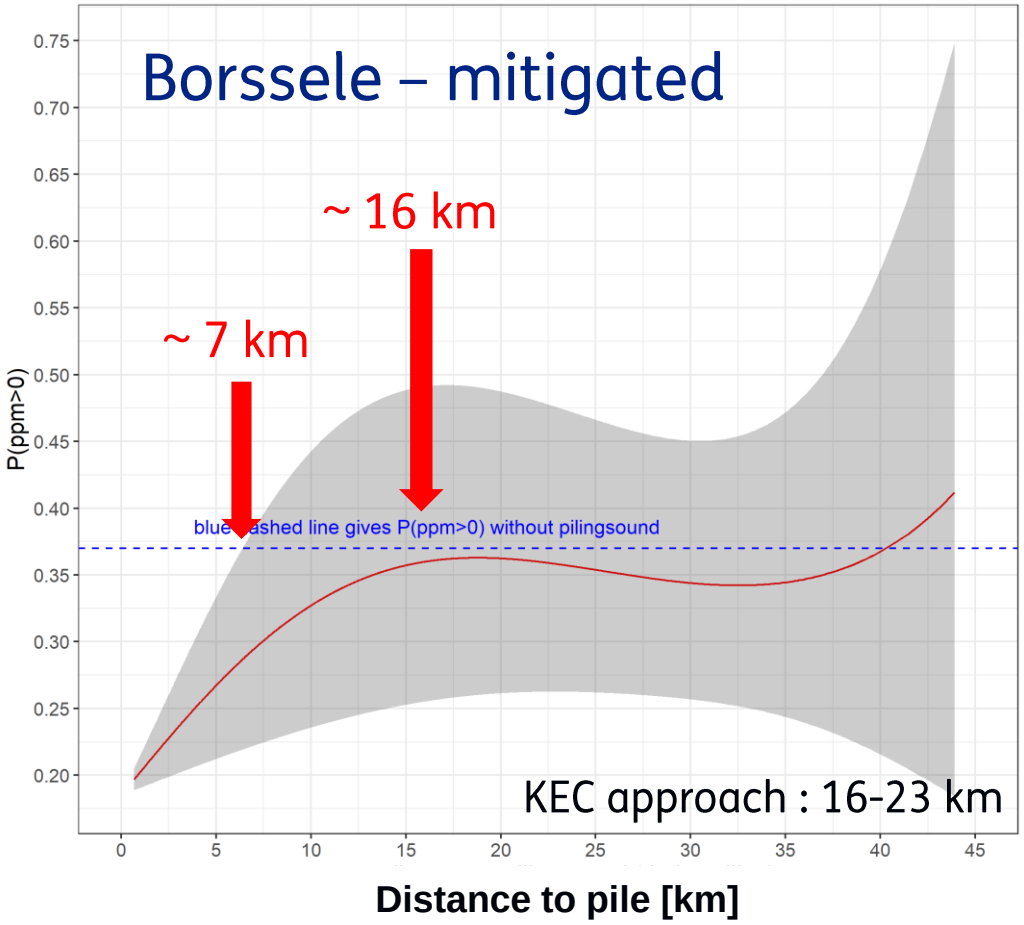
Tougaard et al. [2015] propose an “exposure limit for negative phonotaxis to be 45 dB above the hearing threshold”

Porpoise presence versus distance from pile

Gemini - unmitigated



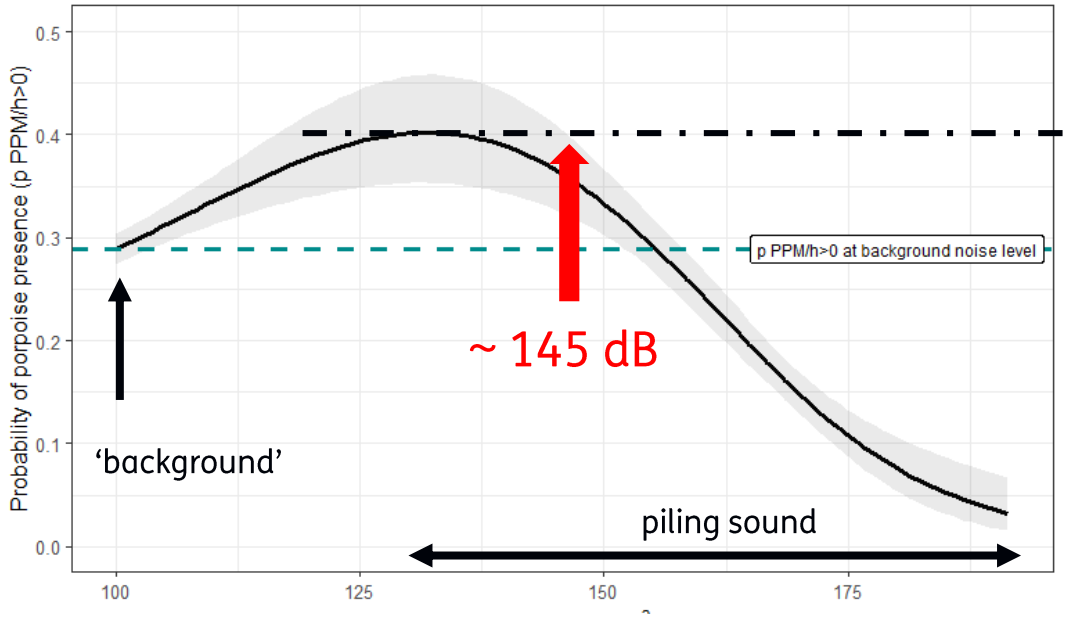
Borssele – mitigated



Porpoise presence versus (unweighted) SELss

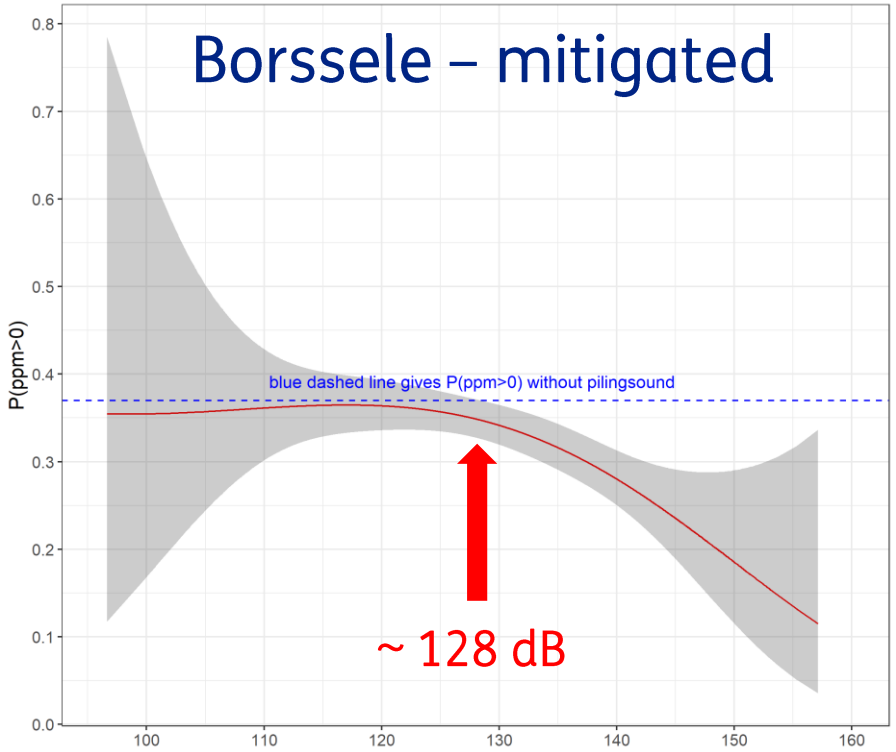
Probability of porpoise presence P(PPM/h)

Gemini - unmitigated



Unweighted SELss (10 Hz – 20 kHz) [dB re 1 µPa²s]

Borssele – mitigated

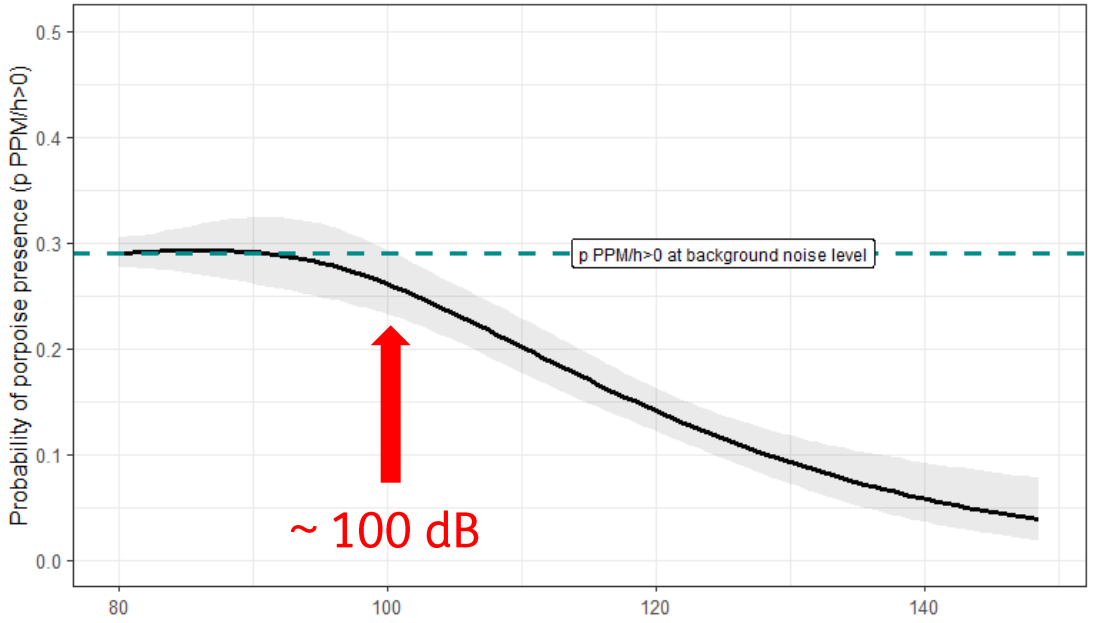


Unweighted SELss (50 Hz – 500 Hz) [dB re 1 µPa²s]

Porpoise presence versus weighted SELss

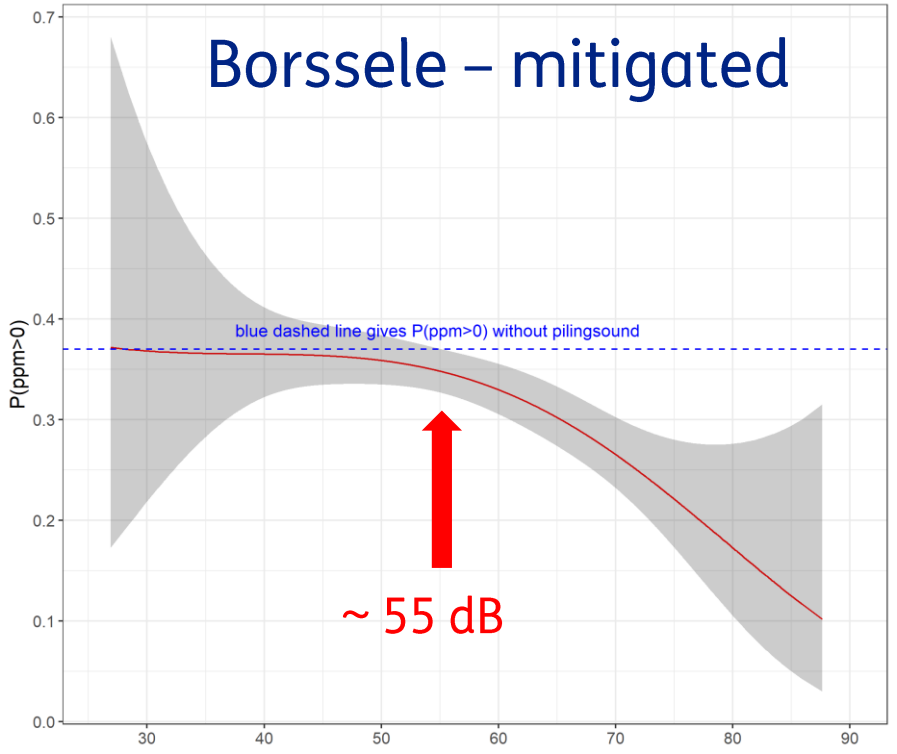
Probability of porpoise presence P(PPM/h)

Gemini - unmitigated



VHF-weighted SELss (10 Hz – 20 kHz) [dB re 1 µPa²s]

Borssele – mitigated



VHF-weighted SELss (50 Hz – 500 Hz) [dB re 1 µPa²s]

incompatible bandwidth

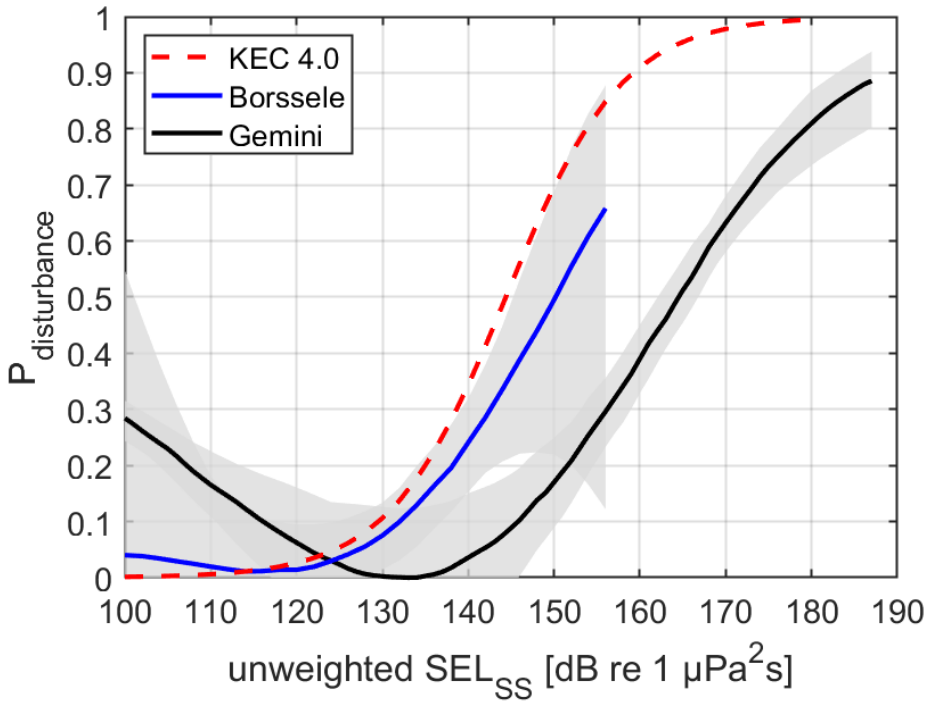
Porpoise presence analysis

- PPM/h versus SELss/h and SELss,w/h seem equally robust (for Borssele and Gemini data)
- Weighted SELss metric is dificult to measure:
  - higher frequencies are masked by background noise
- Weighted SELss metric is dificult to model:
  - Aquarius 4 model underestimates high-frequency piling sound

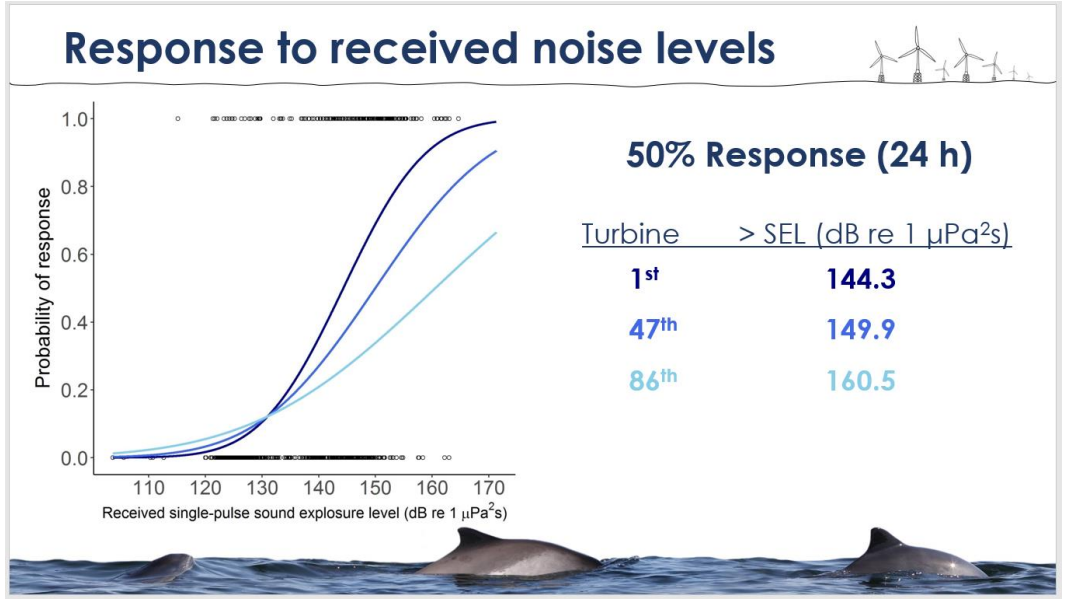
	$SEL_{ss,unw}$ [dB re 1 µPa²s]				$SEL_{ss,VHF}$ [dB re 1 µPa²s]			
Distance (km)	0.7	7	32	66	0.7	7	32	66
Measured	182	164	149	136	141	120	102	100
Aquarius 4	182	167	150	133	137	111	79	66
Difference	0	3	1	-3	**-4**	**-9**	**-23**	**-34**

Dose-effect relationship

Unweighted SELss



Graham et al, INPAS 2018



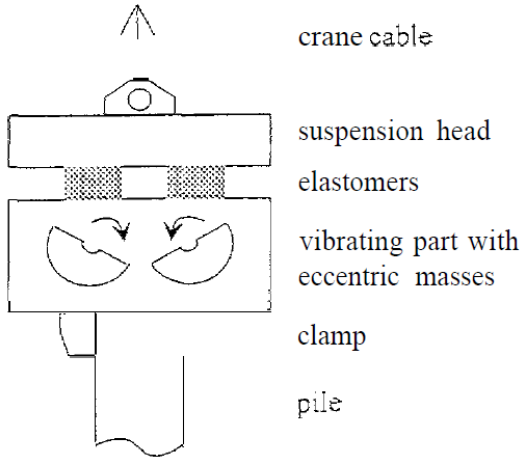
KEC curve derived from effect to piling for 1st turbine

Conclusions from analysis Gemini/Borssele data

- Mitigation reduces distance at which porpoises avoid marine piling
- Using unweighted SELss for the assessment of popoise disturbance seems as reliable as unsing weighted SELss
- Using weighted SELss is more complex (for measuring and modelling)
- KEC dose-effect relationship is conservative

Way ahead …

- KEC is limited to assessment of the effects of impact piling sound
- Observations show that porpoise detections reduce before piling starts
- Alternative piling techniques (variants of vibro-piling) produce more continuous sound (like ships and operational wind turbines)



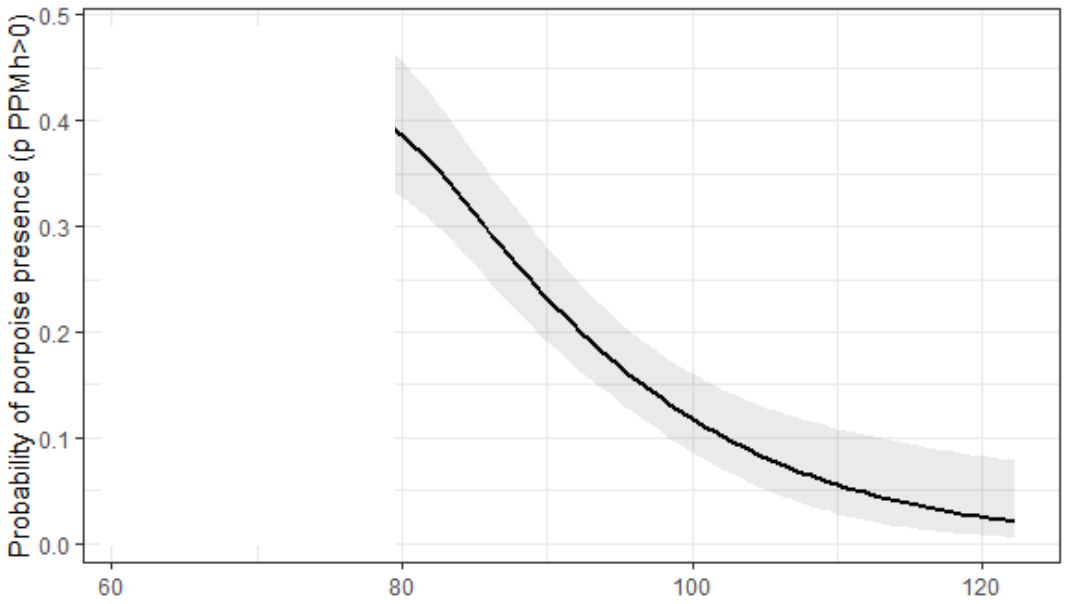
- ⇨ develop assessment framework for ‘continous sound’ exposure

Porpoise presence versus weighted SPL

- ‘continuous’ sound (all sources)
- ‘fast’ time-weighting

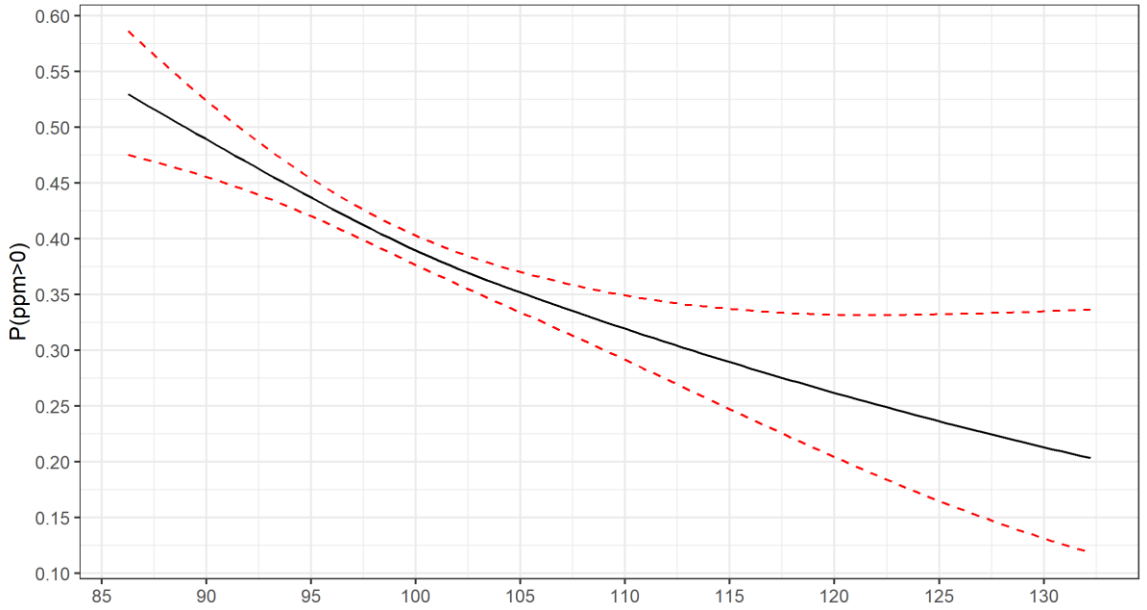
Probability of porpoise presence P(PPM/h)

Gemini



VHF-weighted SPL_{Fast} [dB re 1 µPa]

Borssele



VHF-weighted SPL_{Fast} [dB re 1 µPa]

⇨ Less porpoise clicks in ‘noisy’ environment