itap
INSTITUT FÜR TECHNISCHE UND ANGEWANDTE PHYSIK GMBH

Noise Abatement/Mitigation Systems for impact pile-driving

Technical overview and offshore experiences

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DAkkS Deutsche Akkreditierungsstelle D-PL-18192-01-00

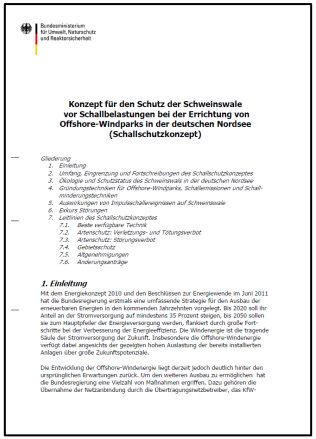
Competent under the terms of ISO/IEC 17025 to carry out determination of emissions and immissions of vibrations, underwater noise.

Underwater noise regulation in Germany

BNatSchG: Not allowed to harm any protected species.

Impulse noise (since 2011)

- Noise Mitigation Values @ 750 m (broadband 160 dB_{SEL05}, 190 $dB_{Lp,pk}$)
- Piling duration: 180 minutes


Konzept für den Schutz der Schweinswale vor Schallbelastungen bei der Errichtung von Offshore-Windparks in der deutschen Nordsee (Schallschutzkonzept)

Gliederung
1. Einleitung
2. Umfang, Eingrenzung und Fortschreibungen des Schallschutzkonzeptes
3. Ökologie und Schutzstatus des Schweinswals in der deutschen Nordsee
4. Grundsätze/techniken für Offshore-Windparks, Schallemissionen und Schallminderungstechniken
5. Auswirkungen von Impulsschallereignissen auf Schweinswale
6. Exkurs Störungen
7. Leitlinien des Schallschutzkonzeptes
   7.1. Beste verfügbare Technik
   7.2. Artenschutz: Verletzungs- und Tötungsverbot
   7.3. Artenschutz: Störungsverbot
   7.4. Gebietsschutz
   7.5. Allgemeinmaßnahmen
   7.6. Änderungsanträge

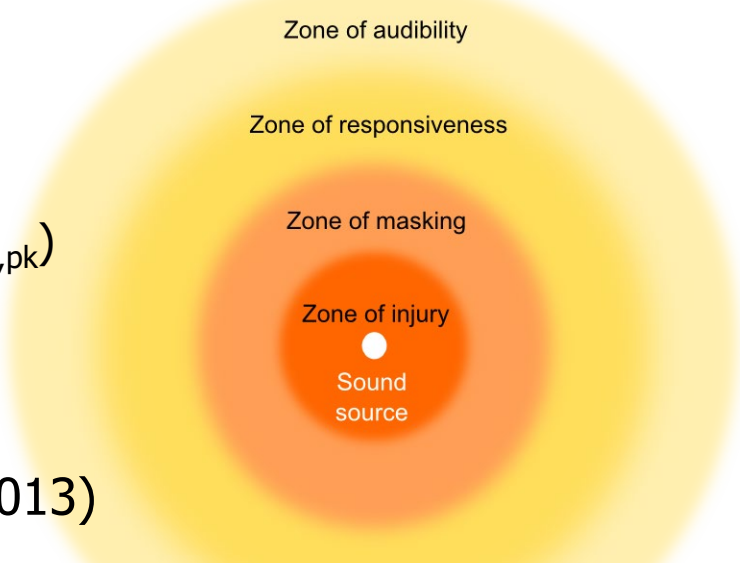
1. Einleitung

Mit dem Energiekonzept 2010 und den Beschlüssen zur Energiewende im Juni 2011 hat die Bundesregierung erstmals eine umfassende Strategie für den Ausbau der erneuerbaren Energien in den kommenden Jahrzehnten vorgelegt. Bis 2020 soll ihr Anteil an der Stromversorgung auf mindestens 35 Prozent steigen, bis 2050 sollen sie zum Hauptpfeiler der Energieversorgung werden, flankiert durch große Fortschritte bei der Verbesserung der Energieeffizienz. Die Windenergie ist die tragende Säule der Stromversorgung der Zukunft. Insbesondere die Offshore-Windenergie verfügt dabei angesichts der geringen hohen Auslastung der bereits installierten Anlagen über große Zukunftspotenziale.

Die Entwicklung der Offshore-Windenergie liegt derzeit jedoch deutlich hinter den ursprünglichen Erwartungen zurück. Um den weiteren Ausbau zu ermöglichen hat die Bundesregierung eine Vielzahl von Maßnahmen ergriffen. Dazu gehören die Übernahme der Netzanbindung durch die Übertragungsnetzbetreiber, das KfW-

BMU Noise Mitigation Concept (2013)

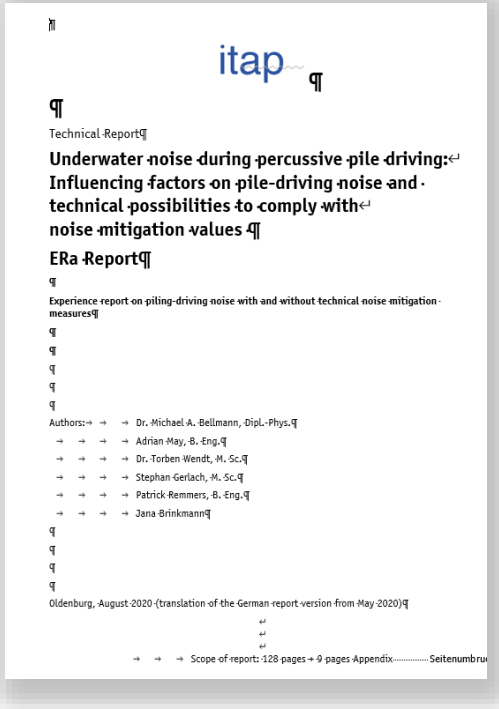
- North Sea 8 km disturbance radius
- Max. 10% of German Sea
- Max. 1% of Special Area of Conservation



Lessons learnt report (1/2)

- Funded R&D-project on behalf of BSH (2016 – 2019) based on German regulator (BSH) underwater noise data base MarinEARS

- 21 German OWF and 28 single installation projects
  - 1,458 foundation installations
  - 2,464 pile installations
  - diameter: 1,829 mm ≤ Ø ≤ 8,100 mm
  - All available **noise mitigation systems** as well as **noise abatement systems** tested in German waters



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Technical Report

Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values

ERa Report

Experience report on piling-driving noise with and without technical noise mitigation measures

Authors: Dr. Michael A. Bellmann, Dipl.-Phys.
Adrian May, B. Eng.
Dr. Torben Wendt, M. Sc.
Stephan Gerlach, M. Sc.
Patrick Remmers, B. Eng.
Jana Brinkmann

Oldenburg, August 2020 (translation of the German report version from May 2020)

Scope of report: 128 pages + 9 pages Appendix

https://www.itap.de/media/experience_report_underwater_era-report.pdf

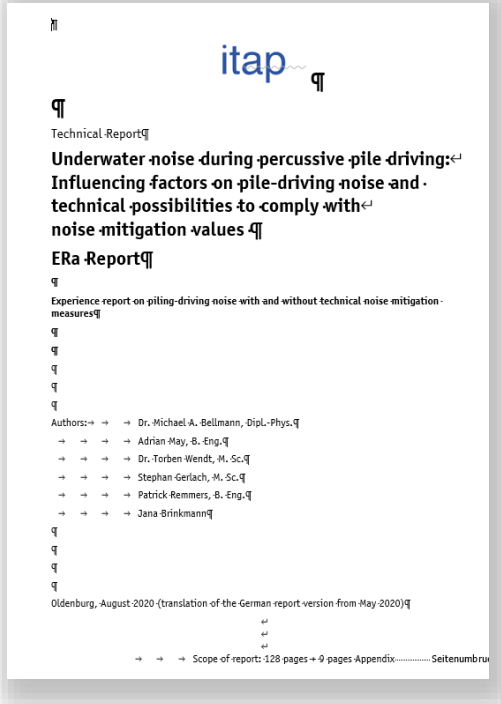
Lessons learnt report (2/2)

Aims:

- Investigation of site-specific and project-specific influencing factors on **unmitigated** pile-driving noise
- Lessons learnt regarding **noise mitigation concepts**

Output:

- ✓ Summary of legal requirements (author BSH)
- ✓ Identified site-specific and project-specific factors
- ✓ Definition of state-of-the-art noise mitigation concepts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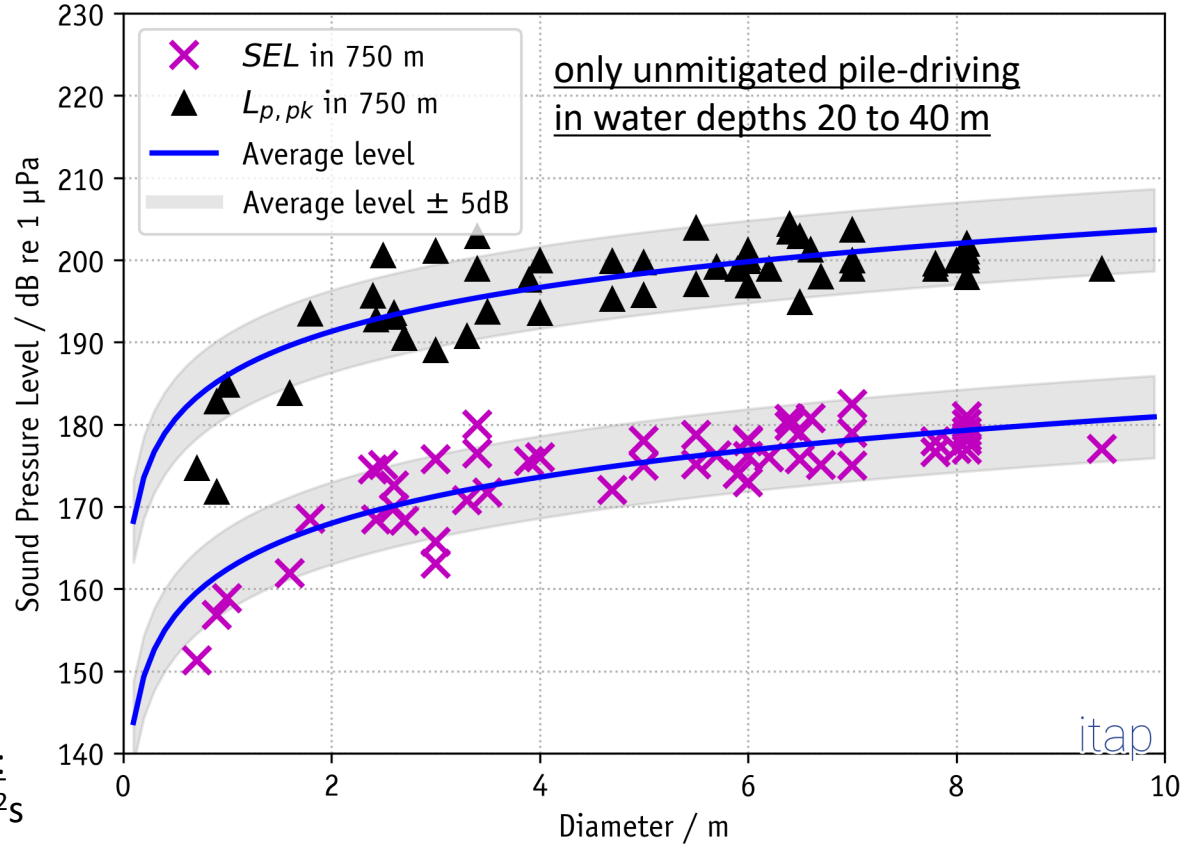
Influencing factor on pile-driving noise

Pile Diameter

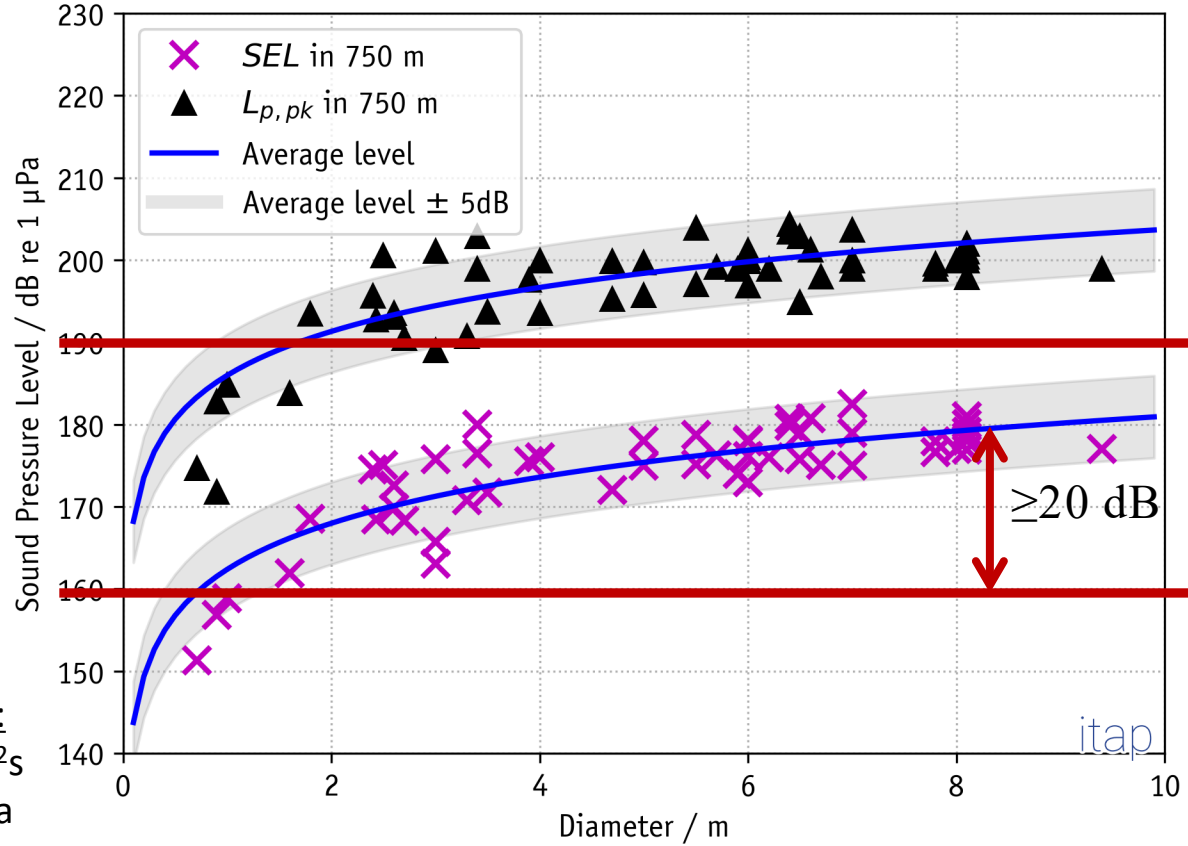


ISO 18406 (2017):
SEL in dB re 1µPa²s
$L_{p,pk}$ in dB re 1µPa

Itap data base (IONIS):

- > 35 OWF projects
- > 40 OSS and converter platforms

Pile-Driving Results @ 750 m
Requirements on Noise Mitigation Systems



German limiting values @750 m

$L_{p,pk}$ ≤ 190 dB

SEL ≤ 160 dB

ISO 18406 (2017):
SEL in dB re 1µPa²s
$L_{p,pk}$ in dB re 1µPa

Noise Mitigation Measures

Noise reduction by

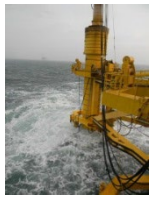
- avoiding underwater noise = Noise Mitigation System (NMS)
- reducing existing underwater noise = Noise Abatement Systems (NAS)

Primary NMS

- reduced impact Pile-Driving Energy (e. g. HiLo- procedure; state-of-the art)
- Vibro-Piling (continuous noise → OWF KASKASI II)
- Suction Buckets (not viable for all projects)
- Gravity foundations (not viable for all projects)
- Blue Piling hammer (prototype, currently not available)
- New hammer technologies PULSE / MNRU first offshore tests within 2022/3
  PULSE unit **3 to 6 dB overall noise reduction**

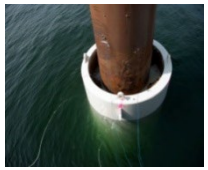
Noise Abatement Systems

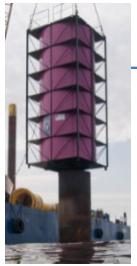
Bubble Curtain system



- Guided & unguided „Small Bubble Curtain“
- Small Bubble Curtain (Menck)
- Big Bubble Curtain

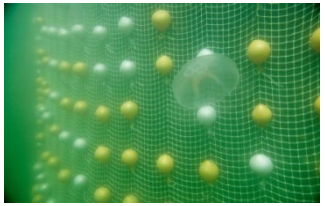
„Shell-in-shell“ system





- Noise Mitigation Screen (IHC)
- Cofferdam & shell-in-shell constructions
- BeKa shell (Weyres Offshore)
- Fire Hose Method (Menck)

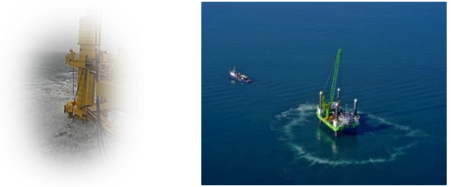
other systems



- Pile wrapped with foam
- Hydro-Sound Damper
- Resonator system
- HydroNas (W^{3}GM)
- ….

Noise Abatement Systems

Bubble Curtain system

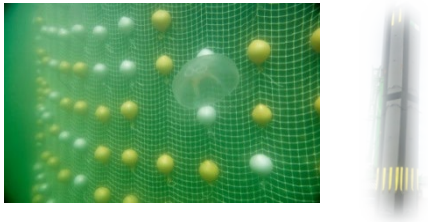


- Guided & unguided „Small Bubble Curtain“
- Small Bubble Curtain (Menck)
- Big Bubble Curtain BBC

„Shell-in-shell“ system

- Noise Mitigation Screen (IHC) IHC-NMS
- Cofferdam & shell-in-shell constructions
- BeKa shell (Weyres Offshore)
- Fire Hose Method (Menck)

other systems



- Pile wrapped with foam
- Hydro-Sound Damper HSD
- Resonator system AdBm
- HydroNas (W^3GM)
- ….

Noise Mitigation Screen (IHC)

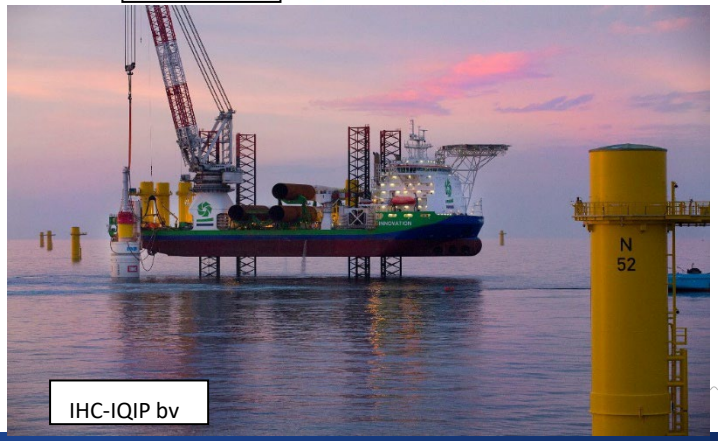
- shell-in-shell system
- close-to-pile NMS
- used in water depth ≤ 40 m
- used for pile diameter ≤ 8 m (sizeable shells)

Advantage

- pile guiding system integrated
- inclination measurement tool integrated

Disadvantage

- weight / dimension
- ground coupling effects
- application @ variied water depth ?
- increased safety risks during deployment



Noise Mitigation Screen (IHC)

Noise reduction is independent of

- water depth (more or less)
- current / direction

successfully applied: > 450

malfunction: < ~1%

➢ measured noise reduction: Δ SEL = 13 ≤ 15 ≤ 17 dB

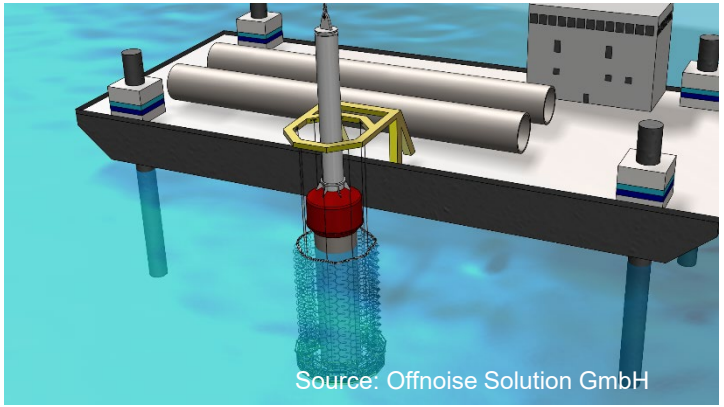
latest generation Δ SEL = 15 ≤ 16 ≤ 17 dB

even @ 40 m water depth

➢ robust and ready for offshore Noise Abatement System

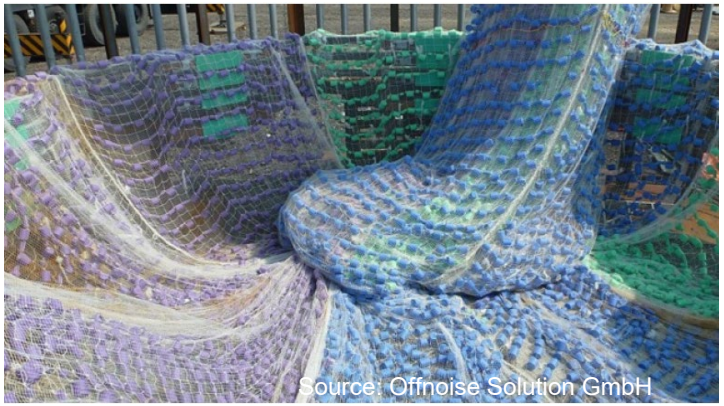
Hydro Sound Damper (HSD)

- Resonator system
- close-to-pile NMS
- consists of: Net + HSD Elements + ballast box
- used in water depths ≤ 45 m
- Used for pile diameters ≤ 9,4 m



Advantage

- „light-weighted“
- HSD-elements tunable (frequency < 500 Hz)



Disadvantage

- ground coupling effects
- ballast box incl. lifting tool
- „life time of HSD Elements“

Hydro Sound Damper (HSD)

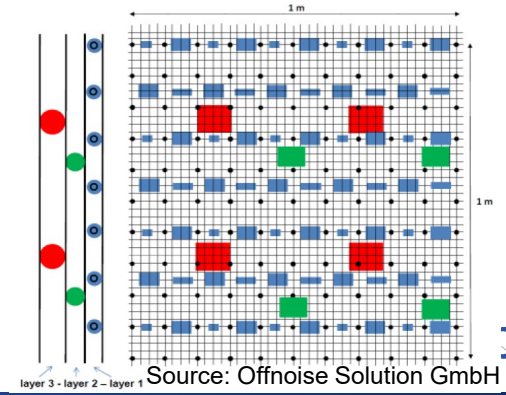
Noise reduction is independent of

- water depth (more or less)
- current / direction

successfully applied: > 340

malfunction: < ~1%

- reduces noise < 100 Hz with different HSD Elements
- measured noise reduction: Δ SEL = 10 ≤ 11 ≤ 12 dB
  even @ 40 m water depth
- requires project-specific design
- ready for offshore Noise Abatement System



AdBm System by AdBm Technologies

- resonator system
- close-to-pile NMS
- consists of: vertical shape blocks + lifting tool
- used in water depths ≤ 30 m
- used for pile diameters ≤ 8 m

Advantage

- „light-weighted“
- block shapes partly tunable (frequency < 500Hz)

Disadvantage

- ground coupling effects
- only prototype available (not much experience)
- lifting tool

AdBm System by AdBm Technologies

Noise reduction seems to be independent of

- water depth (more or less)
- current / direction

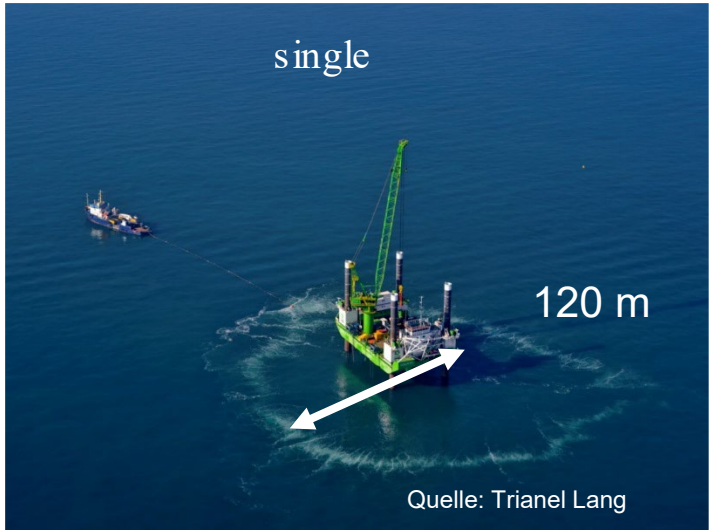
successfully applied: > 6

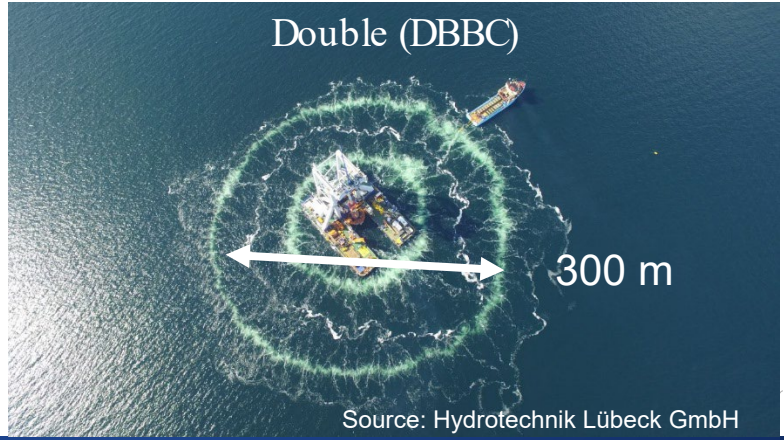
malfunction: /

- ➢ reduces noise ~ 100 Hz with only one block shape
- ➢ measured noise reduction: Δ SEL = < 10 dB (1st application)
- ➢ requires project-specific design

(double) Big Bubble Curtain

- impedance shifts (water vs. water-air mixture)
- far-from-pile NMS (the only one)
- consists of: compressed air + nozzle hose on sea bed
- used in water depths ≤ 45 m (UXO clearance ≤ 70 m)
- used for pile diameters ≤ 9,4 m





Advantage

- independent of foundation design
- „independent“ of installation vessel (pre-laying)

Disadvantage

- separate vessel + compressors required
- coordination installation vessel vs. nozzle hoses

(double) Big Bubble Curtain

Noise reduction depends on

- water depth
- current / direction / shape (max 0.75 m/s current)
- distance between foundation and nozzle hose
- number of nozzle hoses (1, 2, 3 or 4)
- distance between nozzle hoses
- used air flow / pressure distribution
- length of nozzle hose (> 1.000 m)
- used hole configuration
- maintenance of used nozzle hoses

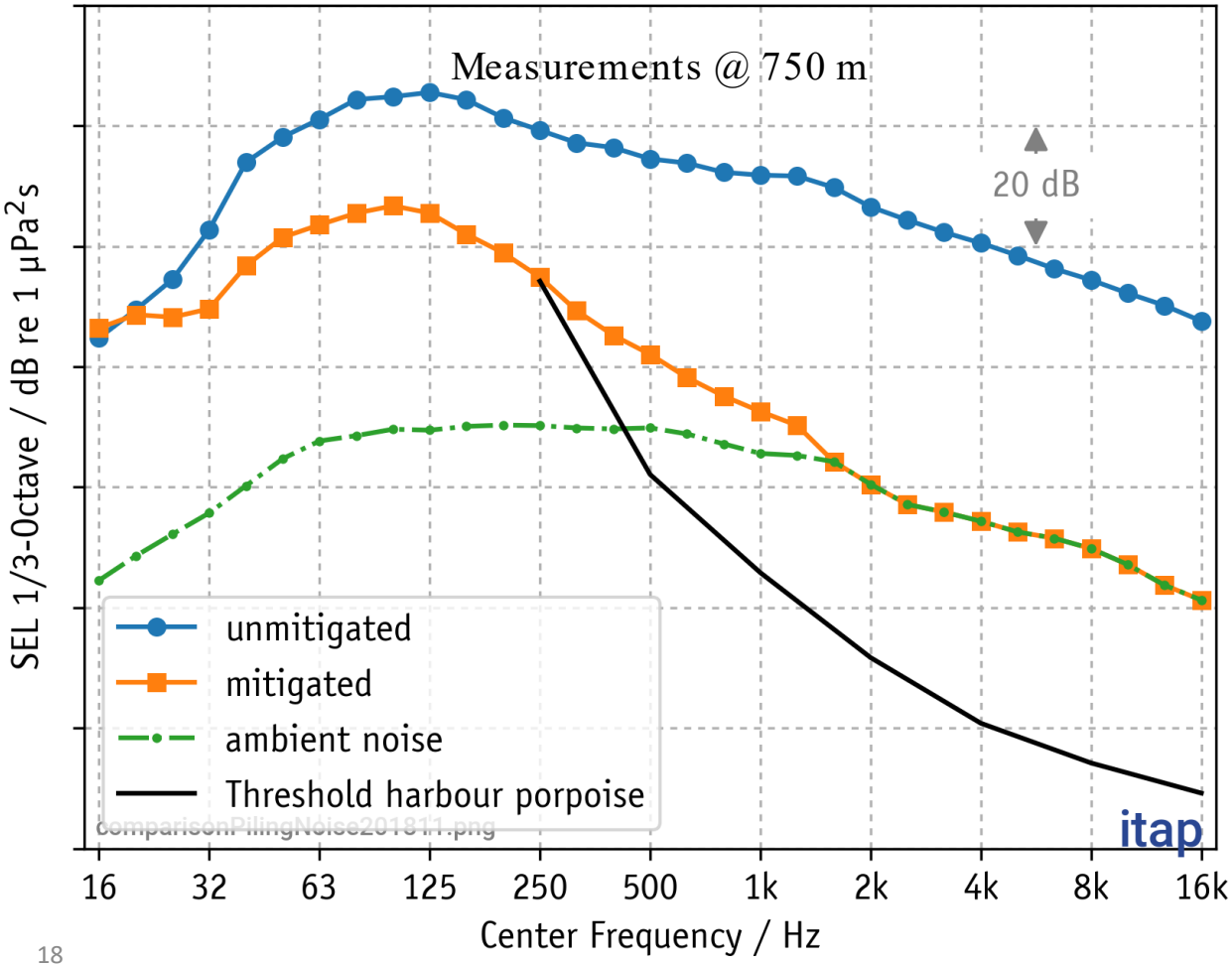
measured noise reduction: Δ SEL = 15 to 16 dB

even in 40m water depth


Source: Hydrotechnik Lübeck GmbH


Source: Hydrotechnik Lübeck GmbH

Effectiveness of Noise Mitigation Systems



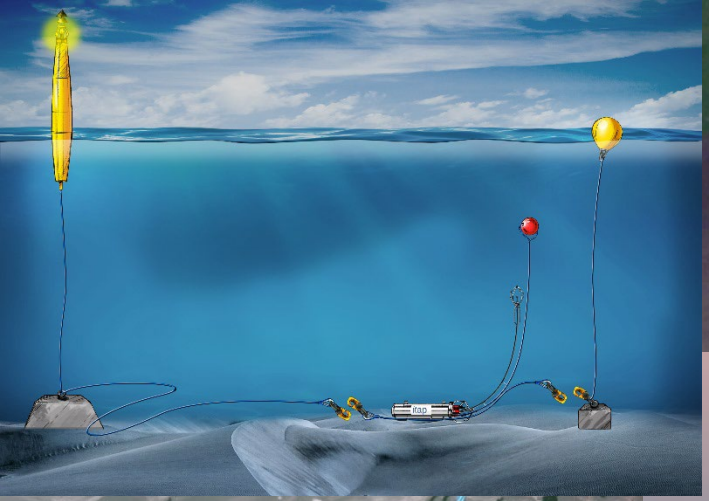
Mitigated pile-driving:
no pile-driving noise in water
@ high frequencies

Take Home Message

- ✓ NMS are limited available: reduced blow energy, maybe new hammer techniques, alternative foundation designs
- ✓ NAS ready for offshore: HSD, IHC-NMS and (D)BBC (AdBm will come)
- ✓ Up to 15 dB for a single NAS; ~ 20 dB for combination of NAS
- ✓ Project-specific adaptation/optimization of each NMS required !
- ✓ Achievable overall noise reduction of NAS highly frequency depending

Not state-of-the-art today but tested under real offshore conditions

- ➢ New BBC technology: single enhanced BBC (similar noise reduction as DBBC)
- ➢ Hammer technology PULSE: 3 to 6 dB



Questions ?