ECOWENDE
Windpark Hollandse Kust West

Innovative installation techniques

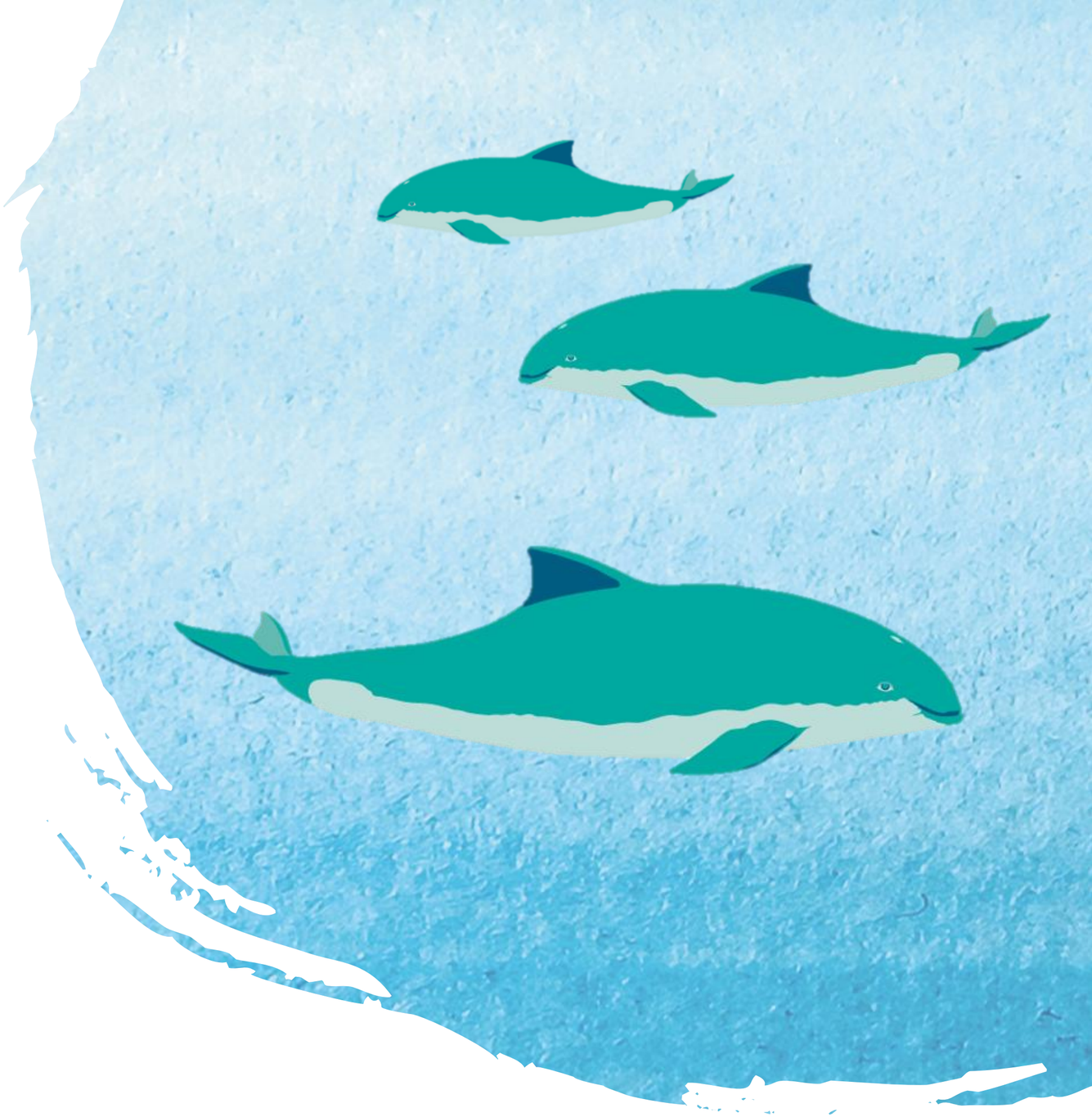
Webinar 3 December 2025

How to build a wind farm in harmony with nature

ECOWENDE
Windpark Hollandse Kust West

Driving innovation

Why we are doing this



Ronald van Dijk
Ecowende

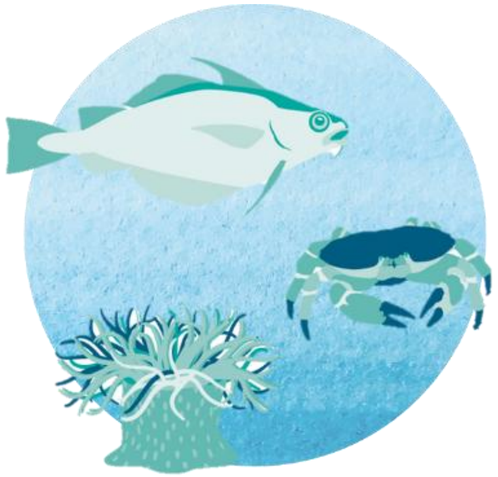
Our mission

We are teaming up with nature, to build and operate Ecowende and lead the way to affordable, sustainable and responsible offshore wind energy.

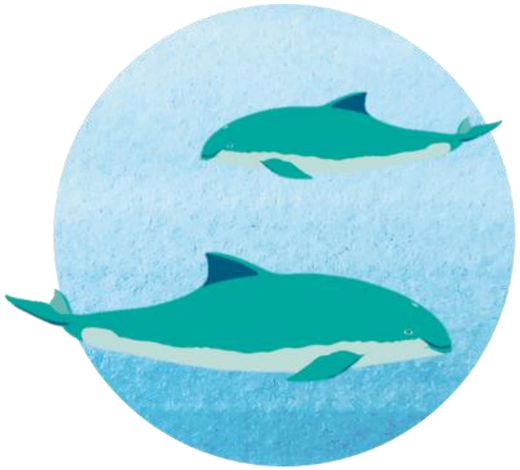
Above and under water

Birds

Bats



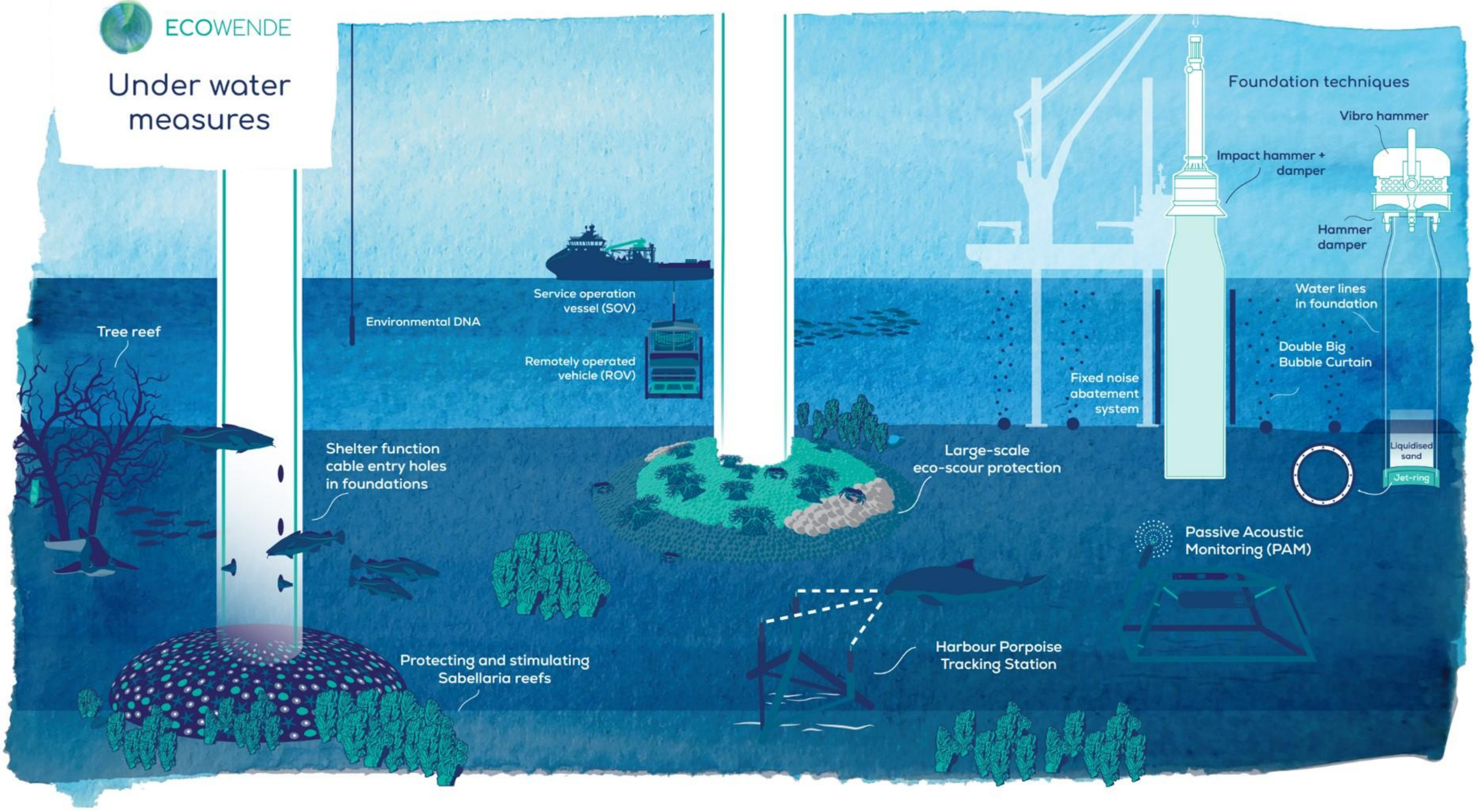
Fish and benthos



Harbour porpoises

ECOWENDE

Under water measures



Negative effects on harbour porpoises

Direct

Installation
of the foundations

Vessel movements
and related noise

Avoidance
with risk of habitat reduction, due to sound disruption

Installation: reduced noise during pile-driving

Measures

Various (effective) measures to mitigate sound during traditional pile-driving:

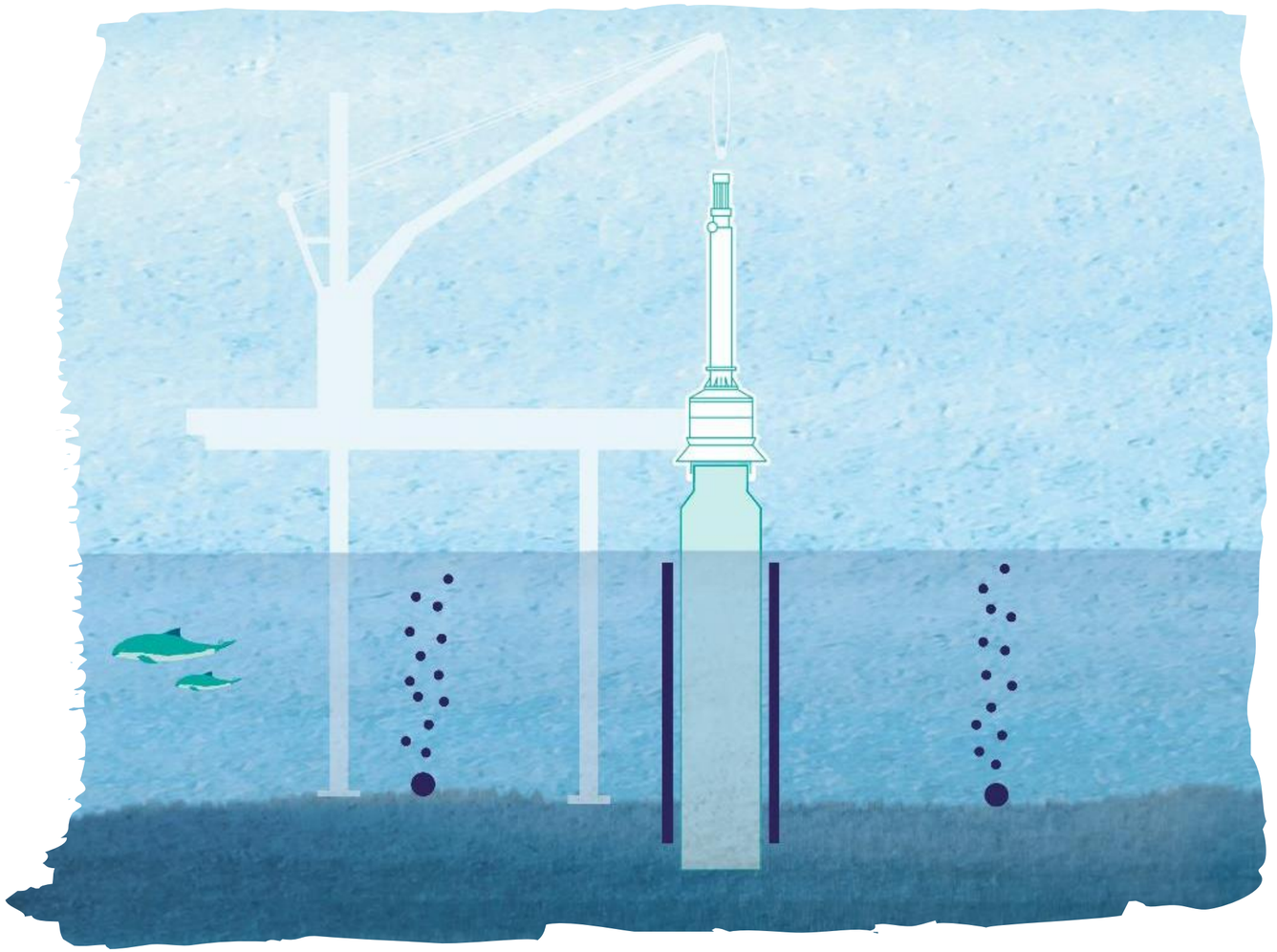
I. Far-Field: Bubble screens

II. Near-Field: Screens around monopile

III. On-Pile: Dampers on the hammer

Goal

- Reduce sound disturbance



Installation: innovative techniques

Measures

We will explore various noise-mitigating techniques:

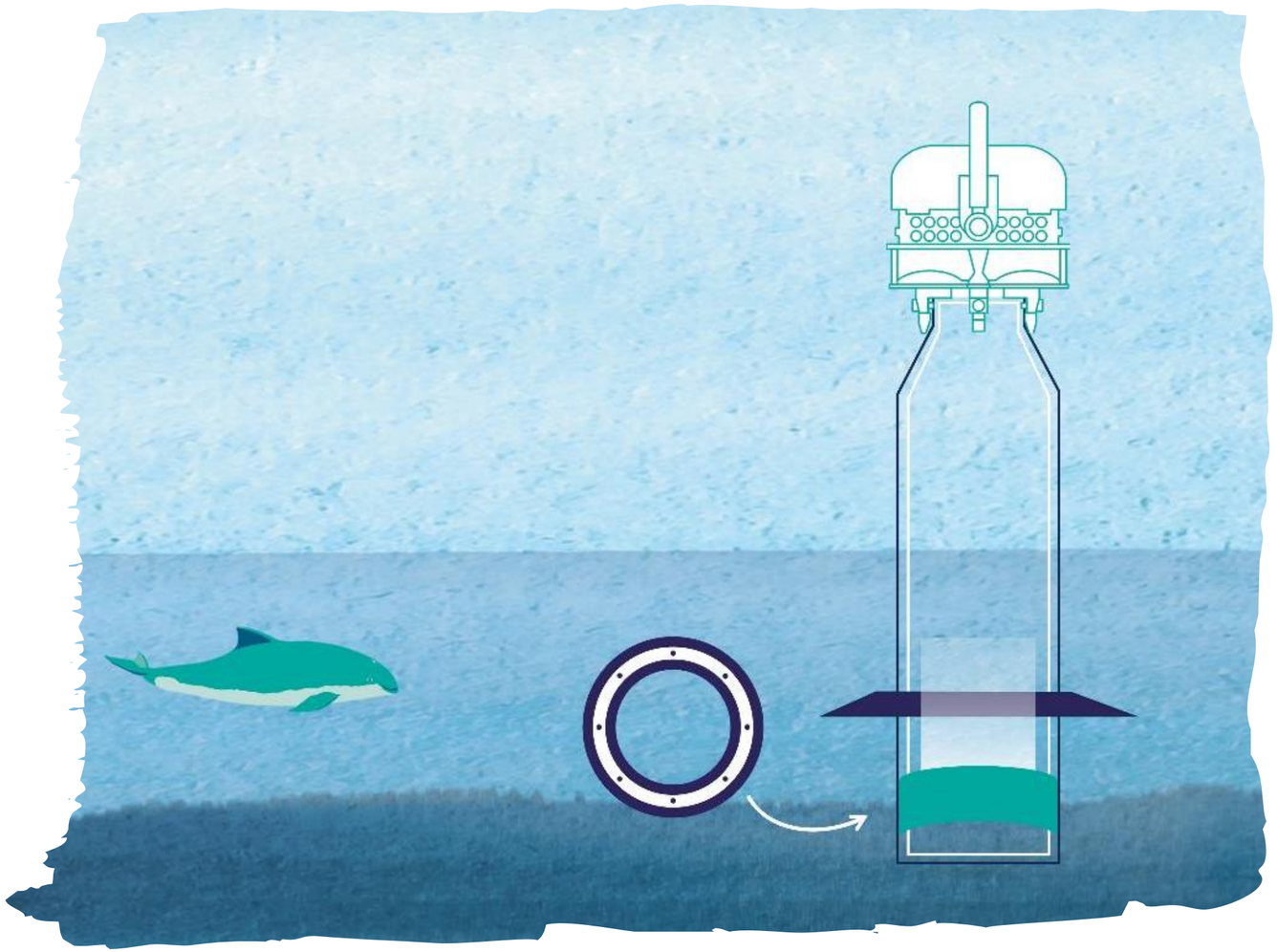
I. Pile driving with a vibro hammer

II. Jetting in support of the vibro hammer

Jetting uses water jets to liquefy the soil so the monopile faces less resistance

Goal

- Reduce sound disturbance



Vessel movements and drones

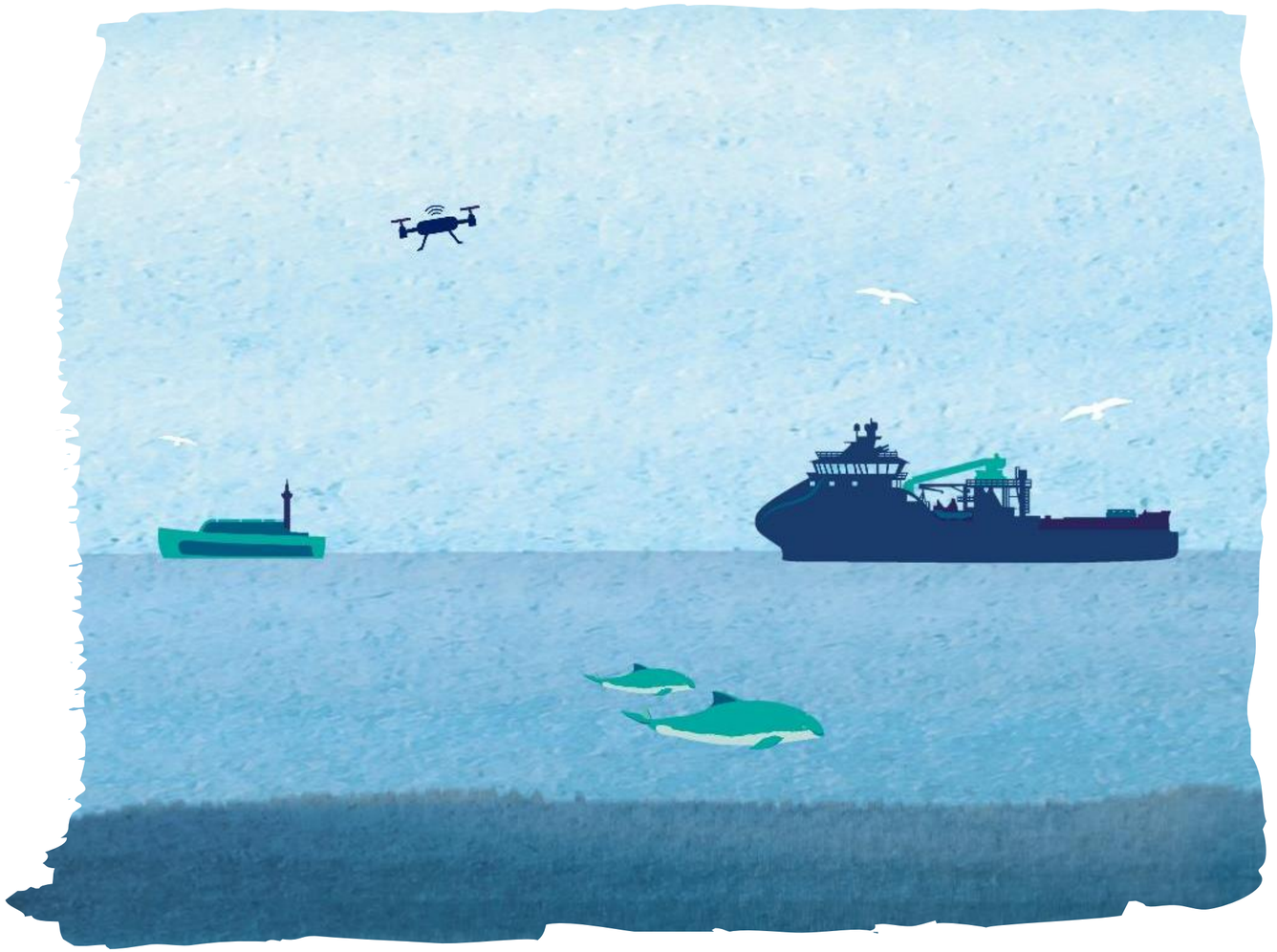
Measures

I. We will reduce vessel movements by streamlining our planning for maintenance work

II. Evaluating the deployment of drones during the operational phase

Goal

- Reduce sound disturbance



Harbour porpoises

Monitoring and research programme

Measuring noise

We will measure the noise of various activities, i.e., the use of vibrating hammers as well as pile driving in combination with various sound-mitigating measures.

Measuring presence

We will deploy a Passive Acoustic Monitoring network for 7 years to measure the presence of the harbour porpoise and investigate the effect of noise on their presence.

Measuring population effects

We will investigate the effect of sound disturbance (and other factors) on reproductive behaviour to learn the potential impact on the total population of the harbour porpoise in the HKW area.

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Questions?

Effect of offshore wind park-related sounds on harbor porpoises

Ron Kastelein, SEAMARCO

Background

- Increased use of North Sea causes an increase in anthropogenic underwater noise.
- Different underwater sound sources can affect behavior of porpoises.
- If behaviors such as resting, feeding, mating, suckling and migration are affected, the animals' fitness can be reduced (population dynamics).
- Harbor porpoise experimental research related to wind parks has focused so far on the effects of impact piling sounds on hearing (TTS) and behavior (dose-response).

Harbor porpoises: ‘life in the fast lane’ compared to other larger odontocetes (toothed whales)

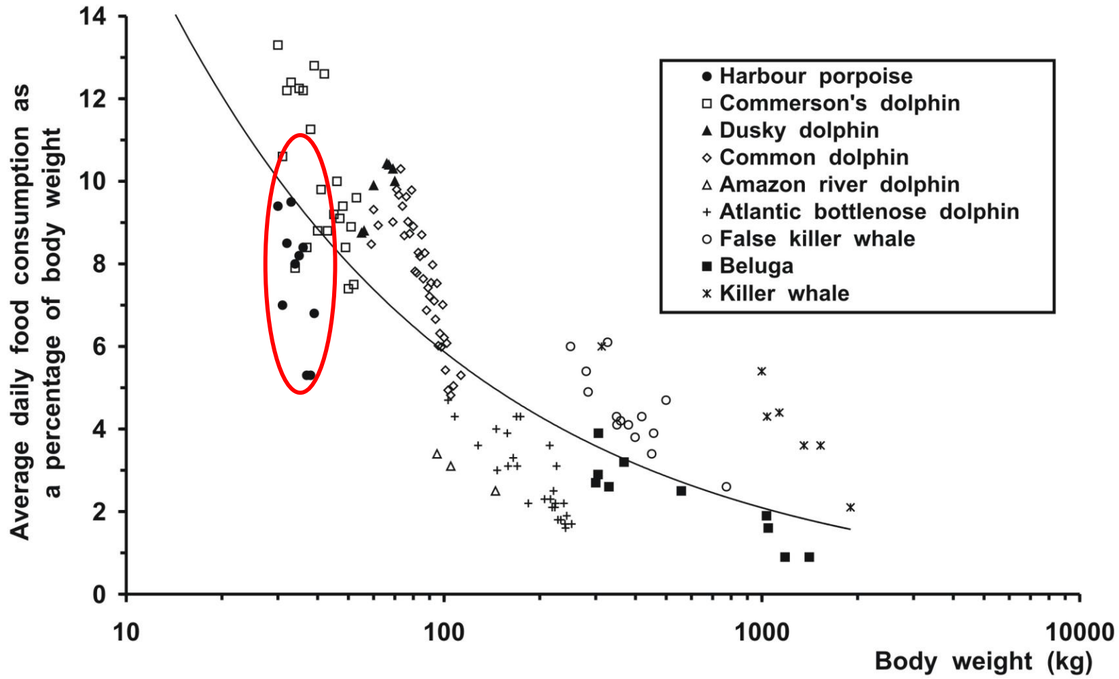
- Start breeding young: 3-4 years
- Short gestation: 10-11 months
- Short suckling period: 8-12 months
- High potential reproductive rate: 1 per year
- Short life-span: < 24 years

Why focus on harbor porpoises?

- Large geographic range in temperate coastal waters of Northern Hemisphere. Large overlap with sound-producing anthropogenic activities.
- One of 3 most abundant marine mammal species in North Sea.
- Top predator, indicator species of functioning of ecosystem.
- Sensitive hearing, especially for high-frequency sound (echolocation).
- Skittish, because small odontocete and prey for orcas, and regionally molested by bottlenose dolphins.

Bio-energetics

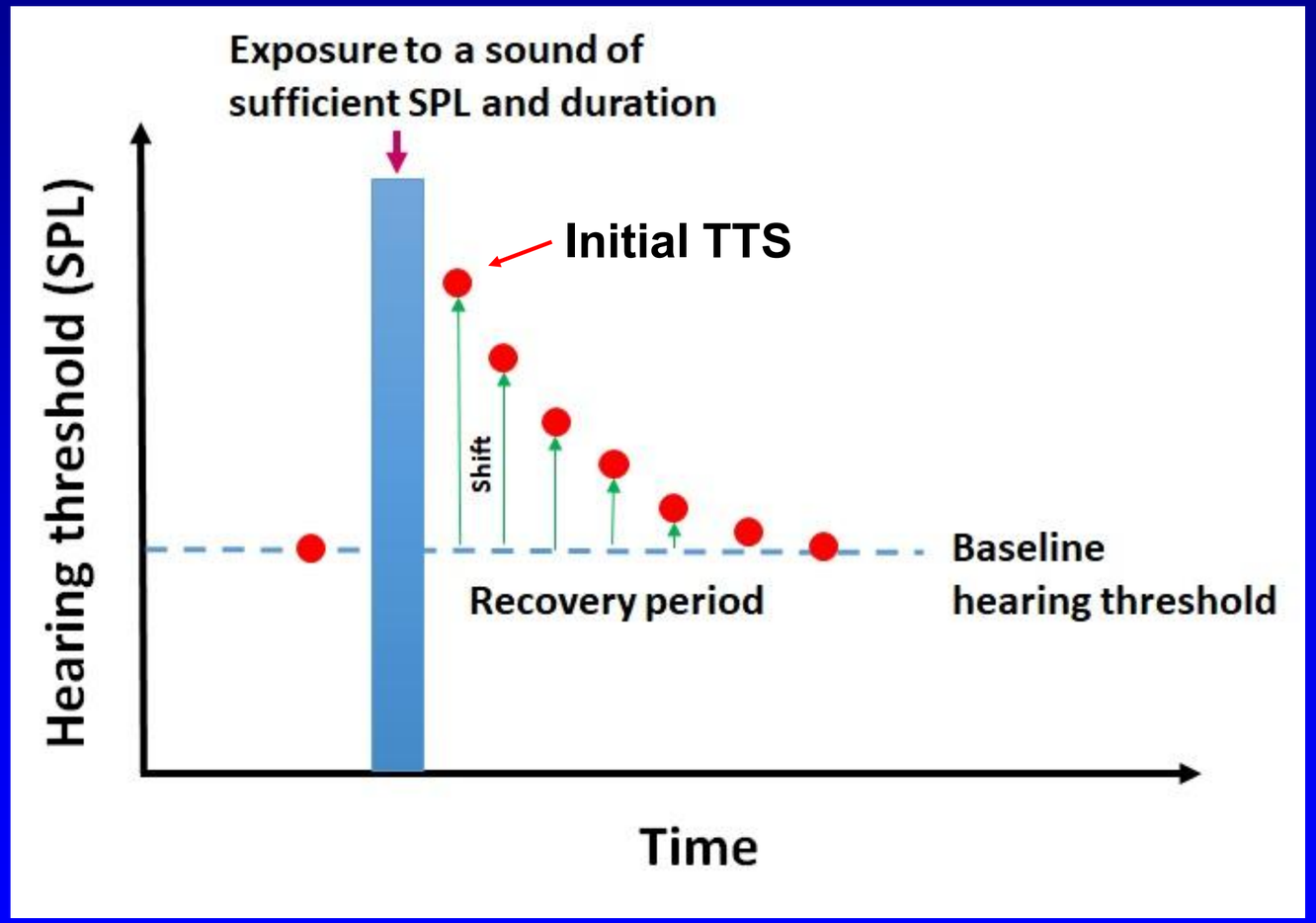
- Because harbor porpoises are small, they have a large skin area per kg of body weight in contact with cold water. Heat conductance of water is 25 times higher than that of air.
- Harbor porpoises have 2 strategies to cope:
  - eat lots
  - good insulation (blubber)
- High metabolic rate:
  food intake 7-10% of body weight/day



Conclusions bio-energetics of harbor porpoises

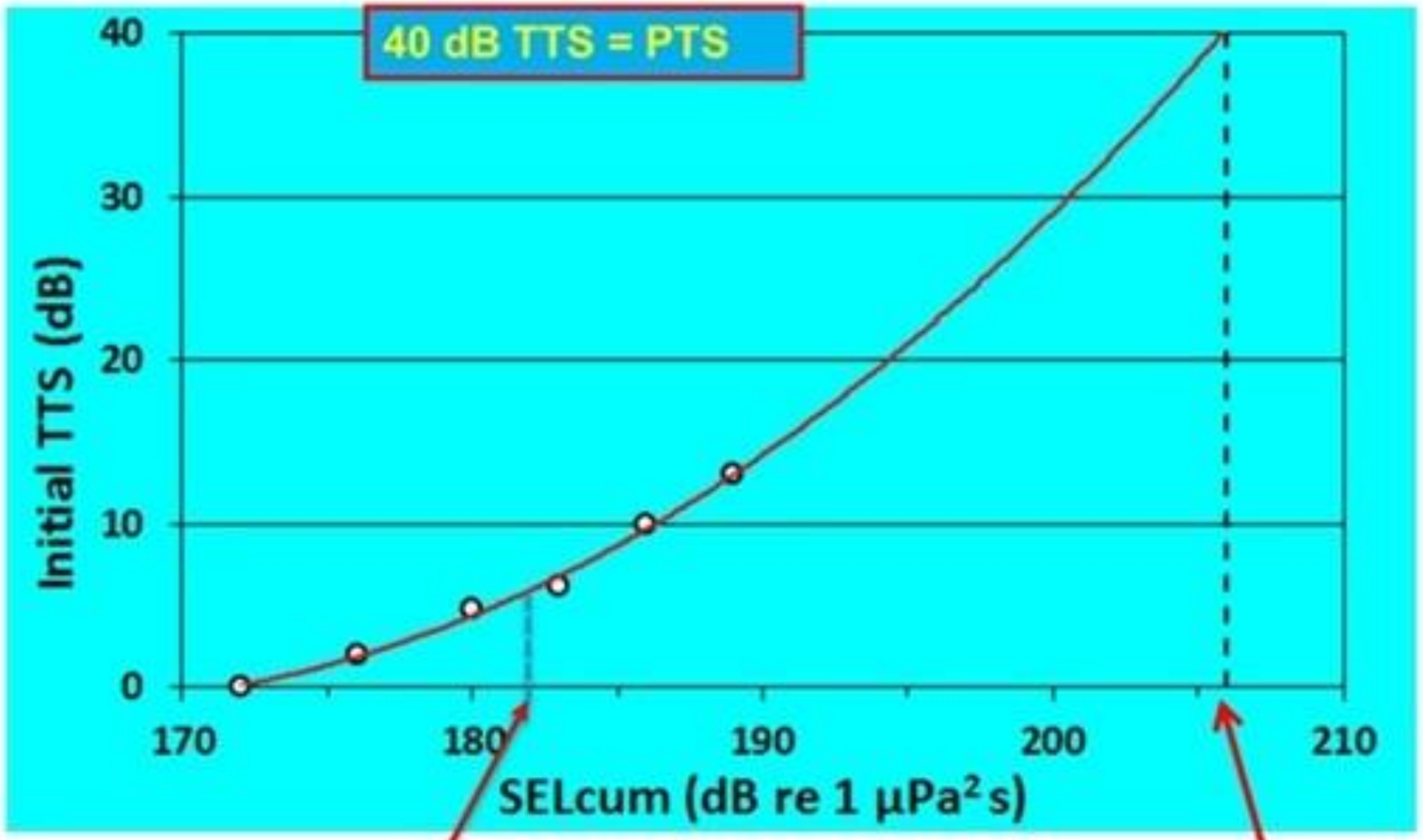
Because harbor porpoises have to eat lots, the effect of disturbances causing missing meals, makes them more vulnerable to disturbances than larger odontocetes.

Effect of impact piling sound on harbor porpoise hearing (Temporary Threshold Shift, TTS)



Pop-concert effect

Estimation of PTS onset SEL_{cum} based on extrapolation of TTS growth curve



~TTS onset SEL_{cum}

PTS onset SEL_{cum}

To prevent impact by pile driving, sound level criteria have been set by governments

KEC 3.0, specifies:

Piling noise limit: SELss (750 m) = 168 dB re 1 μPa^2s

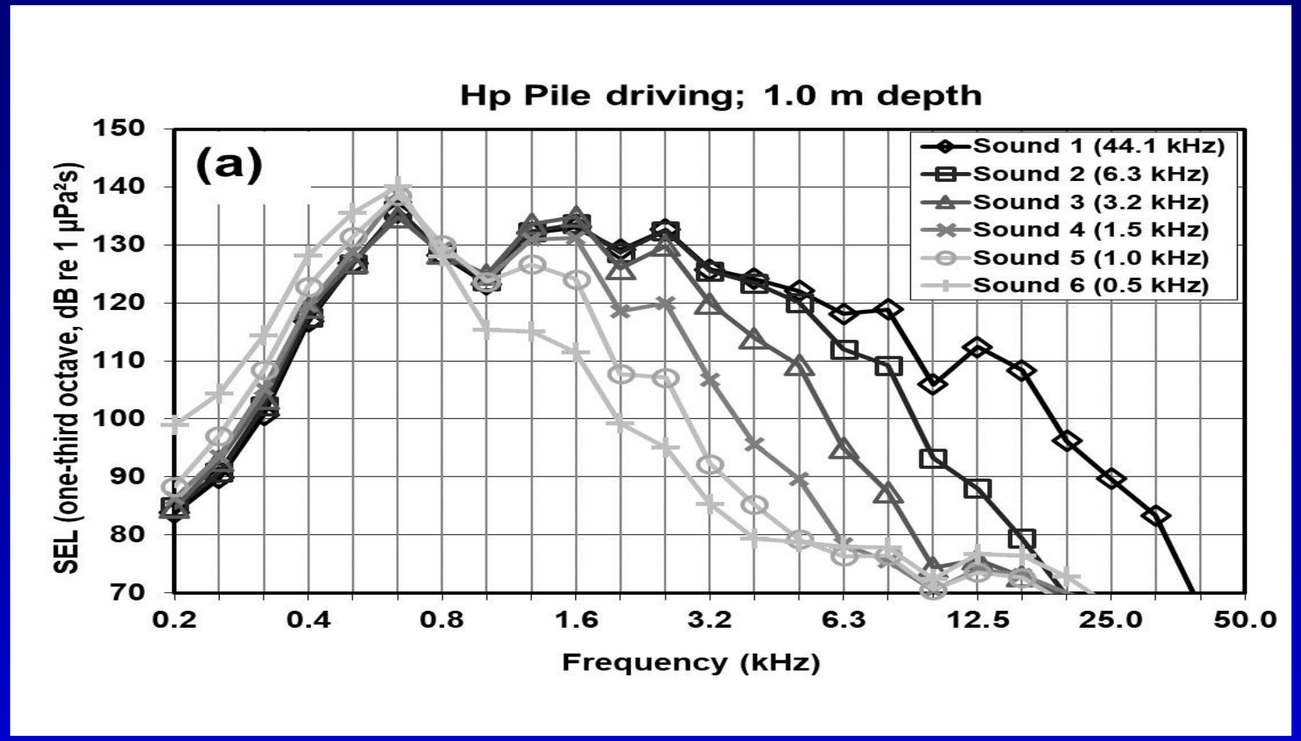
Experimental behavioral research with harbor porpoises can help estimate the effect of acoustic disturbances, and provide ideas for mitigation

Full spectrum impact pile driving sound

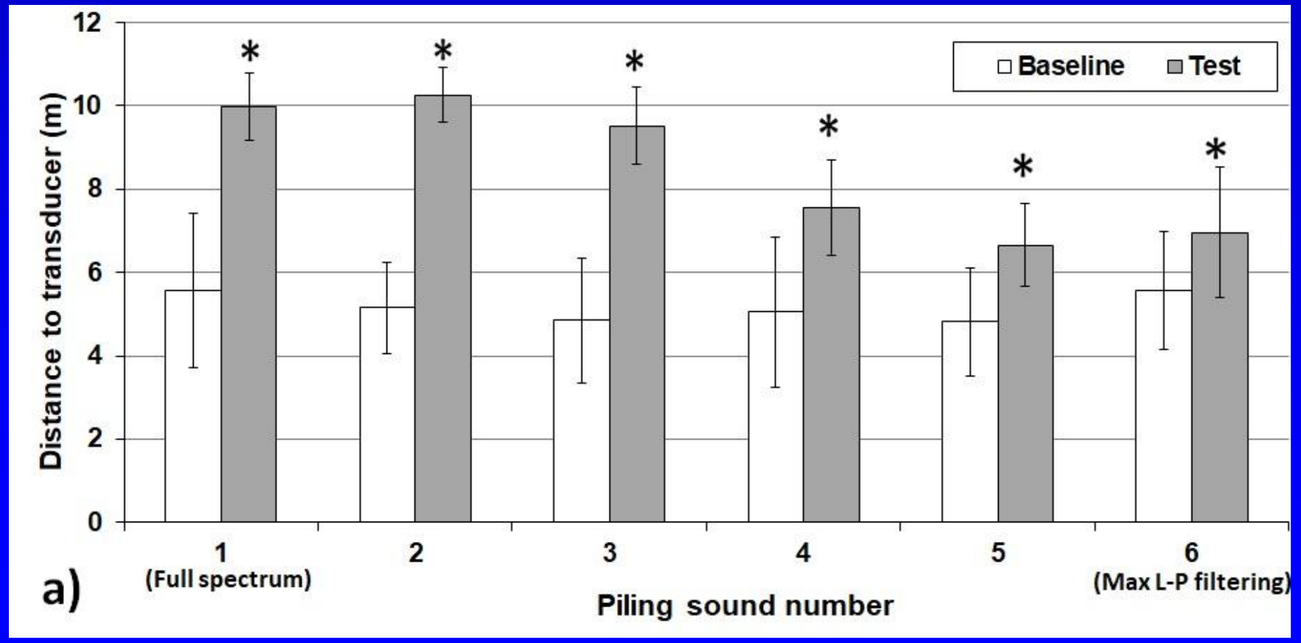
Strong effect: fast swimming and avoiding area near underwater transducer

Same broadband SEL, but with HF part of spectrum reduced

Almost no effect: slow swimming and approaching underwater transducer



Six spectra with same broadband SEL, but different frequency ranges



Effect of sound spectrum on distance of porpoise to the transducer

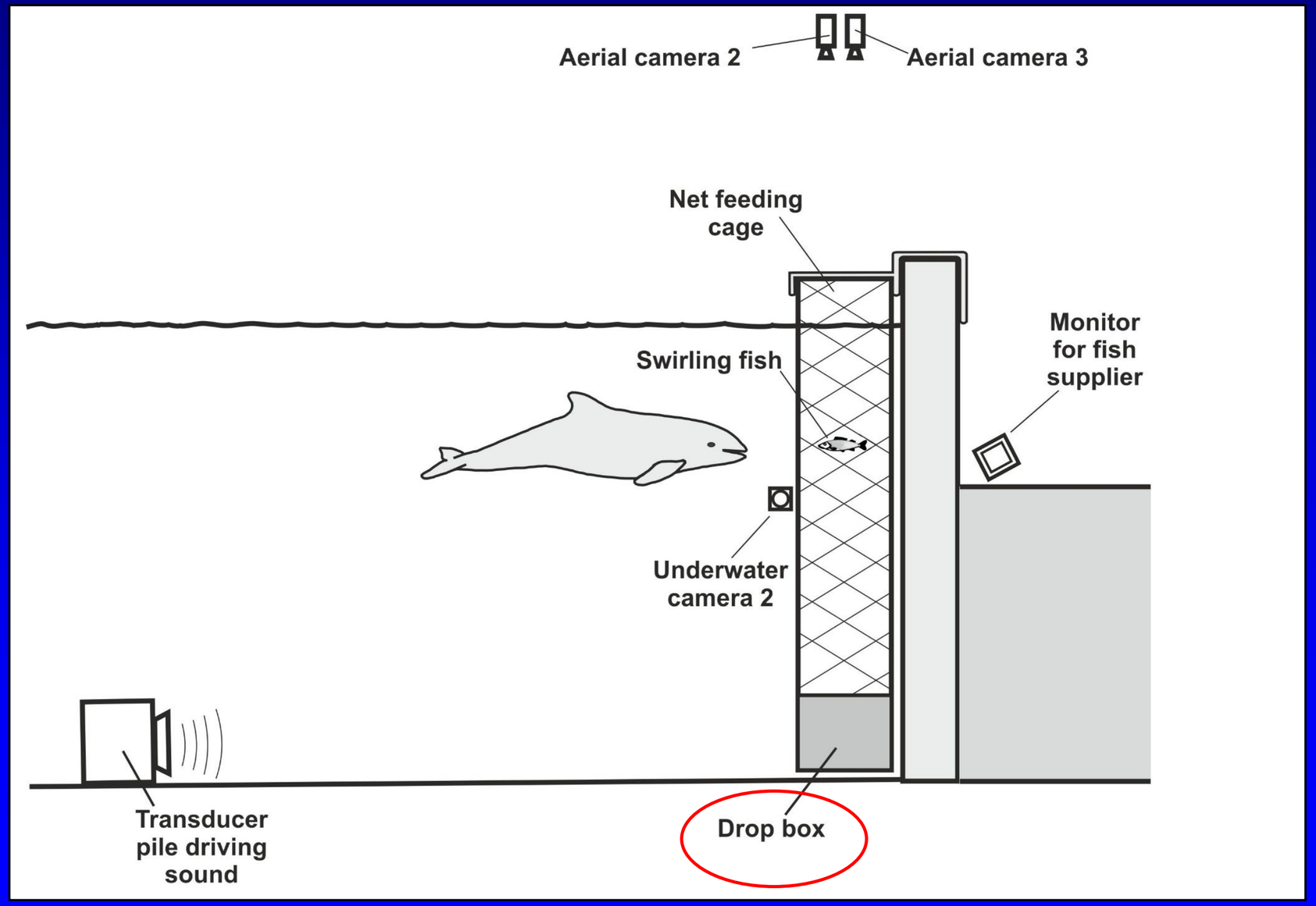
Conclusion

Research with impact piling sounds showed that the high-frequency part of the spectrum caused most of the behavioral effect in harbor porpoises.

This pointed the way for mitigation (use of bubble screens).

Can pile driving sounds reduce foraging efficiency?

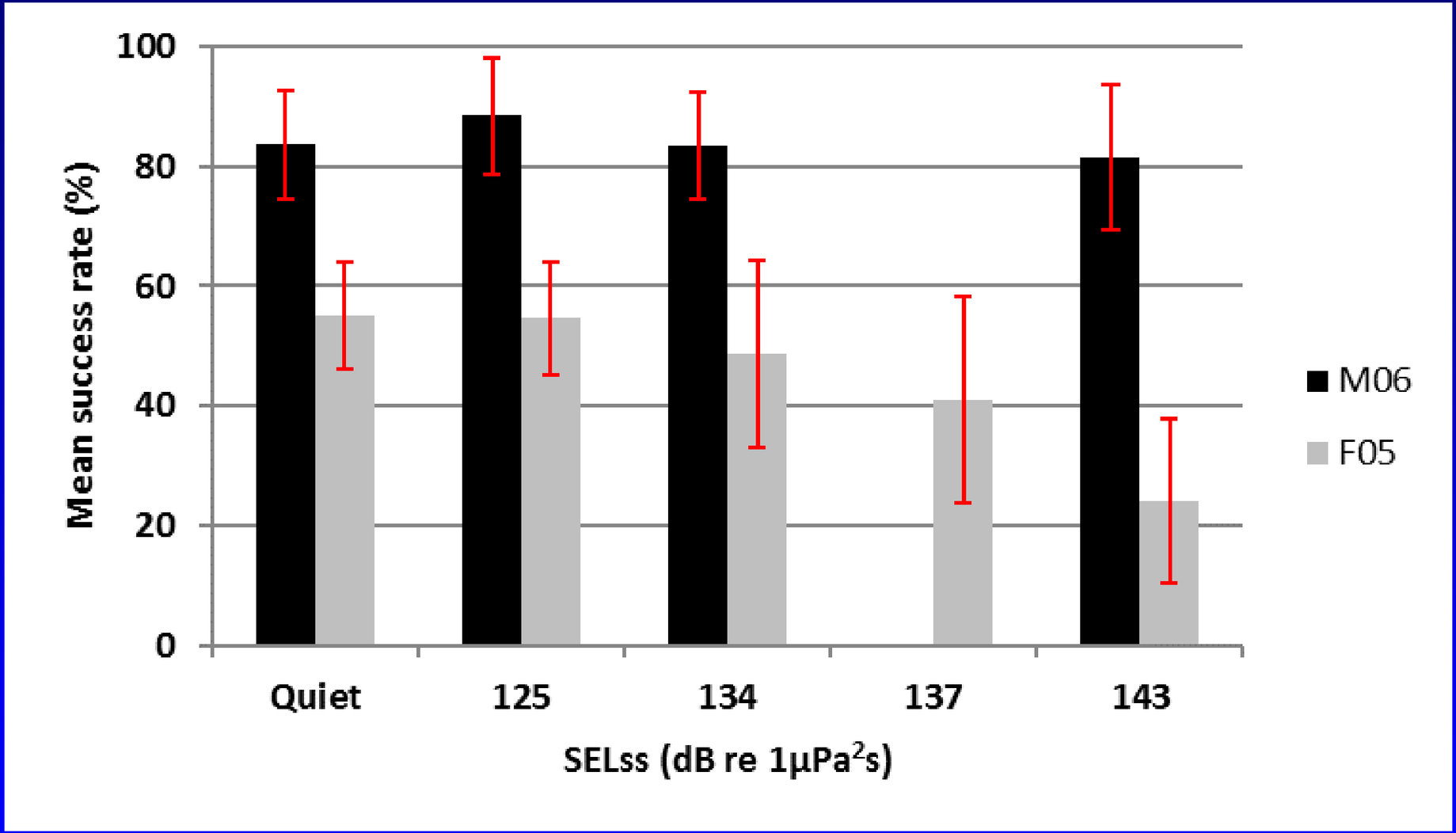
Disturbance = missed opportunities (feeding, resting, mating, travelling)



Side view: hit, hit and miss

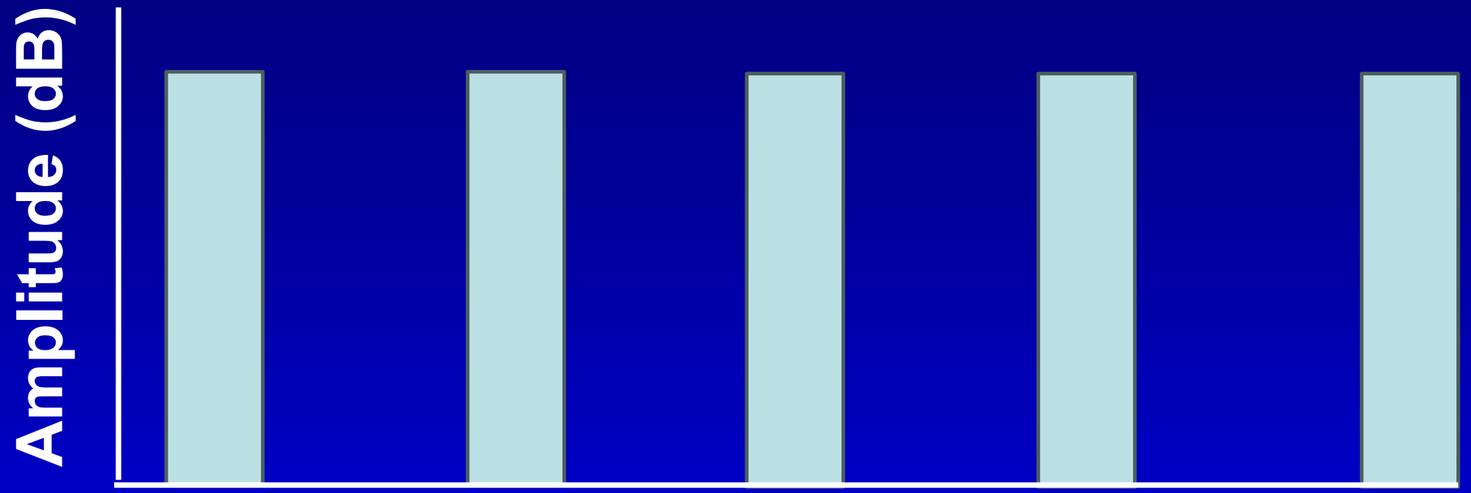
Close-up top view: hit, miss, hit

Results



Pile driving sounds can affect fish-catching success rate.
Porpoise behavior varies individually (also in quiet conditions).

Intermittent sound *versus* continuous sound



Impact pile driving

- **High SPL**
- **Intervals for hearing to recover (chemical process)**

Vibro-piling

- **Lower SPL**
- **No intervals for hearing to recover**

Conclusion: Impact piling studies cannot be used to estimate effect of vibro-piling

Ongoing research by SEAMARCO for Ecowende in relation to vibro-piling

- Effect of 2 vibro-piling sounds on behavior of harbor seals
- Effect of vibro-piling sound on hearing of harbor seals (TTS)

Knowledge gaps regarding vibro-piling – porpoises and seals: suggestions for future research

Harbor porpoises:

- Masking by vibro-piling sound
- Critical bandwidths (related to masking)
- Effect of different vibropiling spectra on behavior
- Bio-energetics (input data for iPCOD & DEPONS)

Harbor seals:

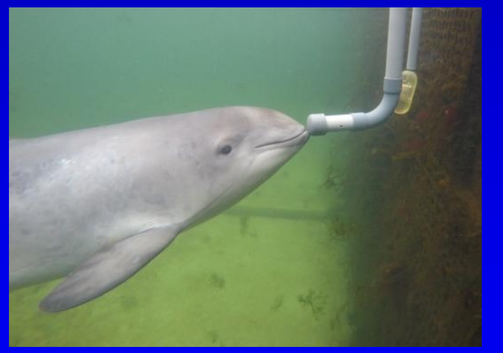
- Masking of biological relevant sounds by vibro-piling sound (need for retro-funding); does masking occur and if yes, how much?
- Effect of different vibro-piling spectra on hearing and behavior. Project funded by SIMPLE III.
- Bio-energetics (input data for iPCOD & DEPONS)

SEAMARCO

Applied research for marine conservation

Questions?

rk@seamarco.nl



SEAMARCO

SEA MAMMAL RESEARCH COMPANY

CAPE HOLLAND

ALL WAYS DRIVEN

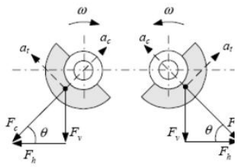
ECOWENDE

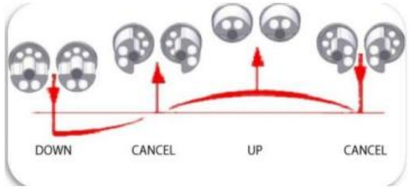
CAPE VLT
VIBRO LIFTING TOOL

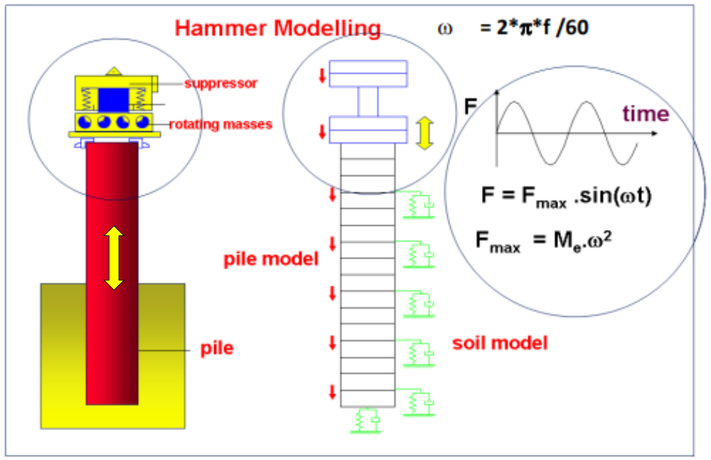
Dick van Wijngaarden
Business Development Manager

PROUDLY PART OF venterra

VIBRO DRIVING
WORKING PRINCIPLE







Pile in vertical vibration

↓

Disturbance of soil

↓

Reduction in soil resistance

↓

Installation:
Pile lowers by gravity
toe & shaft friction

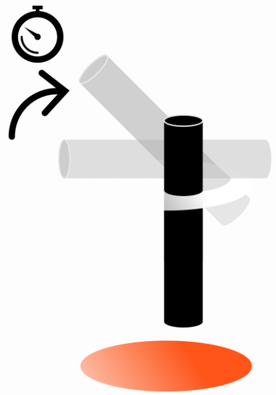
Extraction:
Lifted by crane
shaft friction only

CAPE HOLLAND

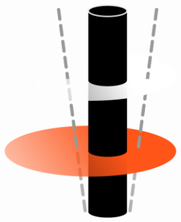
ALL WAYS DRIVEN

ADVANTAGES OF VIBRO LIFTING TECHNOLOGY

FAST PILE HANDLING

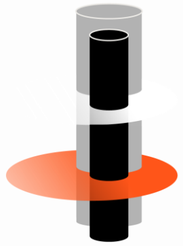


CONTROLLED PILE INSTALLATION

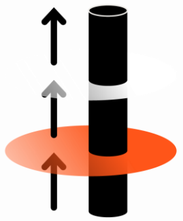


SILENT PILE INSTALLATION

LARGE PILE DIAMETER RANGE



PILE EXTRACTION POSSIBLE



WHY SILENT

- Pile not driven by brute force but gravity
- Accelerations in pile about factor 100 lower
- Therefore, no radial expansion
- Noise not directly related to diameter
- Potential to negate need for noise mitigation

CURRENT STATUS

- In offshore wind projects, the CAPE VLT has (partially) driven:
  - **293** monopiles
  - **483** pin and jacket piles
- Proven fast penetration & low cycle times
- Proven verticality accuracy without gripper
- Accurate predictions in regular density soils

CHALLENGES OF TECHNOLOGY

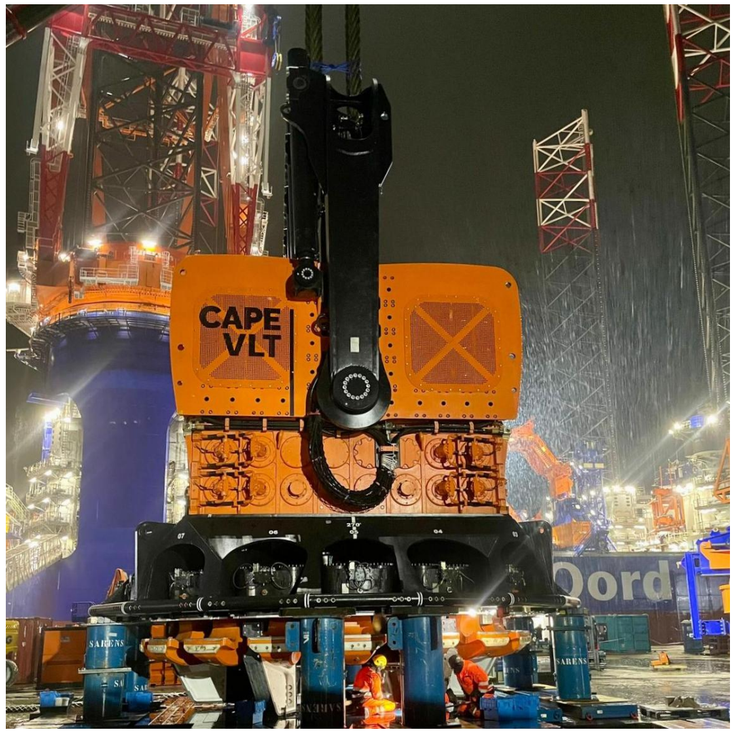
- Gaps in precise knowledge of noise emissions
- Full depth installation in very dense soils
- Limited experience in pile design for vibrated piles

RELEVANT R&D PROJECTS

- Gentle Driving of Piles (GDP)
  - Adding tortional vibrations to vibro driving
- SIMOX
  - Comparing alternative installation technologies
  - DNV Technology Qualification Certificate
- SIMPLE IIb and III
  - Adding jetting to vibro driving

EXPECTATIONS
HKW

- Quality data capture:
  - Noise, Driving and Pile stresses
- Comparison of:
  - Impact vs Vibro vs Vibro + Jetting
- Validation of:
  - Driveability models in dense sands
  - Newly developed noise models for vibro
- Improve:
  - Pile design for vibro driven piles



Q&A

For more details please contact:
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dick.vanwijngaarden@capeholland.com - +31 612910362

Ground
Breaking
Machines

From theory to practice

Vibrojet®

GBM Works

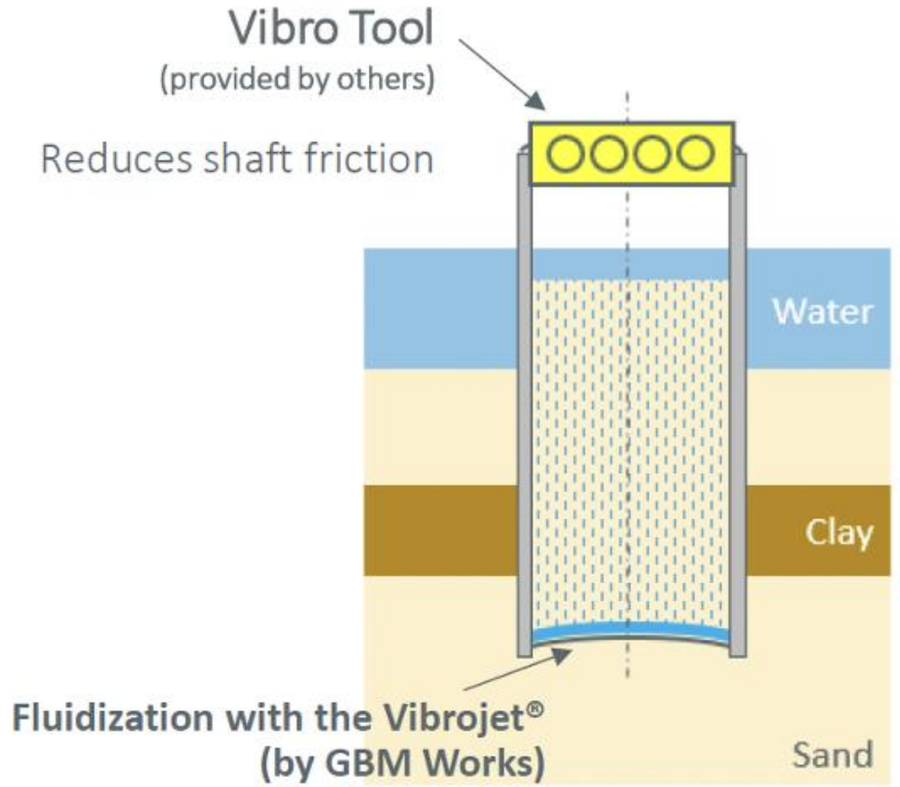
Albart Barents & Hein van Opstal

Problem: noise of the impact hammer during installation is bad news for fauna

Why Vibrojet®

- Enable silent and rapid monopile installation
- Reduce noise emissions – avoiding external mitigation
- Cost-effective solution in comparison to impact hammer with NMS and double bubble screens (50%)
- Support cost-efficient offshore wind development toward 2050 net-zero goal
- Solution for larger monopiles generating more noise during installation
- In longer term 1000 XXL monopiles per year in Europe only expected

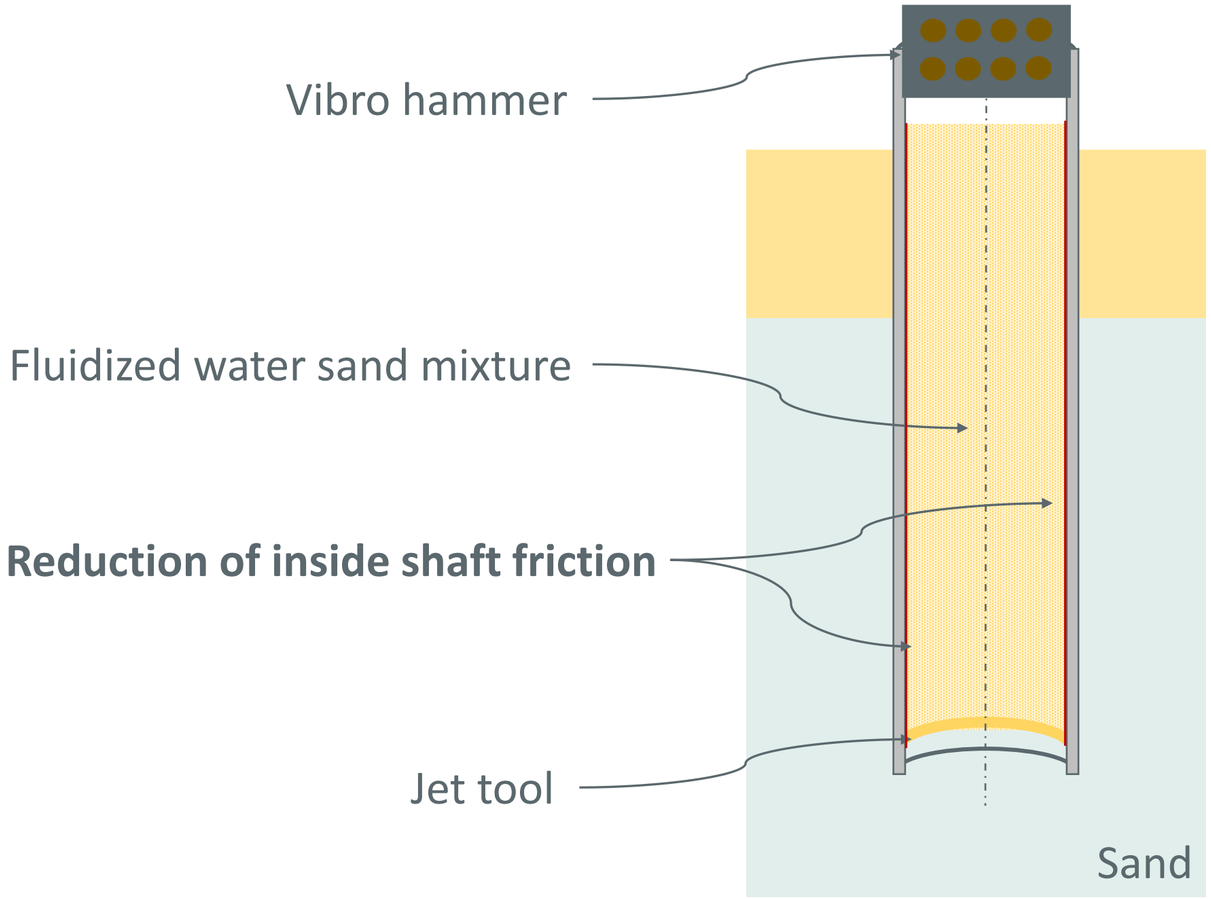
Patented Technology

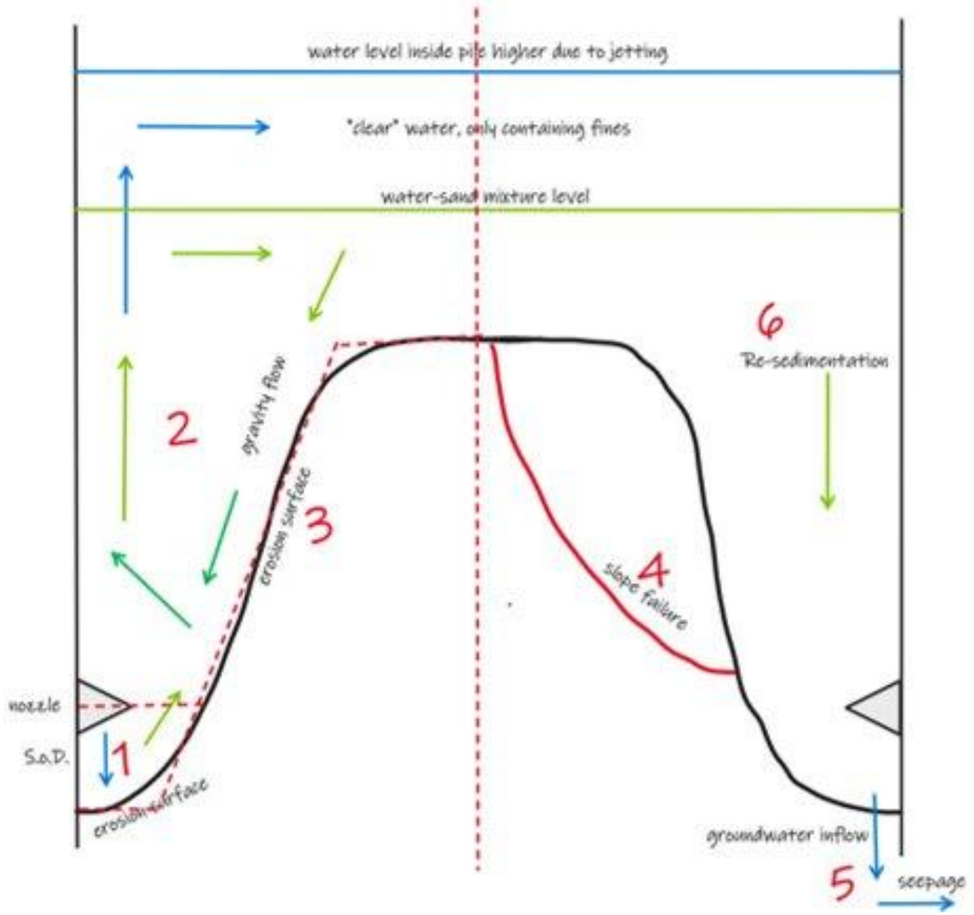


Reduces inside shaft friction.

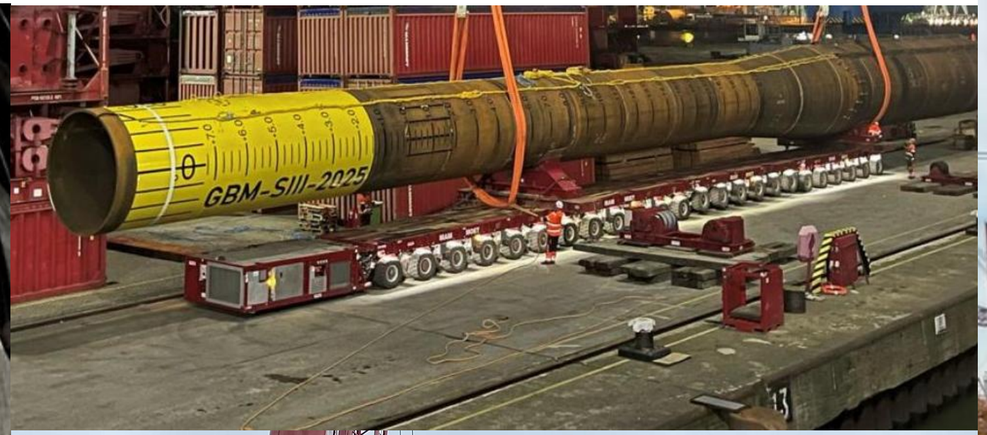
Working Principles Vibrojet®

Fluidisation of inside water sand mixture to reduce shaft friction



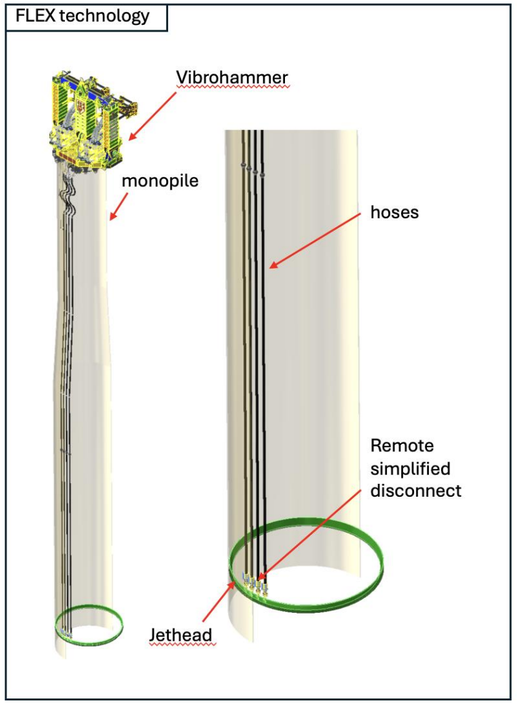


Solution: Vibrojet®

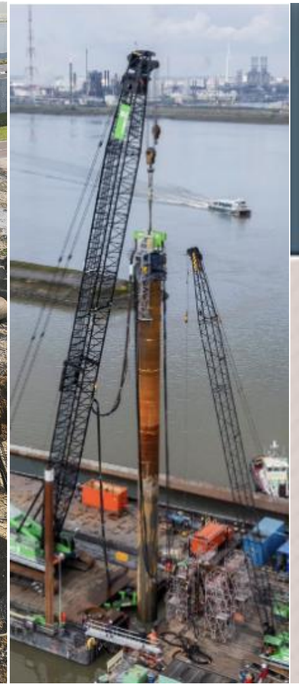


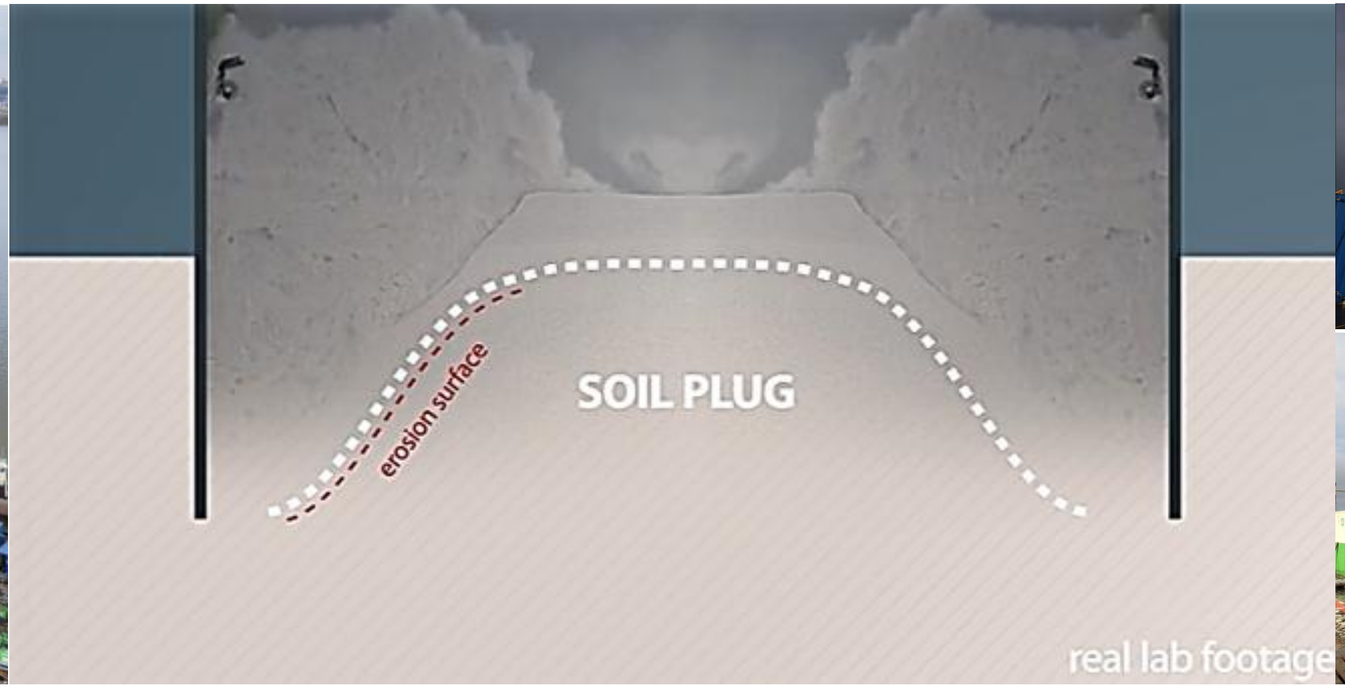
R&D for silent monopile installations

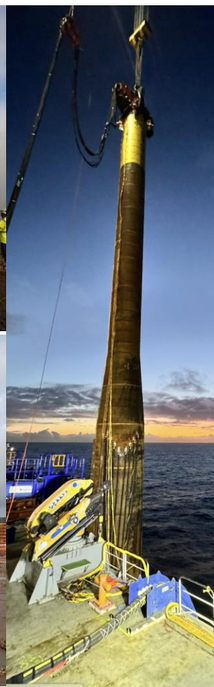
SIMPLE I	On shore sand
SIMPLE II	Near shore
SIMPLE III	Drivability/fluidisation-modelling
SIMOX	LBC, ABC, drivability
SIMPLE III	Offshore at scale
SIMPLER	Retrievability & clay tests



Funded by
the European Union







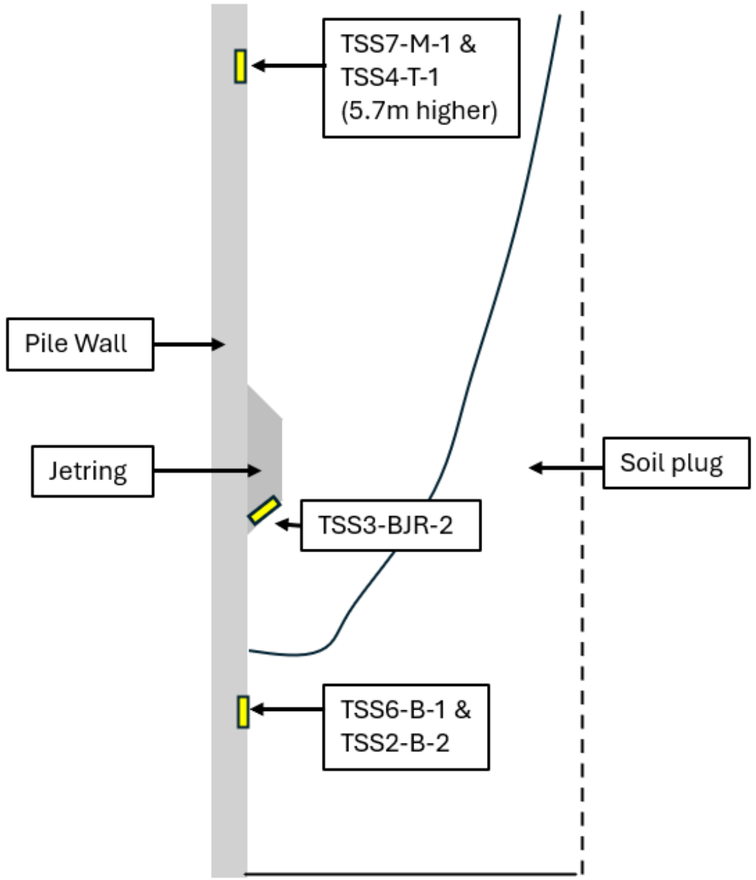
Small-Medium scale demonstration SIMOX

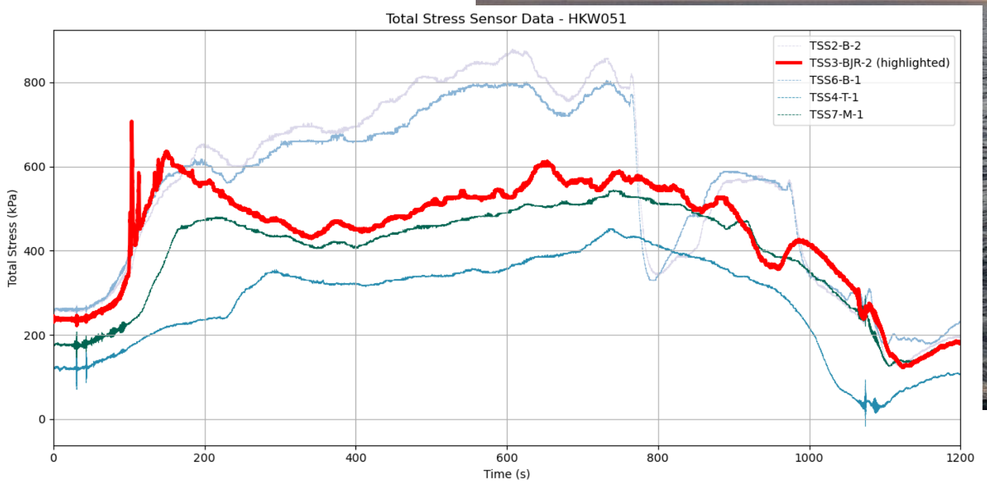
Similar lateral and better axial bearing capacity, compared with Vibro.

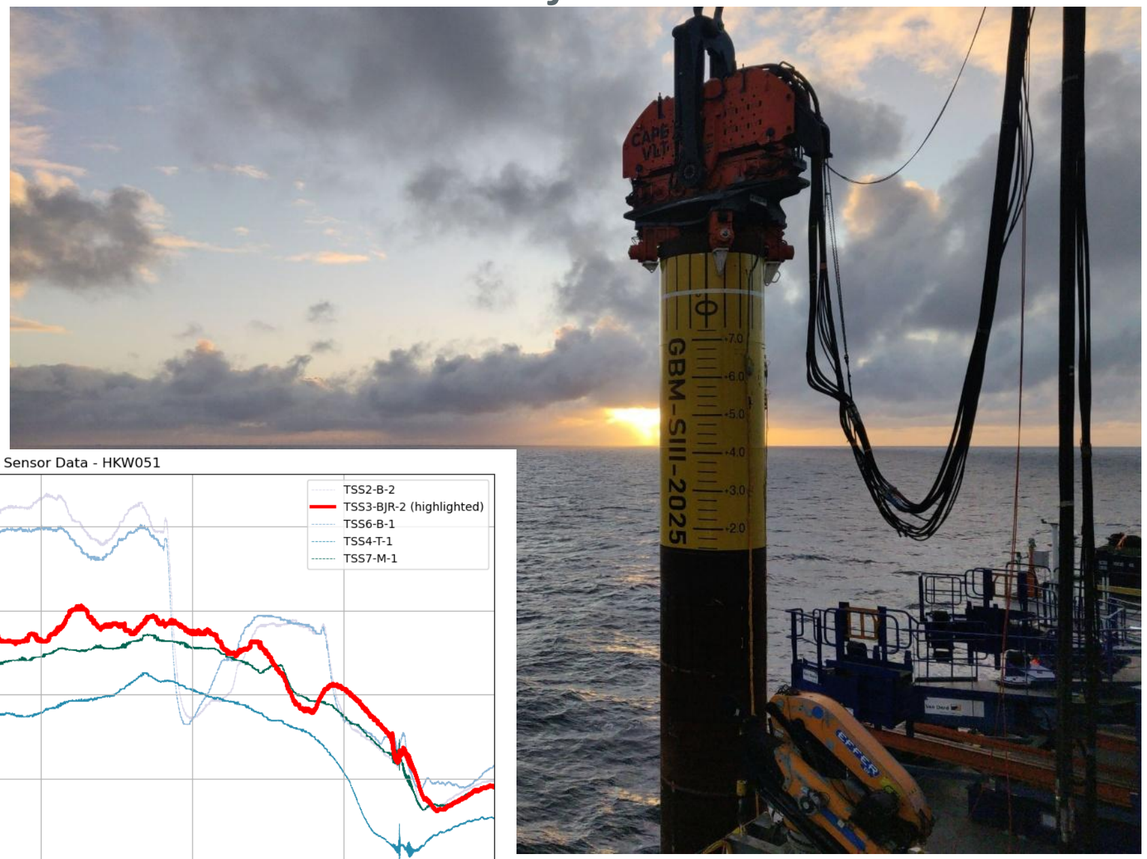
Pictures of the field tests of SIMOX from December 2024

Offshore demonstration SIMPLE III

Full scale proof of controlled fluidisation – Soil fluidised in front of jet

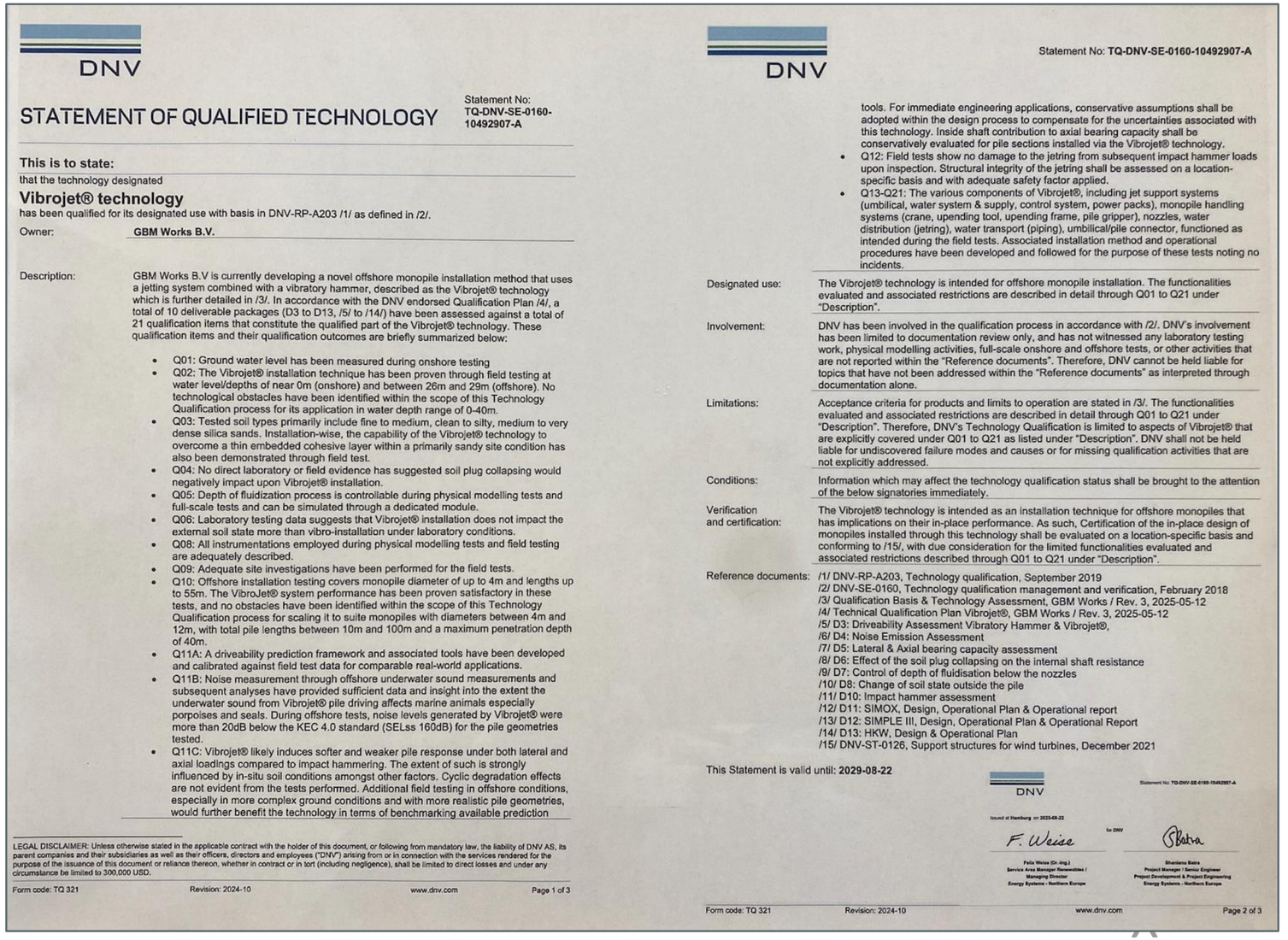






DNV qualification statement Vibrojet®

- For MP between 4m-12m
- Pile length 10-100m
- Sandy soil types
- Water depth 26m-29m
- Controlled fluidisation
- Drivability model verified against field data



DNV

STATEMENT OF QUALIFIED TECHNOLOGY

Statement No: **TQ-DNV-SE-0160-10492907-A**

This is to state:

that the technology designated

Vibrojet® technology

has been qualified for its designated use with basis in DNV-RP-A203 /1/ as defined in /2/.

Owner: **GBM Works B.V.**

Description: GBM Works B.V is currently developing a novel offshore monopile installation method that uses a jetting system combined with a vibratory hammer, described as the Vibrojet® technology which is further detailed in /3/. In accordance with the DNV endorsed Qualification Plan /4/, a total of 10 deliverable packages (D3 to D13, /5/ to /14/) have been assessed against a total of 21 qualification items that constitute the qualified part of the Vibrojet® technology. These qualification items and their qualification outcomes are briefly summarized below:

- Q01: Ground water level has been measured during onshore testing
- Q02: The Vibrojet® installation technique has been proven through field testing at water level/depths of near 0m (onshore) and between 26m and 29m (offshore). No technological obstacles have been identified within the scope of this Technology Qualification process for its application in water depth range of 0-40m.
- Q03: Tested soil types primarily include fine to medium, clean to silty, medium to very dense silica sands. Installation-wise, the capability of the Vibrojet® technology to overcome a thin embedded cohesive layer within a primarily sandy site condition has also been demonstrated through field test.
- Q04: No direct laboratory or field evidence has suggested soil plug collapsing would negatively impact upon Vibrojet® installation.
- Q05: Depth of fluidization process is controllable during physical modelling tests and full-scale tests and can be simulated through a dedicated module.
- Q06: Laboratory testing data suggests that Vibrojet® installation does not impact the external soil state more than vibro-installation under laboratory conditions.
- Q08: All instrumentations employed during physical modelling tests and field testing are adequately described.
- Q09: Adequate site investigations have been performed for the field tests.
- Q10: Offshore installation testing covers monopile diameter of up to 4m and lengths up to 55m. The VibroJet® system performance has been proven satisfactory in these tests, and no obstacles have been identified within the scope of this Technology Qualification process for scaling it to suite monopiles with diameters between 4m and 12m, with total pile lengths between 10m and 100m and a maximum penetration depth of 40m.
- Q11A: A driveability prediction framework and associated tools have been developed and calibrated against field test data for comparable real-world applications.
- Q11B: Noise measurement through offshore underwater sound measurements and subsequent analyses have provided sufficient data and insight into the extent the underwater sound from Vibrojet® pile driving affects marine animals especially porpoises and seals. During offshore tests, noise levels generated by Vibrojet® were more than 20dB below the KEC 4.0 standard (SELss 160dB) for the pile geometries tested.
- Q11C: Vibrojet® likely induces softer and weaker pile response under both lateral and axial loadings compared to impact hammering. The extent of such is strongly influenced by in-situ soil conditions amongst other factors. Cyclic degradation effects are not evident from the tests performed. Additional field testing in offshore conditions, especially in more complex ground conditions and with more realistic pile geometries, would further benefit the technology in terms of benchmarking available prediction

tools. For immediate engineering applications, conservative assumptions shall be adopted within the design process to compensate for the uncertainties associated with this technology. Inside shaft contribution to axial bearing capacity shall be conservatively evaluated for pile sections installed via the Vibrojet® technology.

- Q12: Field tests show no damage to the jetring from subsequent impact hammer loads upon inspection. Structural integrity of the jetring shall be assessed on a location-specific basis and with adequate safety factor applied.
- Q13-Q21: The various components of Vibrojet®, including jet support systems (umbilical, water system & supply, control system, power packs), monopile handling systems (crane, upending tool, upending frame, pile gripper), nozzles, water distribution (jetring), water transport (piping), umbilical/pile connector, functioned as intended during the field tests. Associated installation method and operational procedures have been developed and followed for the purpose of these tests noting no incidents.

Designated use: The Vibrojet® technology is intended for offshore monopile installation. The functionalities evaluated and associated restrictions are described in detail through Q01 to Q21 under "Description".

Involvement: DNV has been involved in the qualification process in accordance with /2/. DNV's involvement has been limited to documentation review only, and has not witnessed any laboratory testing work, physical modelling activities, full-scale onshore and offshore tests, or other activities that are not reported within the "Reference documents". Therefore, DNV cannot be held liable for topics that have not been addressed within the "Reference documents" as interpreted through documentation alone.

Limitations: Acceptance criteria for products and limits to operation are stated in /3/. The functionalities evaluated and associated restrictions are described in detail through Q01 to Q21 under "Description". Therefore, DNV's Technology Qualification is limited to aspects of Vibrojet® that are explicitly covered under Q01 to Q21 as listed under "Description". DNV shall not be held liable for undiscovered failure modes and causes or for missing qualification activities that are not explicitly addressed.

Conditions: Information which may affect the technology qualification status shall be brought to the attention of the below signatories immediately.

Verification and certification: The Vibrojet® technology is intended as an installation technique for offshore monopiles that has implications on their in-place performance. As such, Certification of the in-place design of monopiles installed through this technology shall be evaluated on a location-specific basis and conforming to /15/, with due consideration for the limited functionalities evaluated and associated restrictions described through Q01 to Q21 under "Description".

Reference documents:
/1/ DNV-RP-A203, Technology qualification, September 2019
/2/ DNV-SE-0160, Technology qualification management and verification, February 2018
/3/ Qualification Basis & Technology Assessment, GBM Works / Rev. 3, 2025-05-12
/4/ Technical Qualification Plan Vibrojet®, GBM Works / Rev. 3, 2025-05-12
/5/ D3: Driveability Assessment Vibratory Hammer & Vibrojet®,
/6/ D4: Noise Emission Assessment
/7/ D5: Lateral & Axial bearing capacity assessment
/8/ D6: Effect of the soil plug collapsing on the internal shaft resistance
/9/ D7: Control of depth of fluidisation below the nozzles
/10/ D8: Change of soil state outside the pile
/11/ D10: Impact hammer assessment
/12/ D11: SIMOX, Design, Operational Plan & Operational report
/13/ D12: SIMPLE III, Design, Operational Plan & Operational Report
/14/ D13: HKW, Design & Operational Plan
/15/ DNV-ST-0126, Support structures for wind turbines, December 2021

This Statement is valid until: **2029-08-22**

DNV Statement No: TQ-DNV-SE-0160-10492907-A

Issued at Hamburg on 2025-08-25 for DNV

F. Weise

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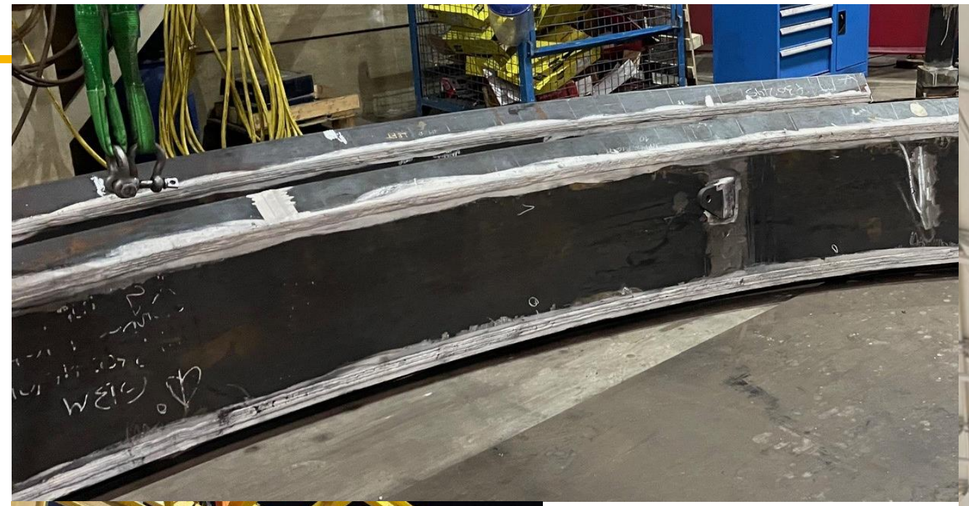
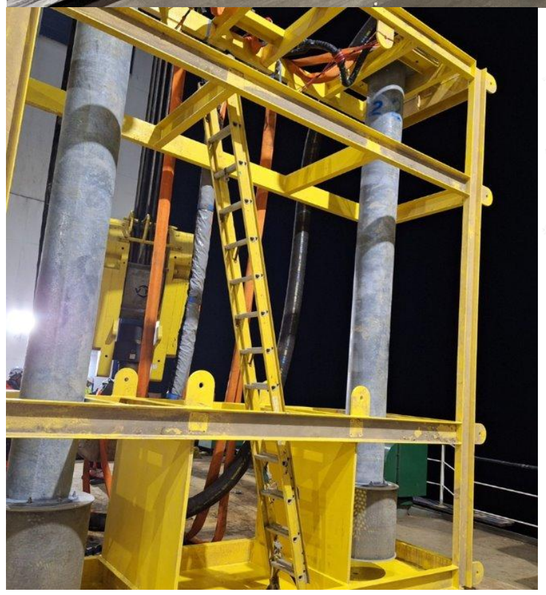
Service Area Manager Renewables / Managing Director
Energy Systems - Northern Europe

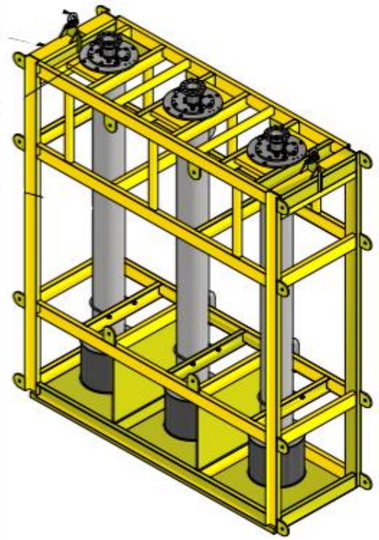
S Batra

Shantanu Batra
Project Manager / Senior Engineer
Project Development & Project Engineering
Energy Systems - Northern Europe

HKW design–Vibrojet®

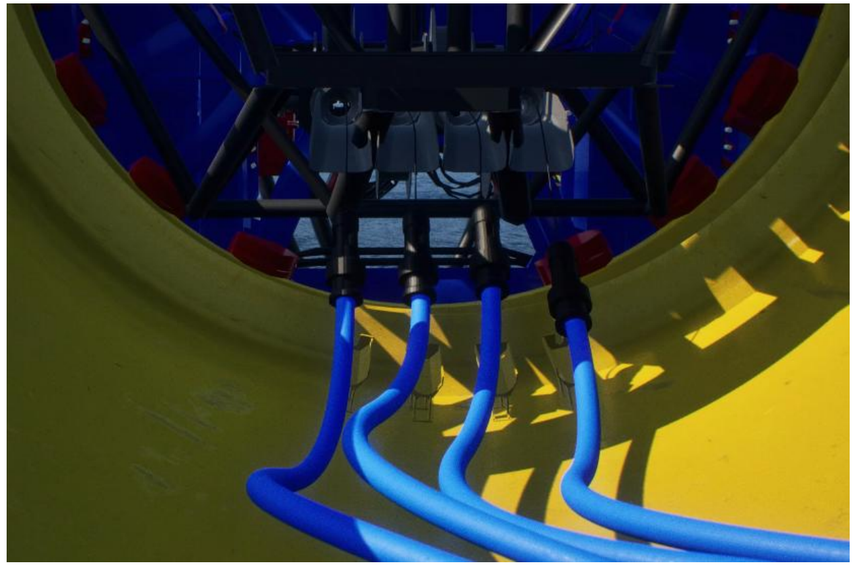




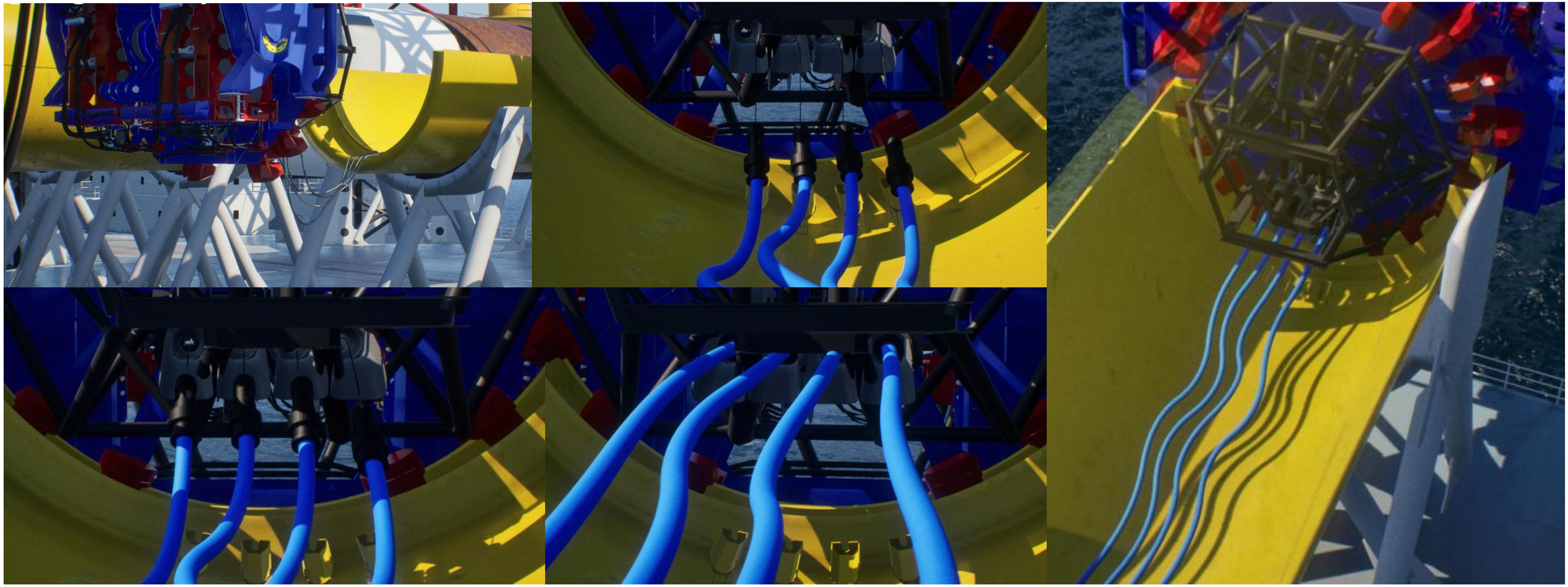


Future developments

- Flexible retrievable hoses inside MP (no clamps/hard piping)
- New Jetring design (Jetring 2.0) possibility for later installation
- Jetting only solutions
- More challenging soil conditions (clay and high-density sand)



Flexible retrievable hoses inside MP



Vibrojet® for Hollandse Kust West March 2026

GBM Works

Contact

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Measuring success

Monitoring underwater noise

Simon Beelen, WaterProof

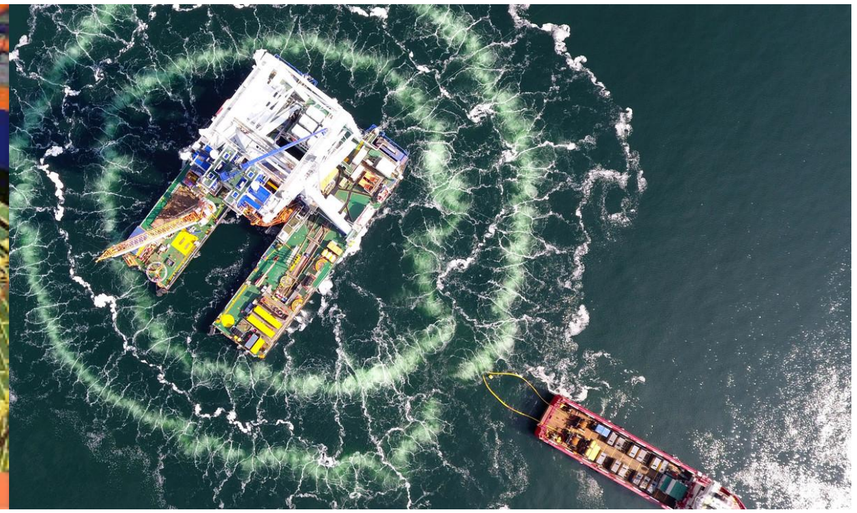
Introduction to underwater noise monitoring

Regulations might contain:
- Maximum sound exposure level single strike (SEL_{ss}=168 dB re 1µPa^2s)
- Maximum harbour porpoise disturbance days

Ambition:
- Minimize negative impact of installation on marine life

Innovative installation techniques

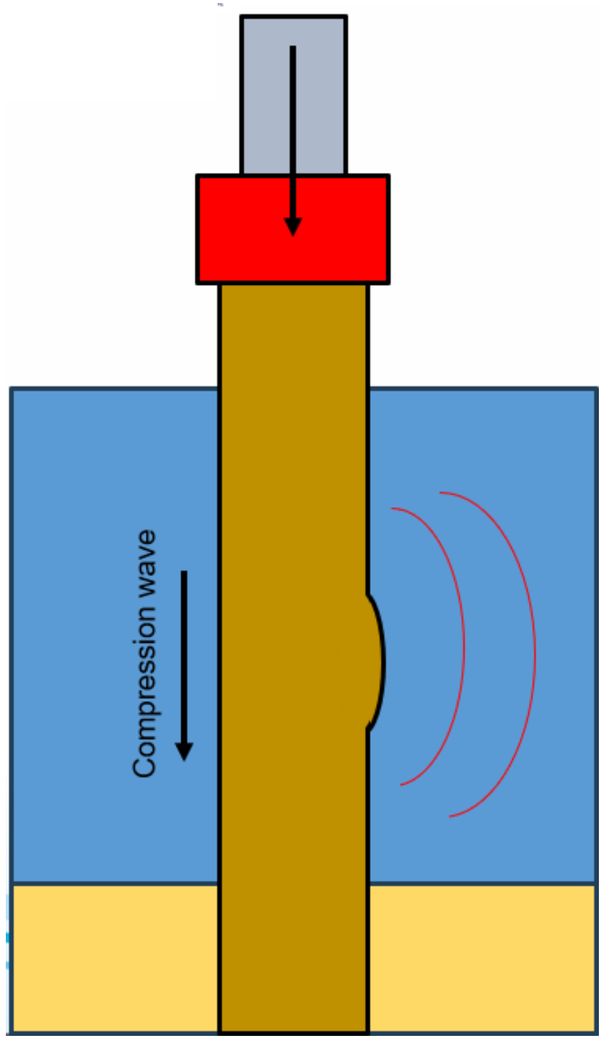
Mitigation measures

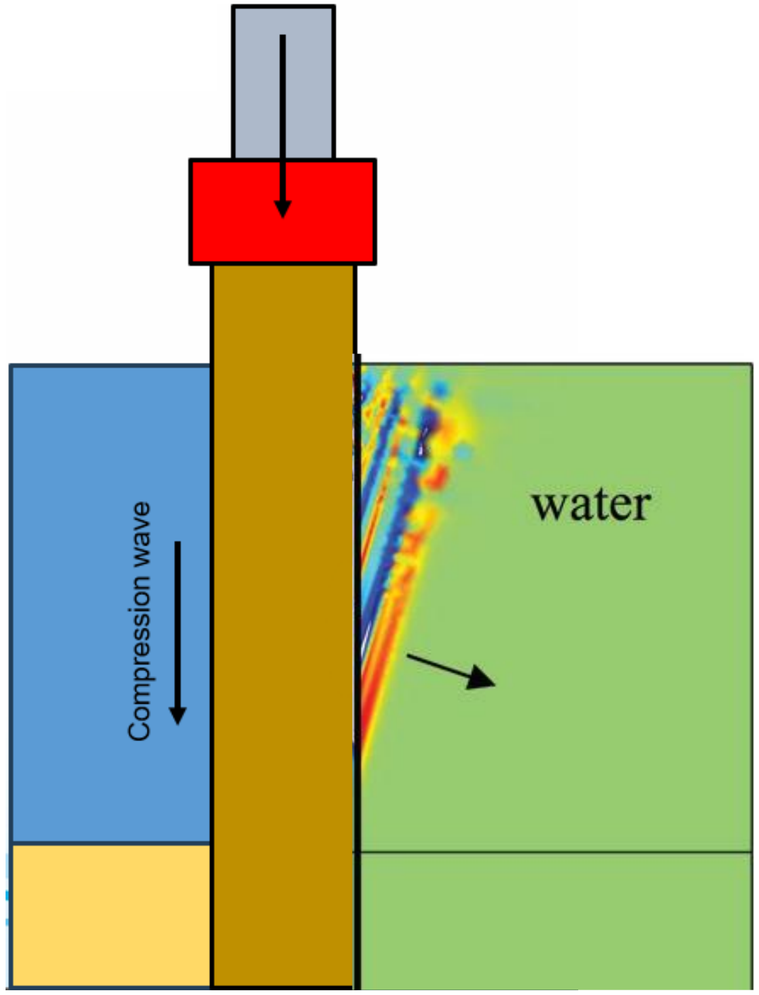


How do we know if it works (beforehand)?

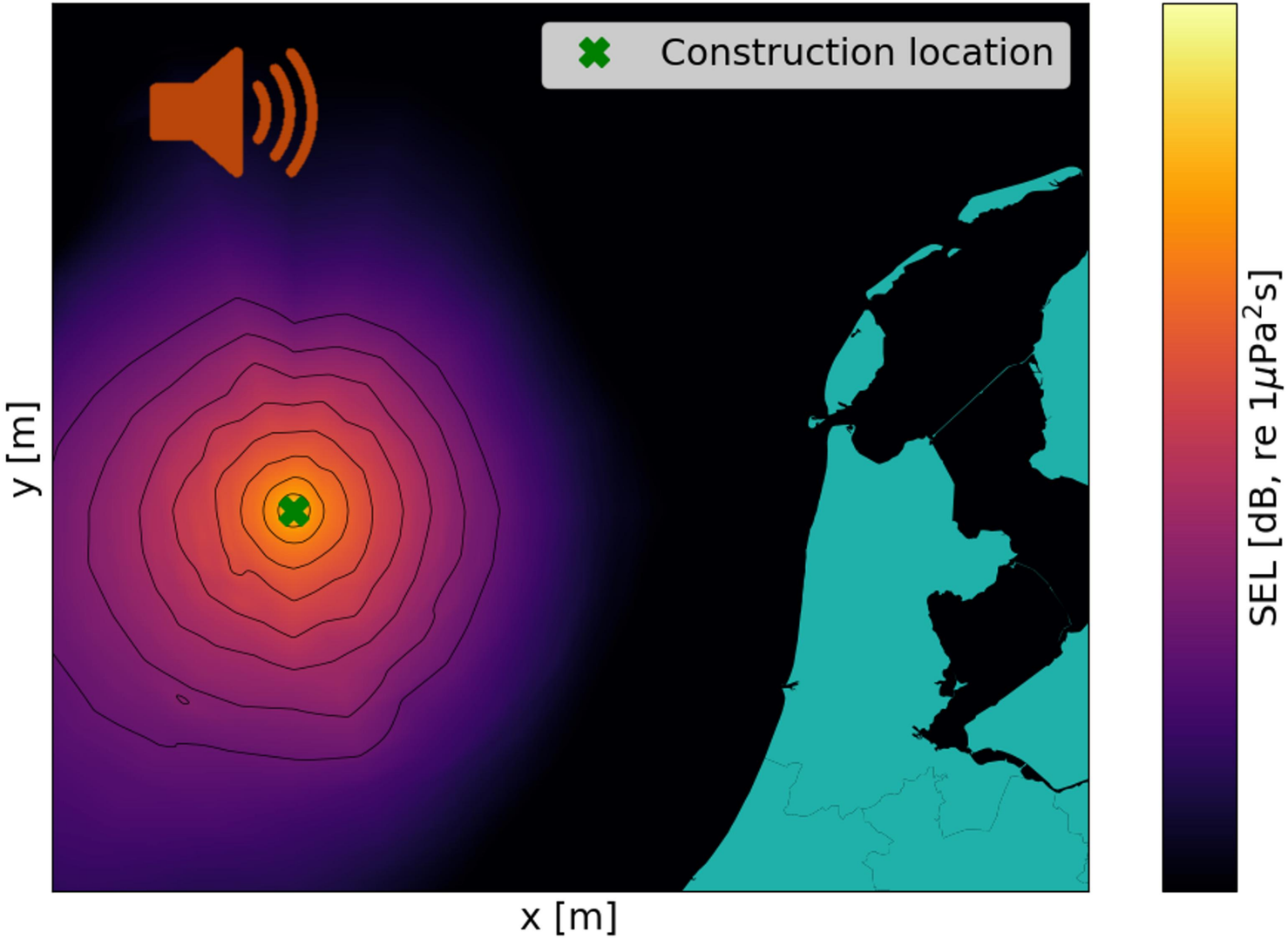
What are the knowledge gaps?

Impact hammering



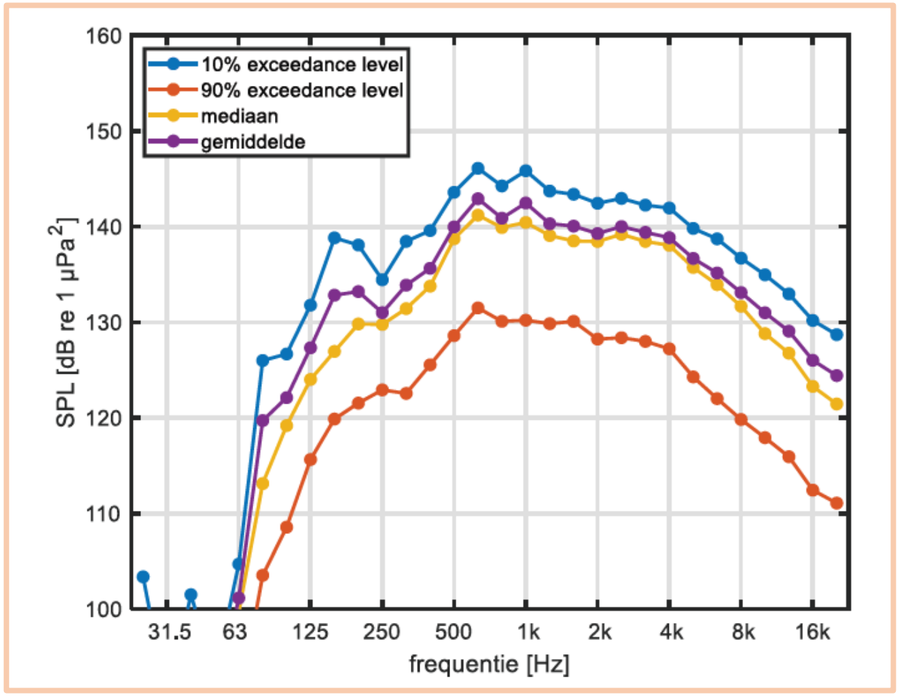


Impact hammering



What do innovative techniques do differently?

What we have for vibro noise levels



- Reference spectrum (1.7 m pile)
- Eccentric mass (ref: 110 kgm)
- Rotational rate (ref: 1350 rpm)

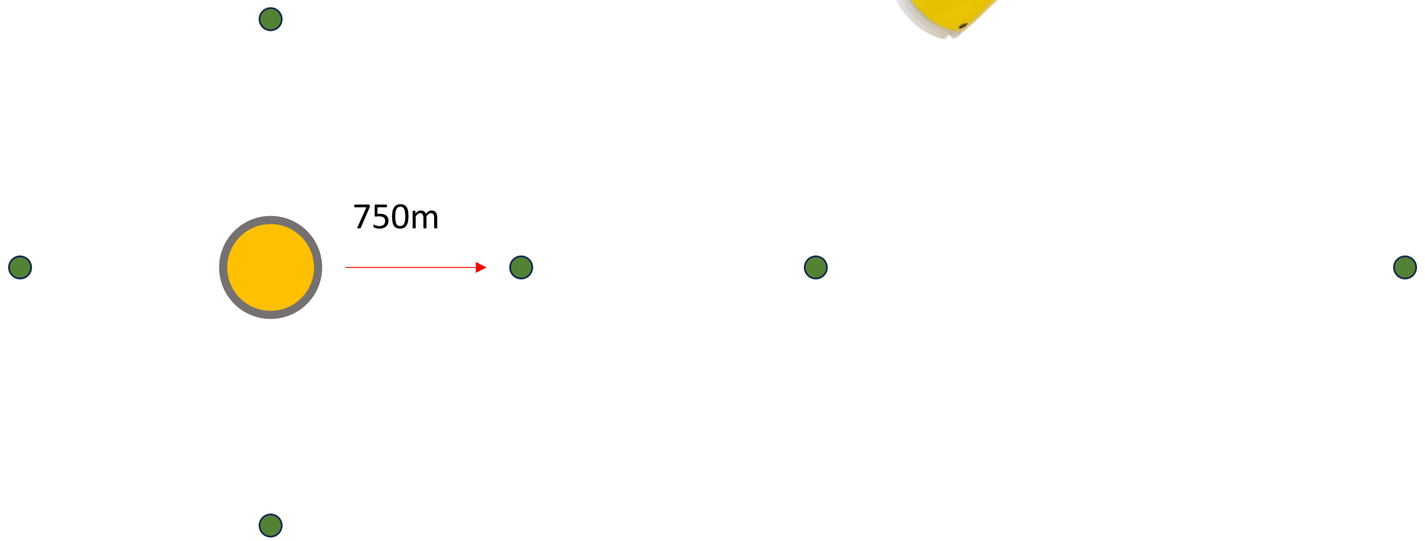
$$L_p^{M,W} \approx L_p^{M_{ref},\Omega_{ref}} + 10\log_{10}\left(\frac{M}{M_{ref}}\right)\ \text{dB} + 20\log_{10}\left(\frac{\Omega}{\Omega_{ref}}\right)\ \text{dB}$$

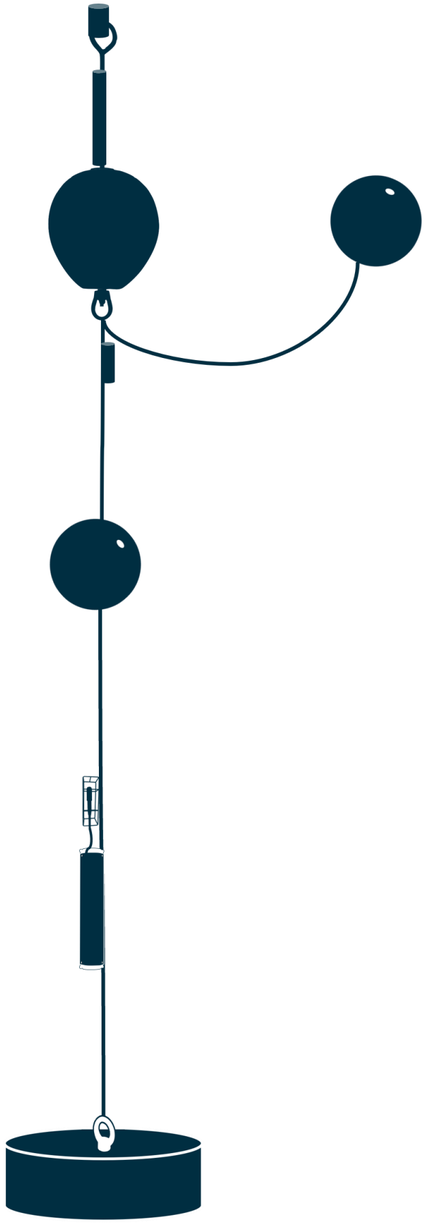
WATER PROOF

Scaling of vibro (jet) noise levels

Measurement station

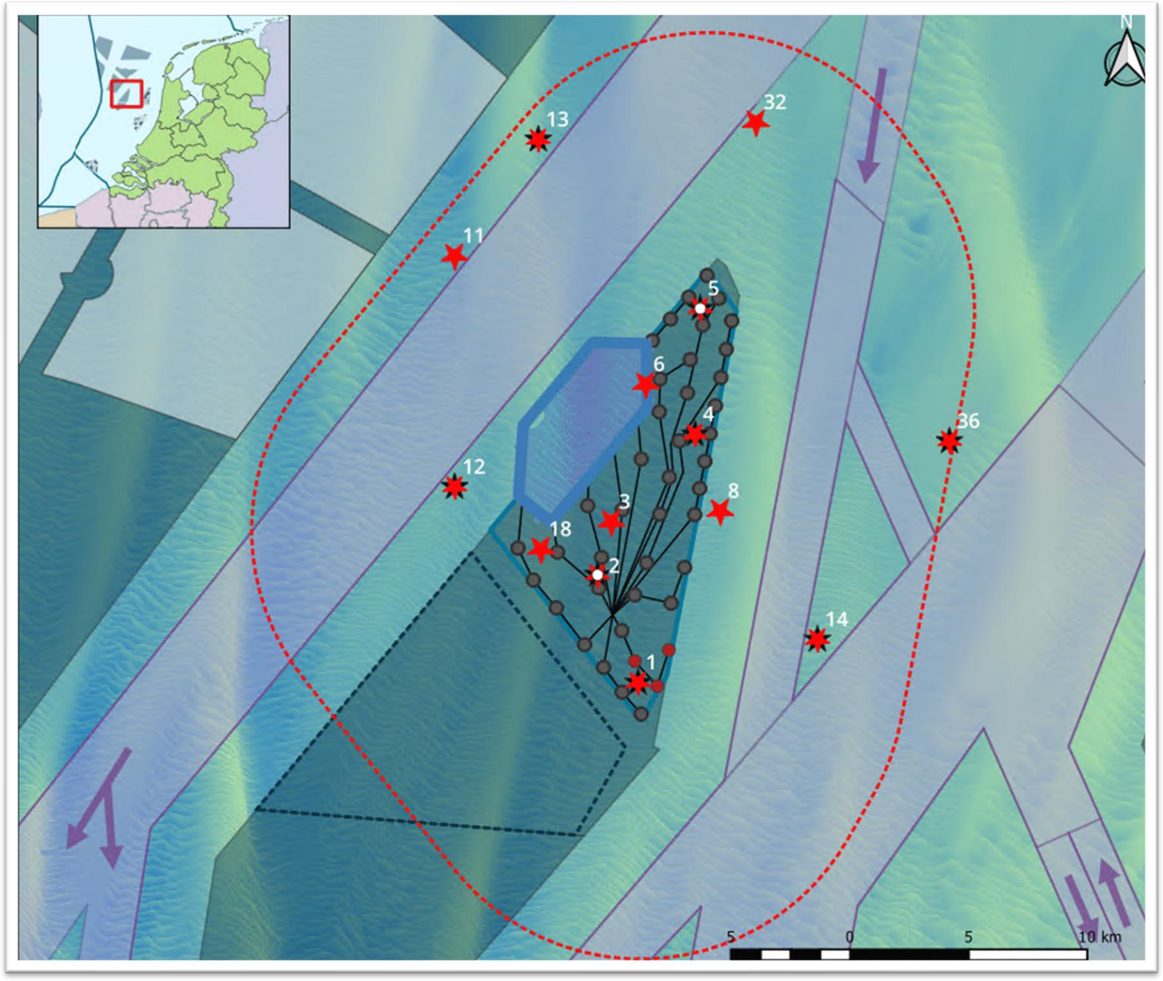
Monopile

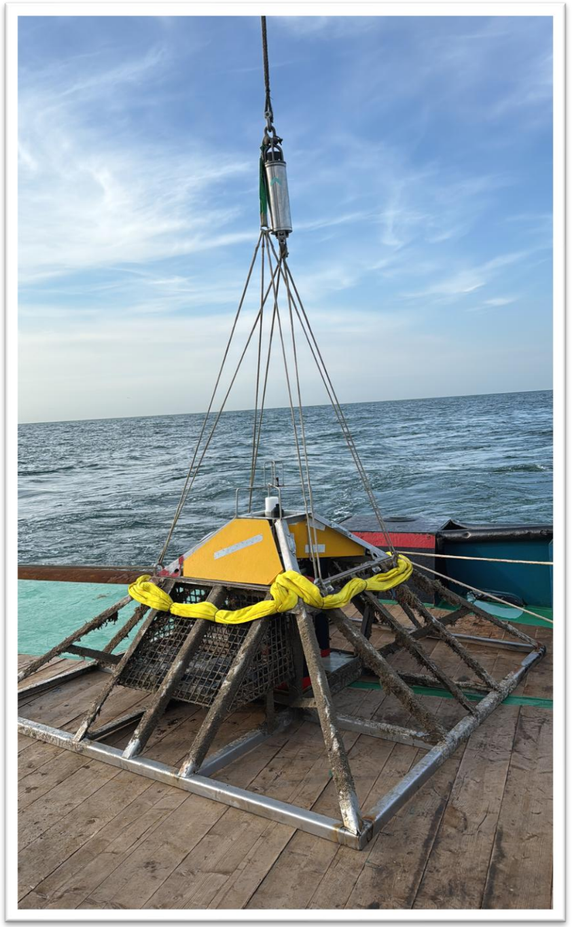


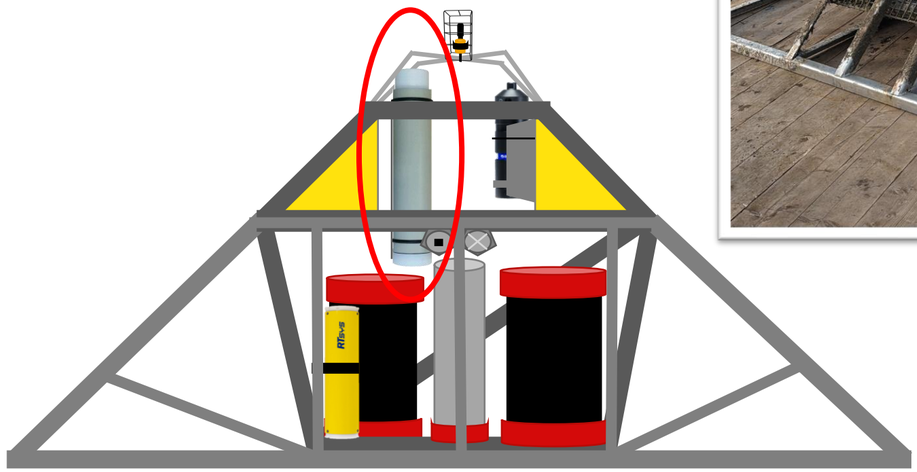


WATER PROOF

Impact on marine life







Questions?

Simon Beelen

Simon.Beelen@WaterProofbv.nl

ECOWENDE
Windpark Hollandse Kust West

Look ahead

Tjalling de Bruin
CEO Ecowende

ECOWENDE

Windpark Hollandse Kust West

SEP 2025	First layer scour protection completed
NOV 2025	Site closed (construction vessels only)
DEC 2025	Start monopile installation
MAR 2026	Start cable installation
Spring 2026	Onshore base completed
Mid 2026	Start wind turbine installation
End 2026	Installation tree reefs and oyster hubs
End 2026	Wind park commissioned

Questions or comments during our construction works?

Email: info@ecowende.nl

ECOWENDE
Windpark Hollandse Kust West

Thank you