

Harbor seals & harbor porpoises-pile driving: detection, behavioral response and TTS



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Ecological impacts of offshore pile driving
27 November 2013
Brussels, Belgium

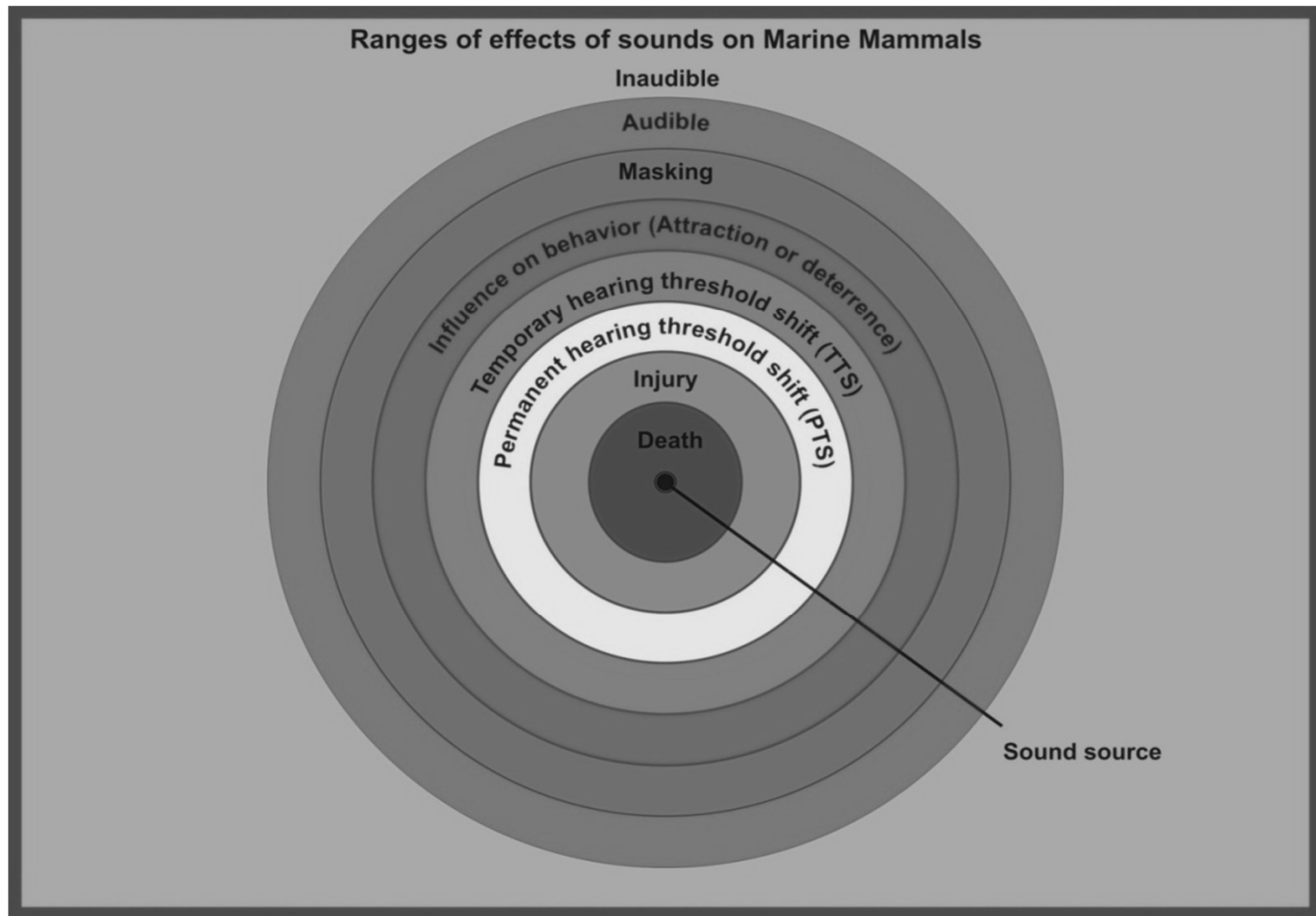
Marine animals use sound for:



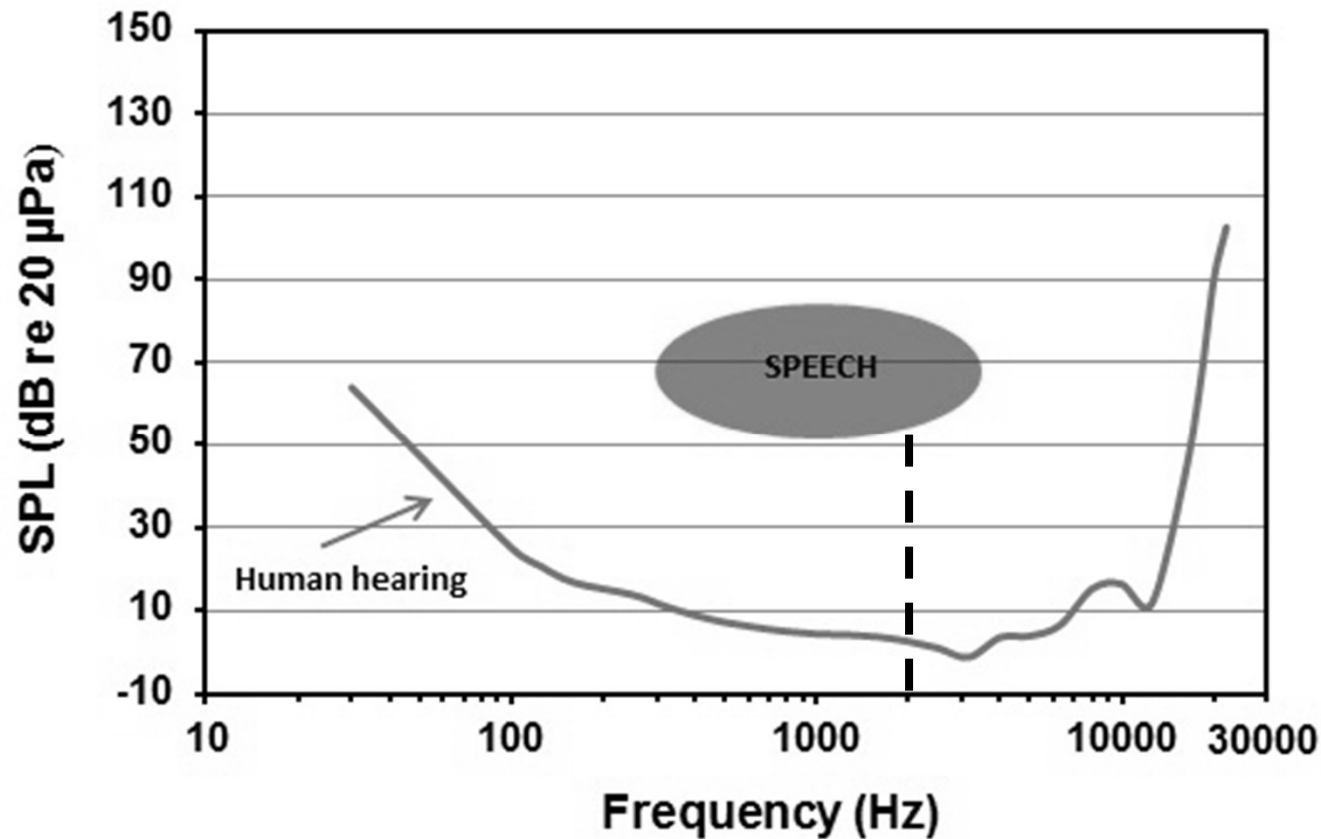
- **Communication (find partner)**
- **Navigation (just listening or echolocation)**
- **Food finding (just listening or echolocation)**
- **Avoiding predators**

Anthropogenic underwater noise may reduce the efficiency of these activities

Potential effects of sound



Hearing thresholds for pile driving sounds

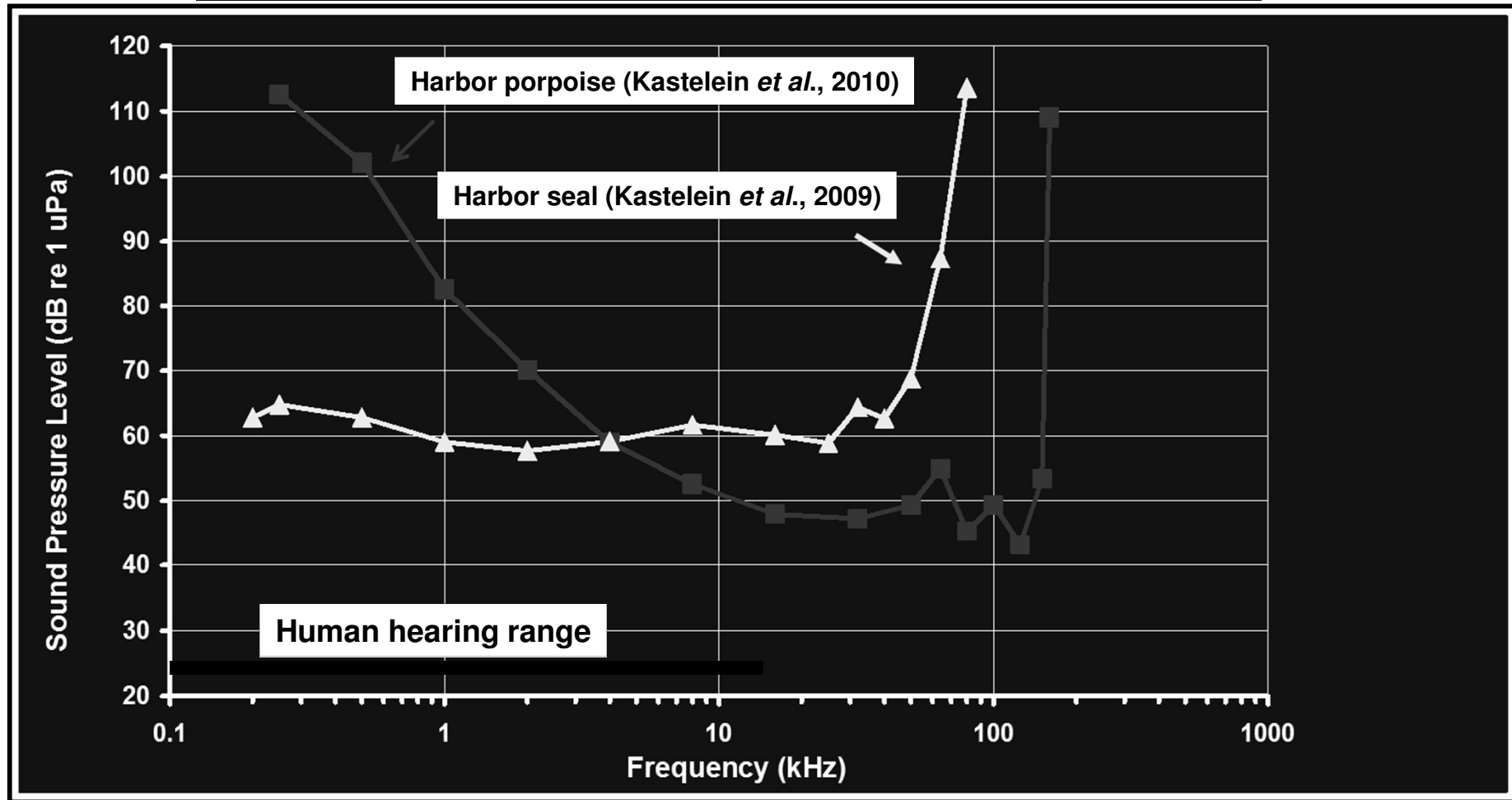


0.5, 1, 2, 4, 8, 16 kHz



2 kHz

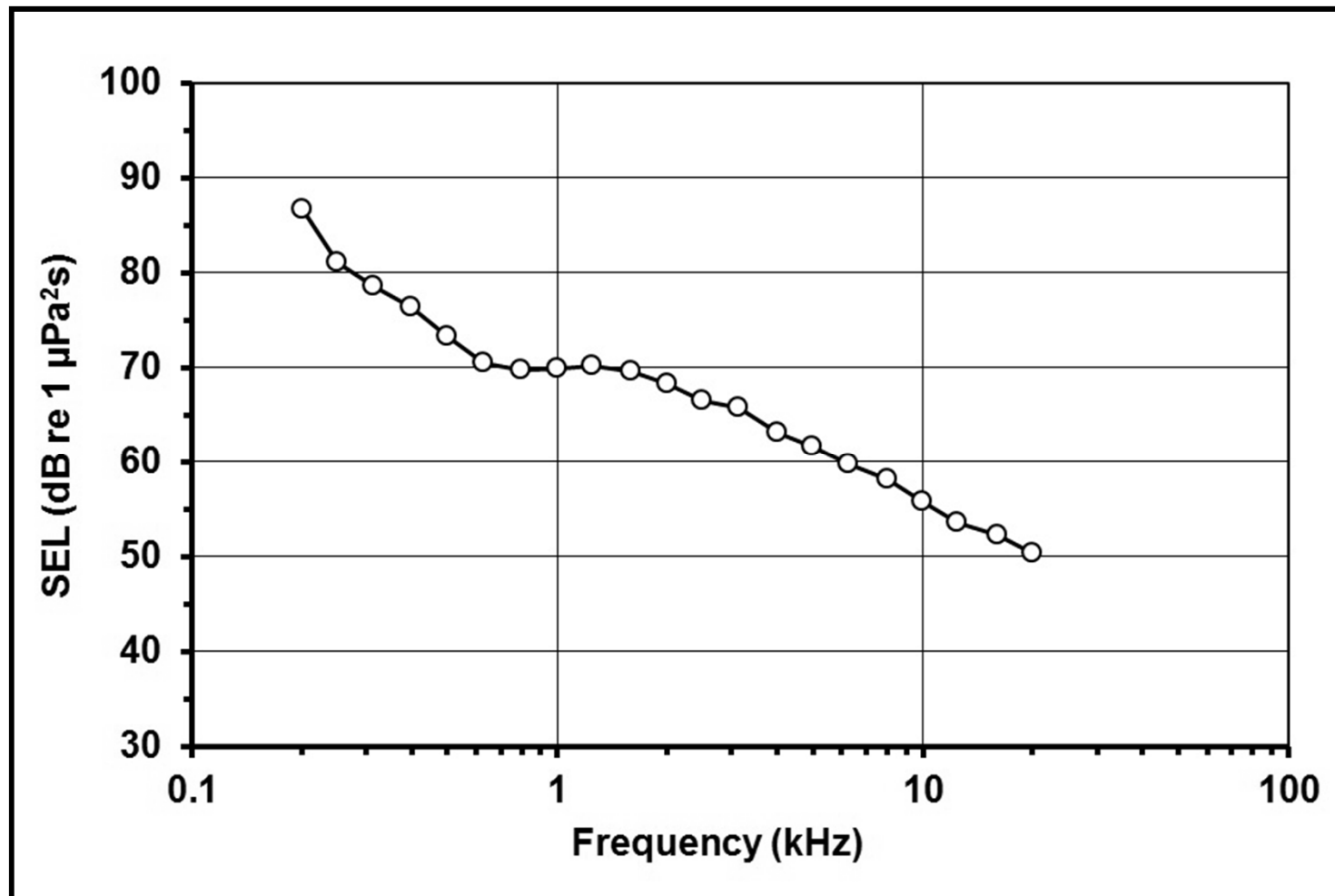
Underwater audiograms for tones



Each species has a different hearing range & sensitivity depending on their ecology



Example spectrum of offshore pile driving sound (Broad-band sound)



H. threshold difficult to estimate based on tonal audiogram⁶

Harbor seal & harbor porpoise: pile driving detection

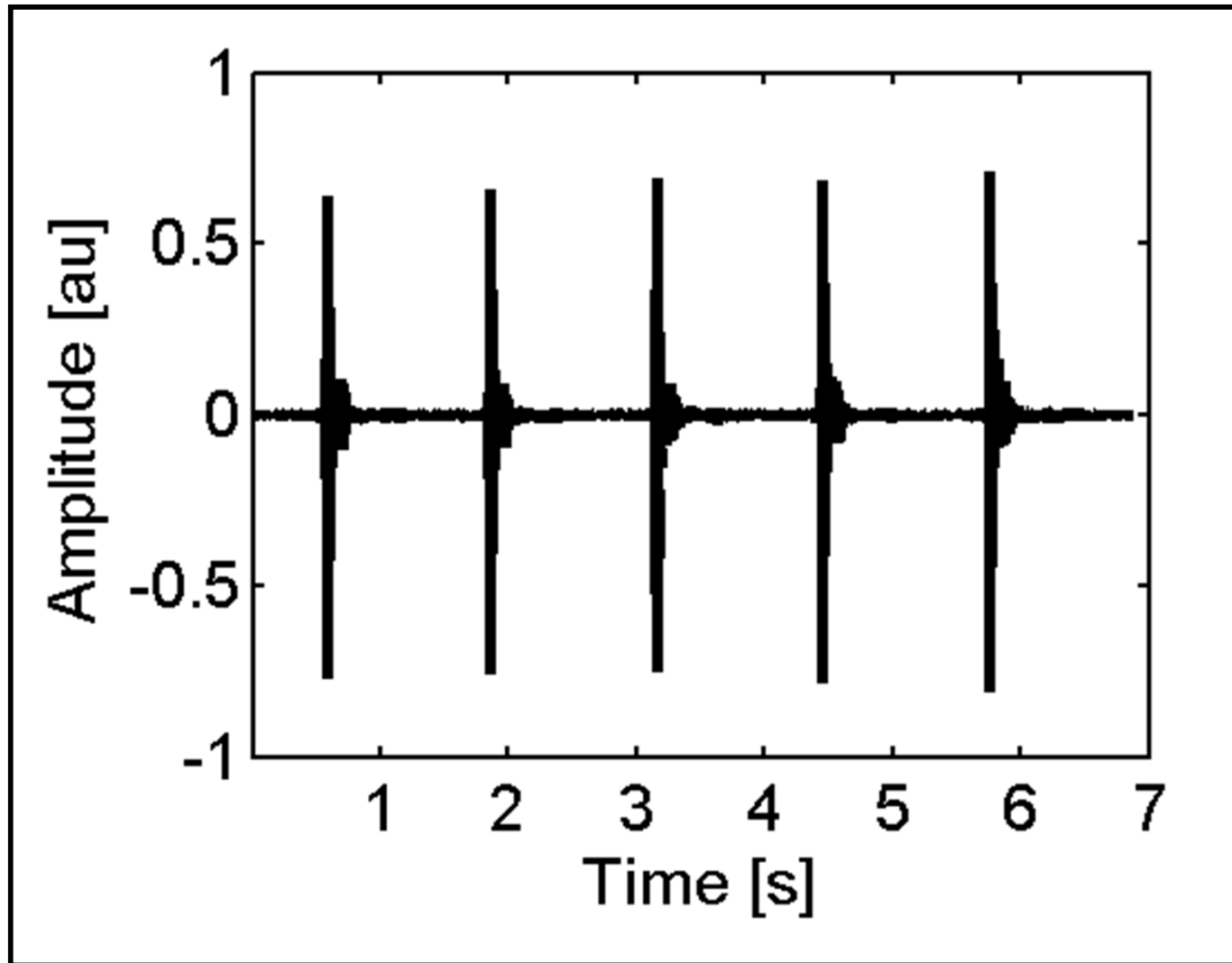


Goals hearing studies:

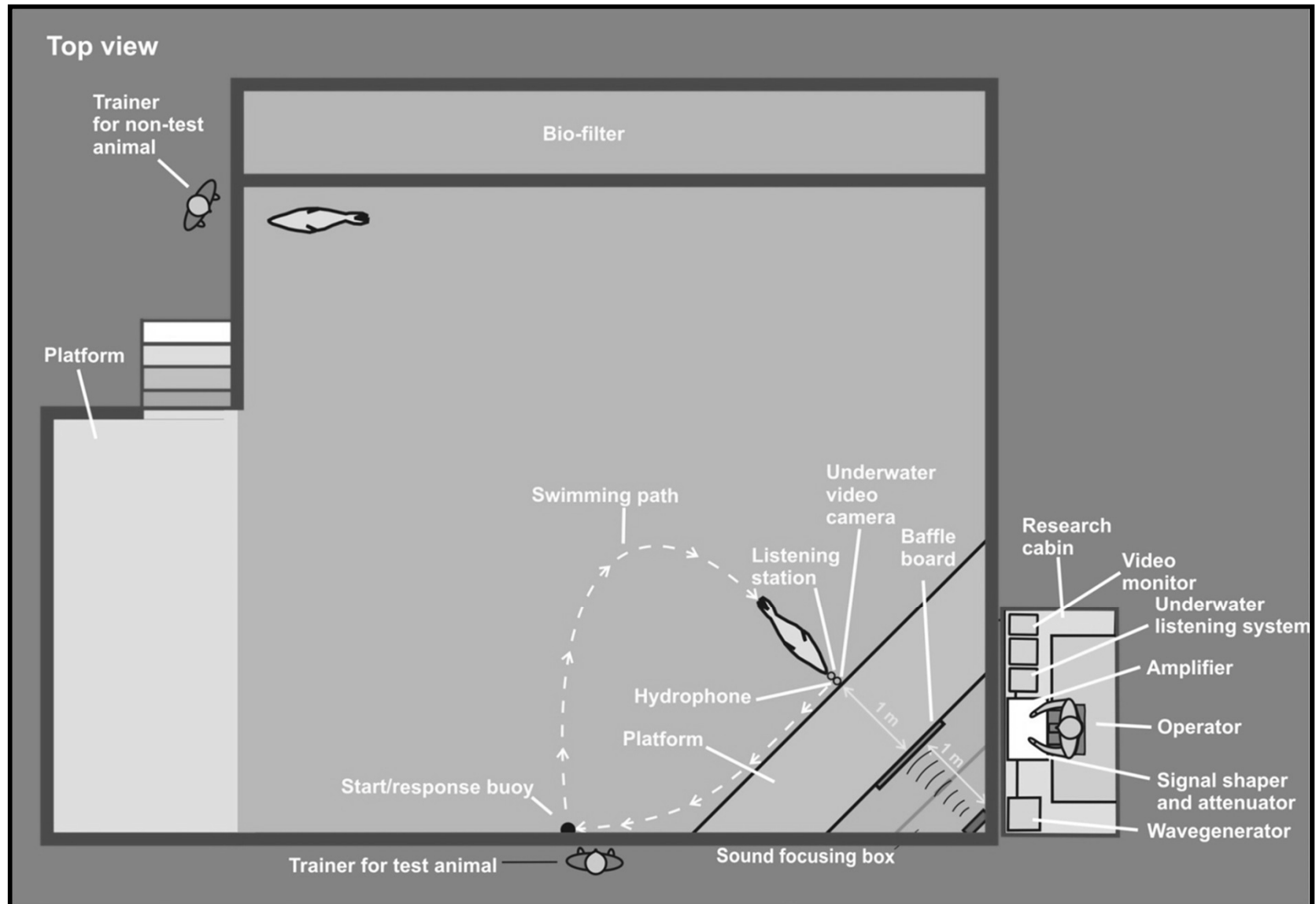
- 1) Determine hearing thresholds for playbacks of pile driving sounds (to determine audibility distances).**
- 2) Effect multiple strike sounds (at a normal pile driving rate).**

Input data for the Soriant tool to estimate effects of anthropogenic underwater sounds on marine fauna (developed by TNO)

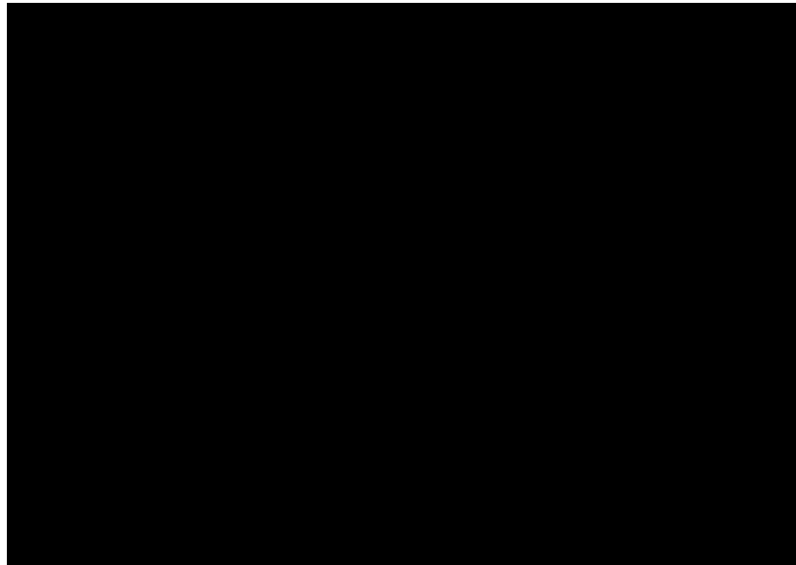
Series of 5 strike sounds from the North Sea (recorded by TNO)



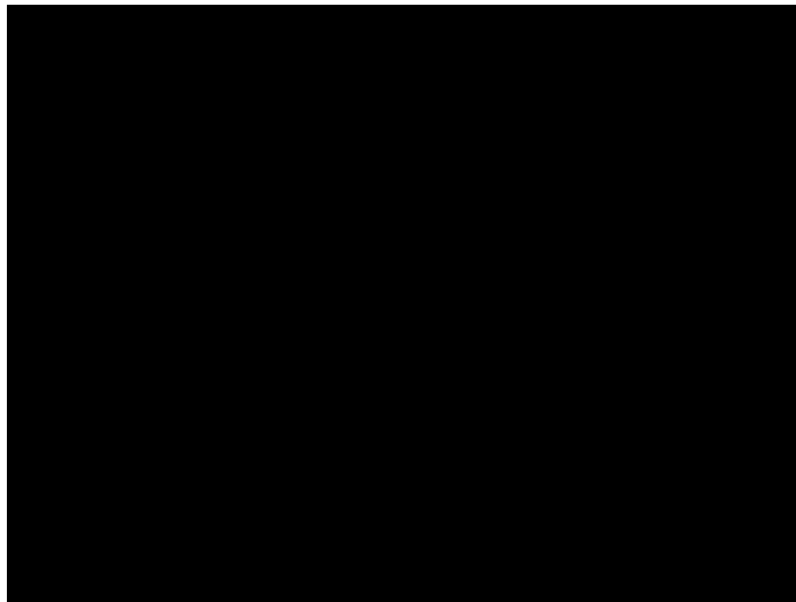
Hearing thresholds h. seals for pile driving sounds



Hearing study with harbor seals

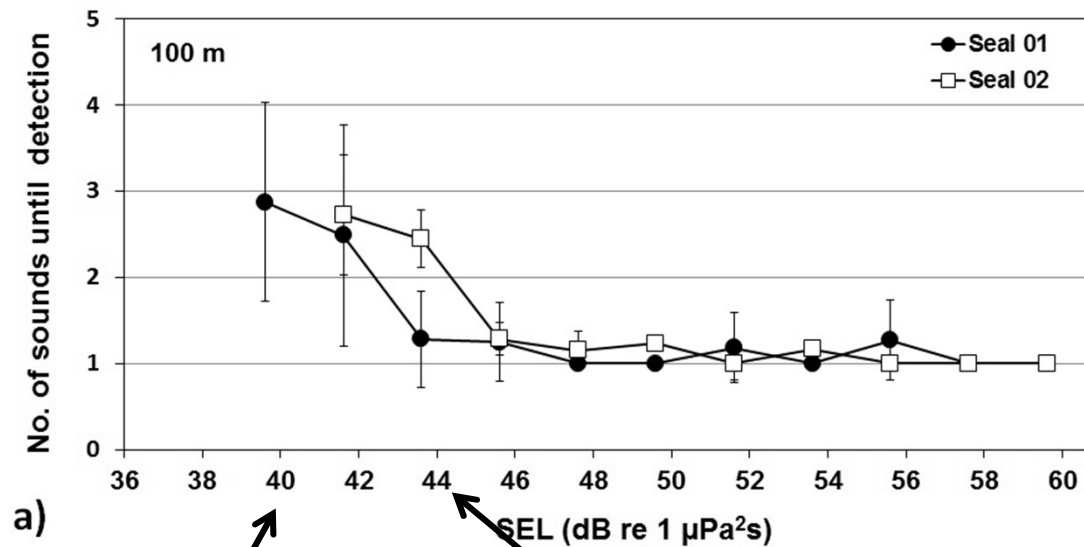


**Heard at
first strike**



**Heard at
4th strike**

Results harbor seals

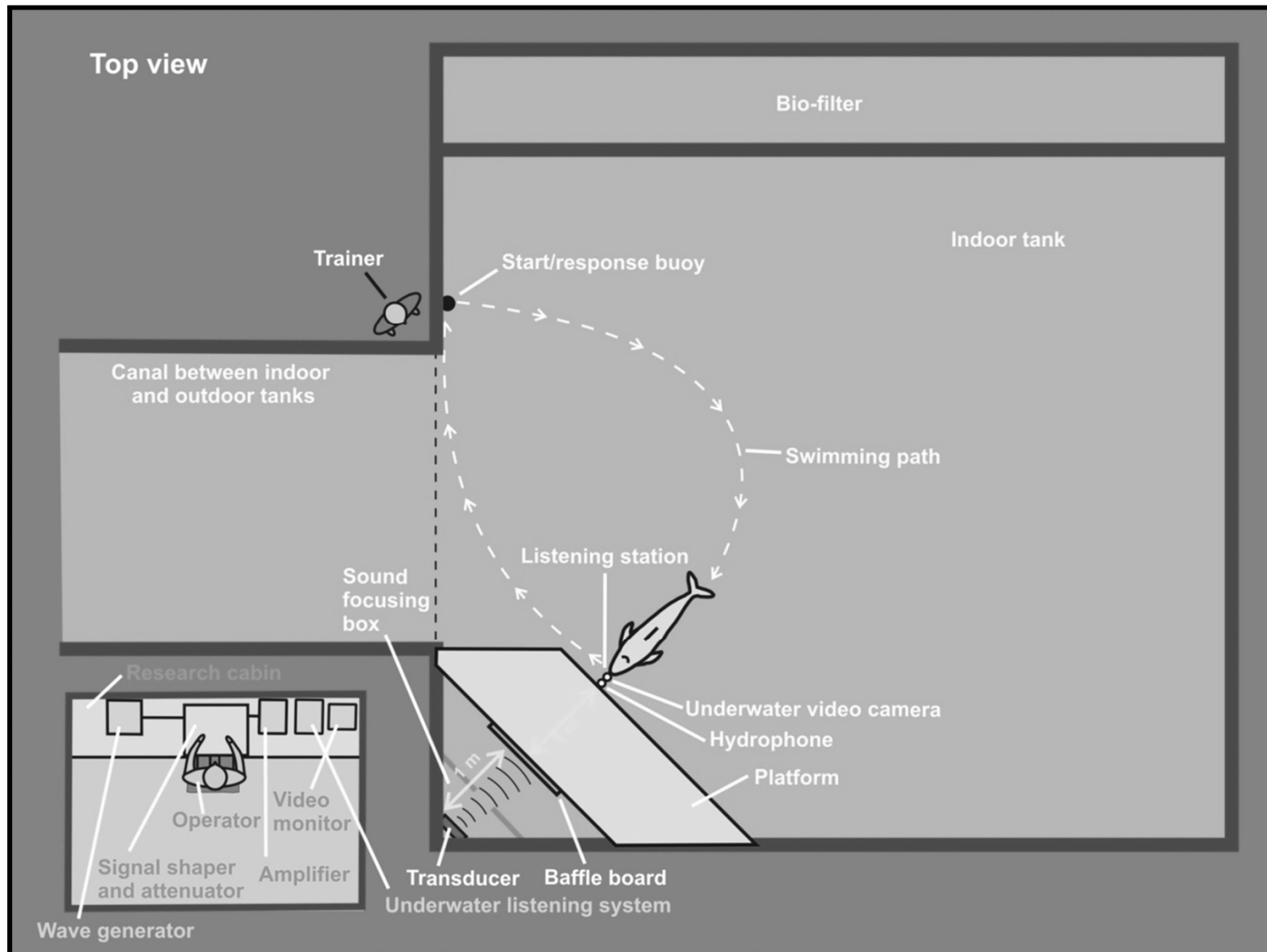


Seal 01:
50% det. thr. SEL any strike:
40 dB re 1 $\mu\text{Pa}^2\text{s}$

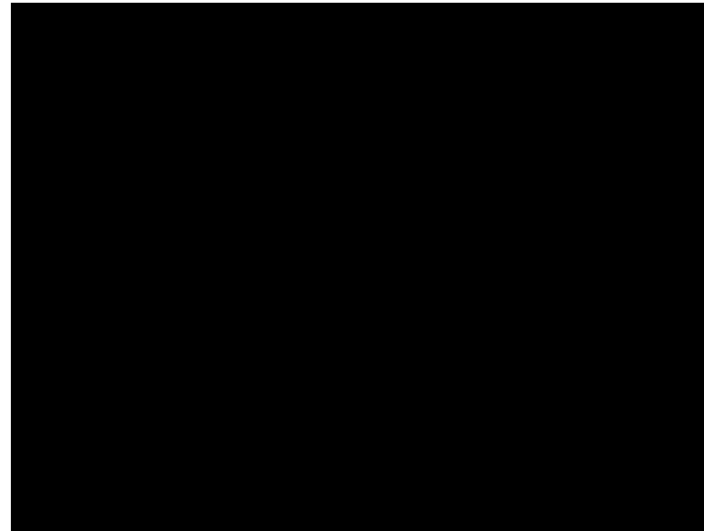
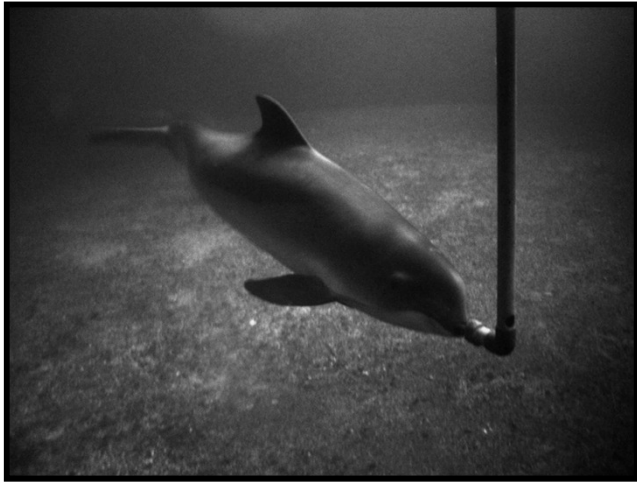
Seal 01:
50% det. thr. SEL first strike:
44 dB re 1 $\mu\text{Pa}^2\text{s}$

Kastelein, R.A., Hoek, L., Gransier, R., de Jong, C.A.F., and Jennings, N. (2013). "Hearing thresholds of two harbor seals (*Phoca vitulina*) for playbacks of multiple pile driving strike sounds," J. Acoust. Soc. Am. 134, 2307-2312. DOI: <http://dx.doi.org/10.1121/1.4817889>.

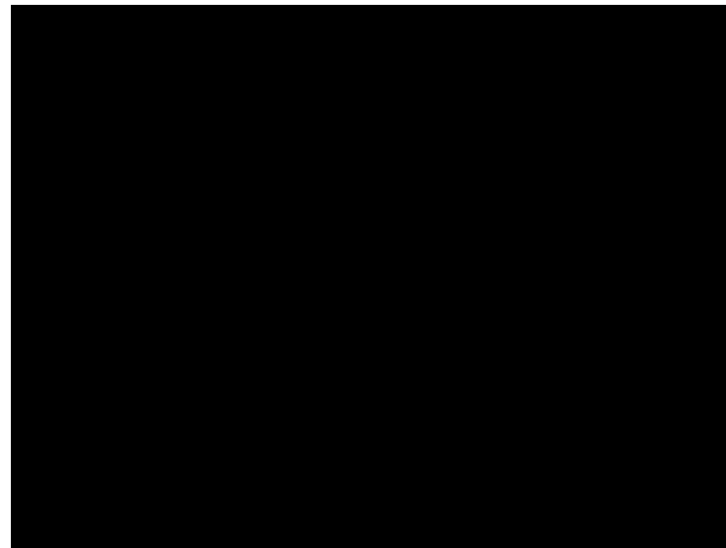
Hearing thresholds h. porpoise for pile driving sounds



Hearing study with harbor porpoise

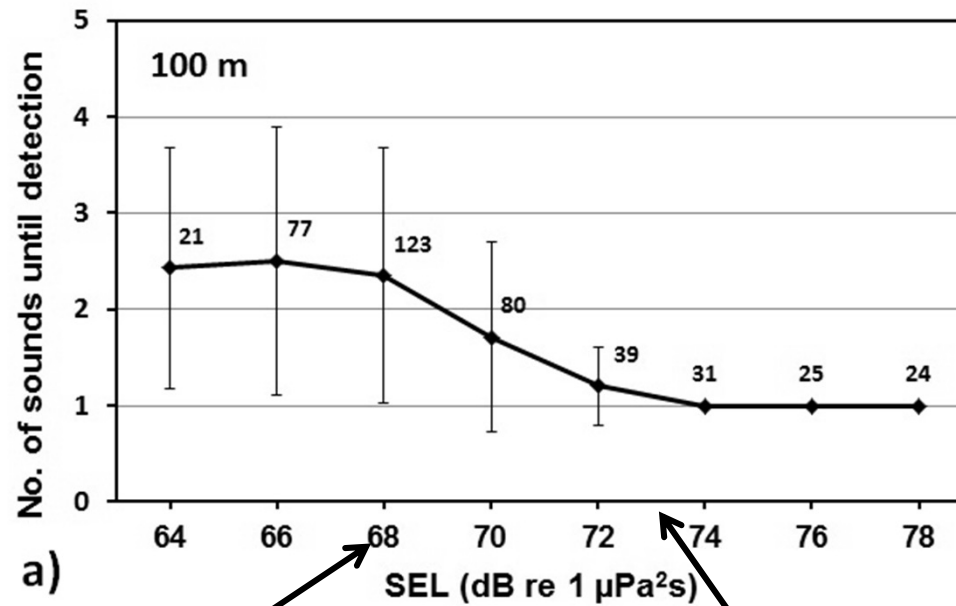


**Heard at
first strike**



**Heard at
3rd strike**

Results harbor porpoise



**50% det. thr. SEL any strike:
68 dB re 1 $\mu\text{Pa}^2\text{s}$**

**50% det. thr. SEL first strike:
73 dB re 1 $\mu\text{Pa}^2\text{s}$**

About 28 dB higher thresholds than the seals

Kastelein, R.A., Hoek, L., Gransier, R., and de Jong, C.A.F. (2013). "Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for playbacks of multiple pile driving strike sounds, " J. Acoust. Soc. Am. 134, 2302-2306. DOI: <http://dx.doi.org/10.1121/1.4817842>.

Funding agencies:

- **Netherlands Ministry of Infrastructure & Environment**
- **Netherlands Ministry of Economic Affairs**

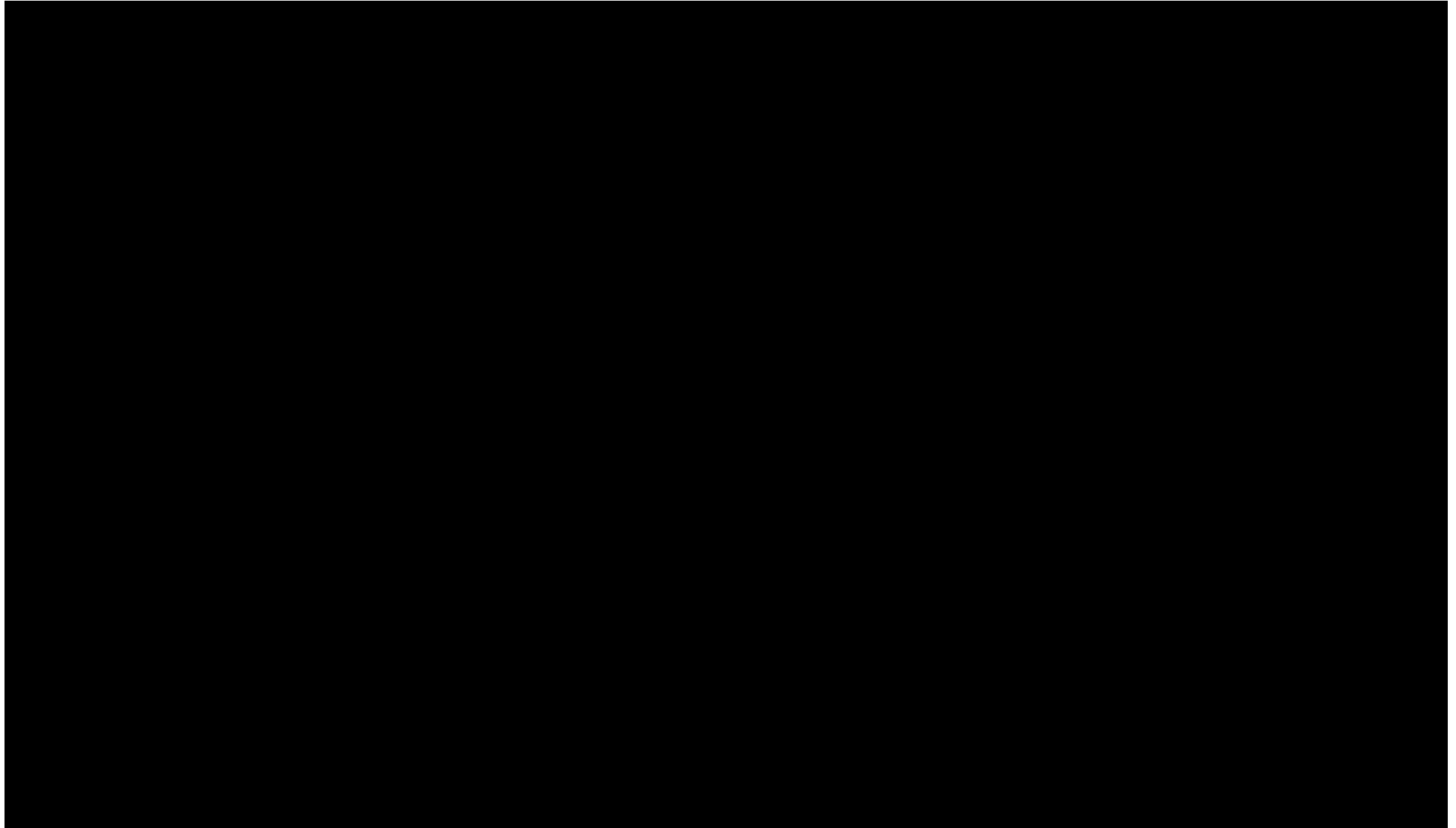
Contact: Martine Graafland, RWS Zee en Delta.



Behavioral response to pile driving sound

- **Input data for Soriant tool developed by TNO**
- **Dose-response relationship (7 SPLs)**

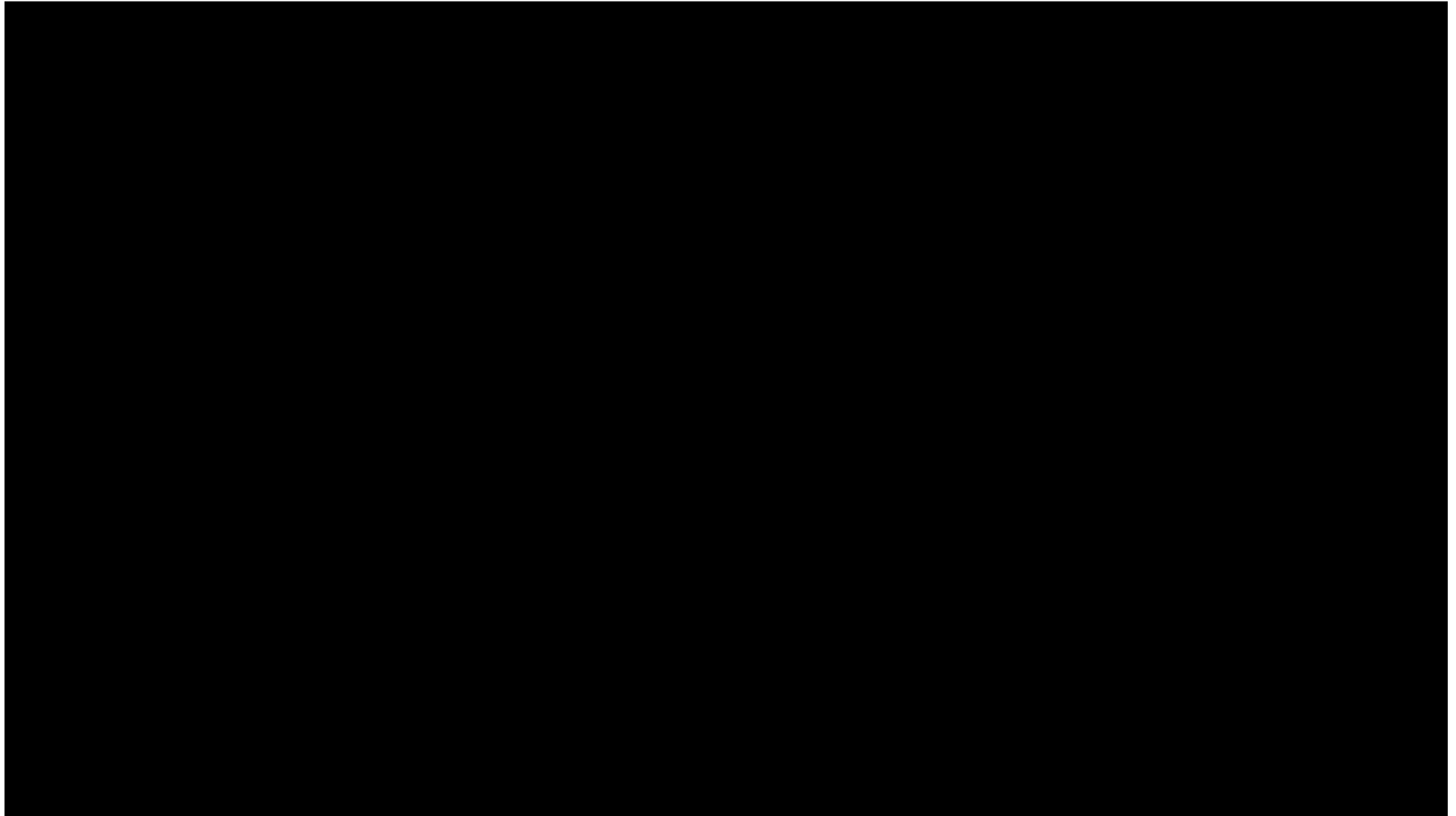
Example behavior during baseline period



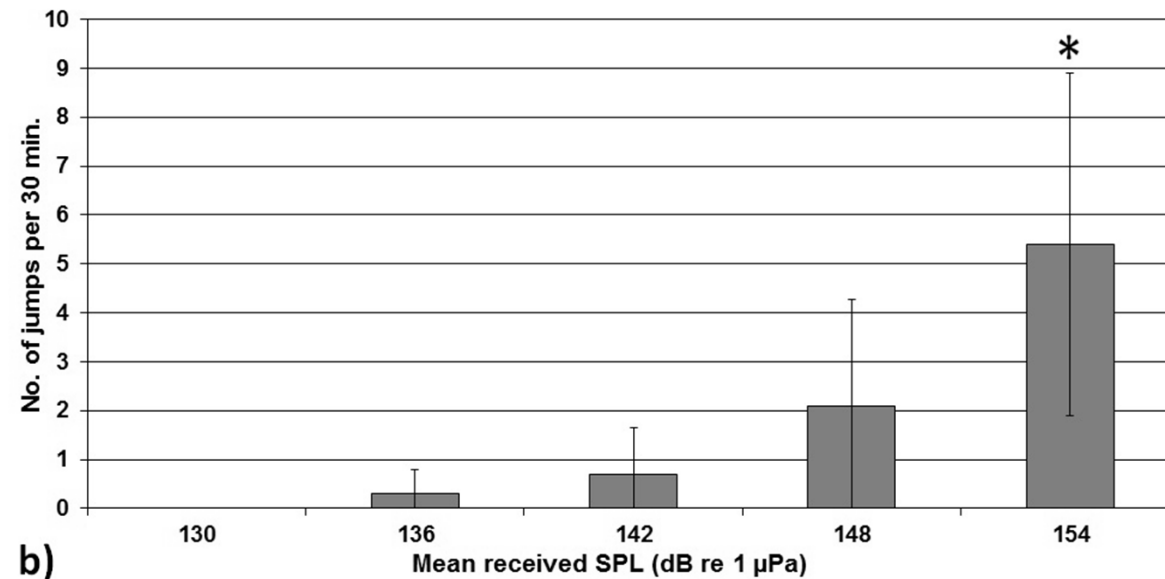
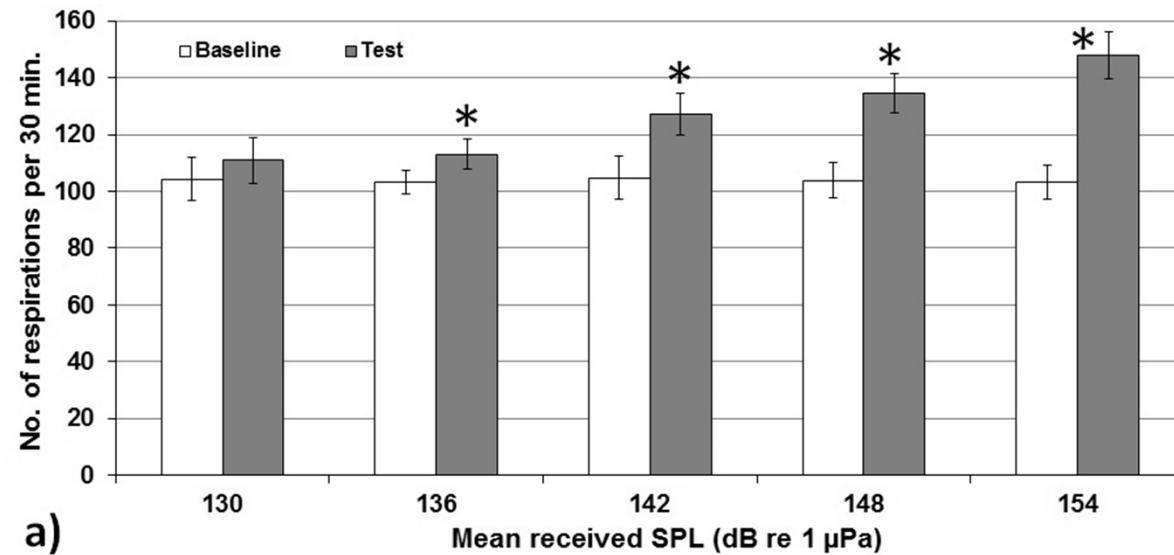


Behavioral response to pile driving sound

Example behavior during test period with highest level



Results behavioral response study



Conclusions

Effects of pile driving sound on harbor porpoises are expected to occur up to ~30 km under quiet conditions.

This puts an upper limit to the effect ranges found in Germany, Denmark and Belgium where effects were seen *at least* up to 15, 20 or 22 km. They did not measure beyond these distances.

Funding agency:

Netherlands Ministry of Infrastructure and Environment.

Martine Graafland, RWS Zee en Delta.

Kastelein, R. A., van Heerden, D., Gransier, R., and Hoek, L (2013). “Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to playbacks of broadband pile driving sounds,”

Marine Environmental Research 92, 206-214, DOI: 10.1016/j.marenvres.2013.09.020

Effects displacement due to pile driving sound

- Less time for foraging
- Potential displacement to less favorable foraging areas
- Increased activity level leads to increased food requirement
- Mother calf separation

A harbor porpoise needs more food per kg body weight and needs to eat more often than larger dolphins

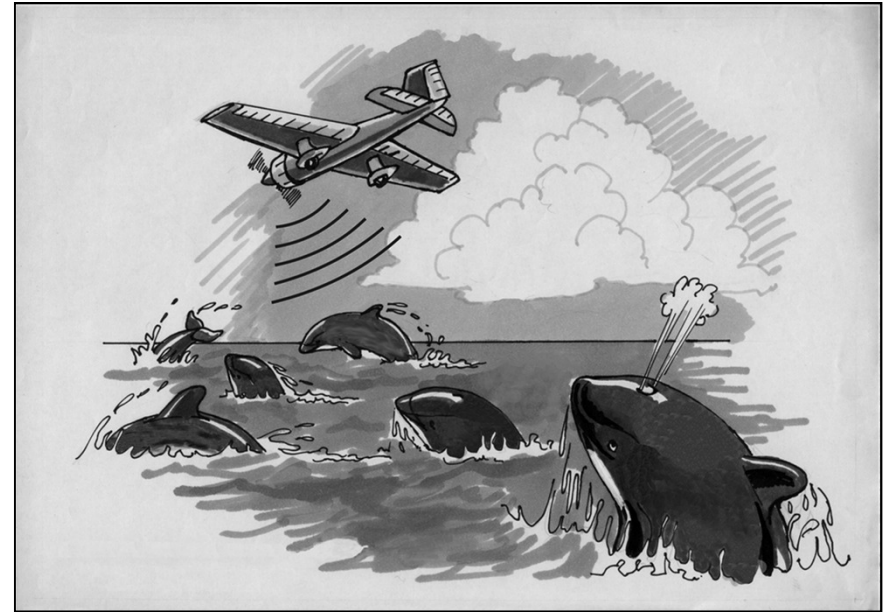


Potential effects of u/w sounds

1) Effects on behavior

a) Use of space

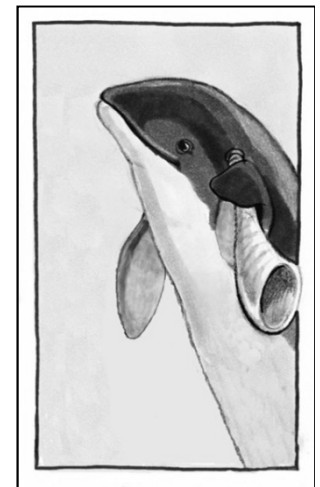
b) Activity level



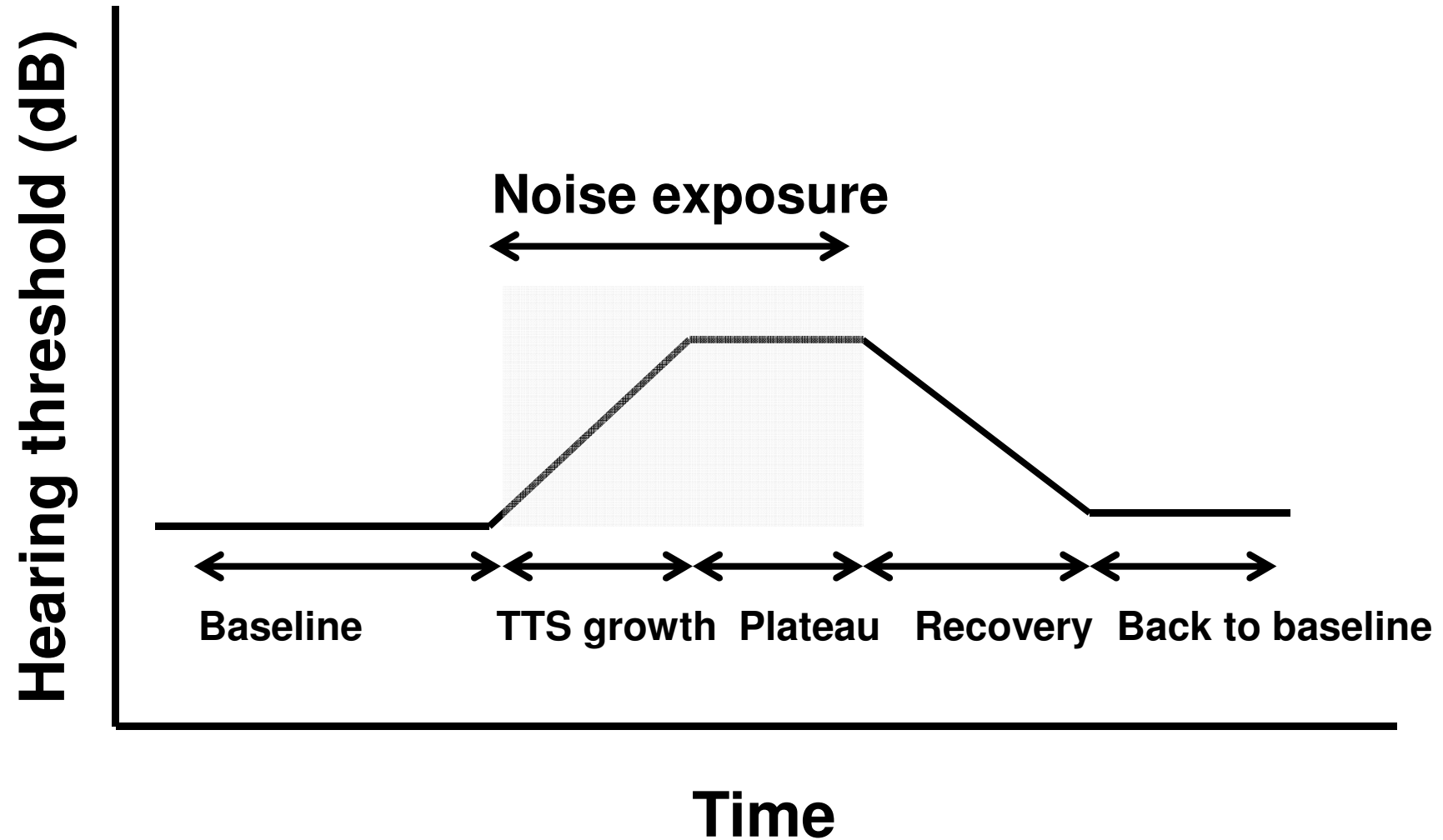
2) Effect on hearing

a) Masking (Listening and echolocation)

b) Effects on hearing sensitivity (TTS & PTS)



Temporary hearing Threshold Shift (TTS)

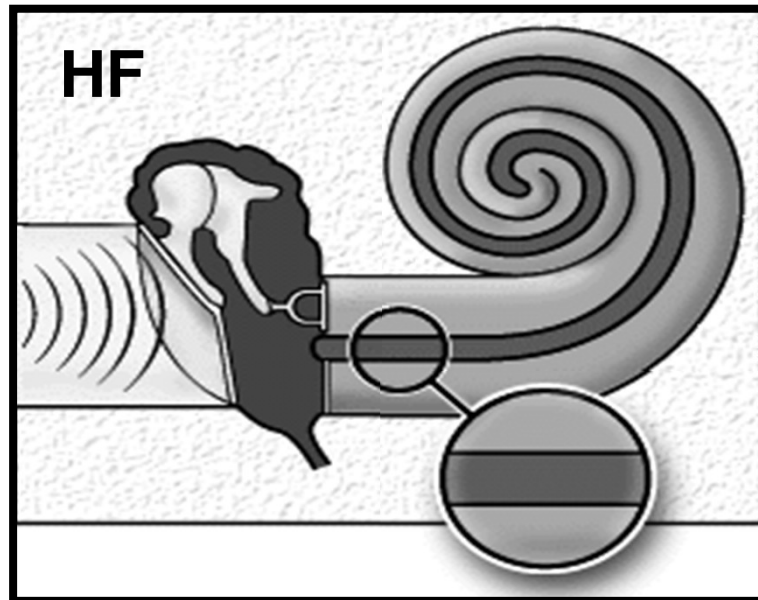
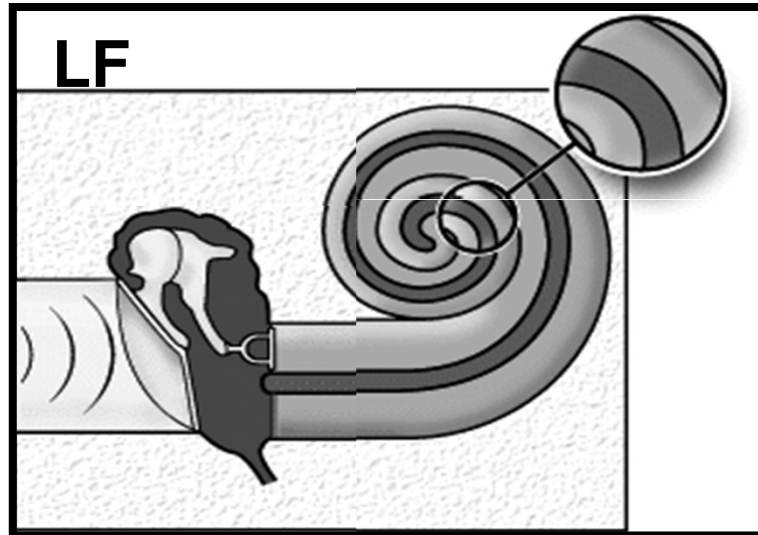


TTS in harbor porpoises due to pile driving sound

Part 1: affected hearing frequencies

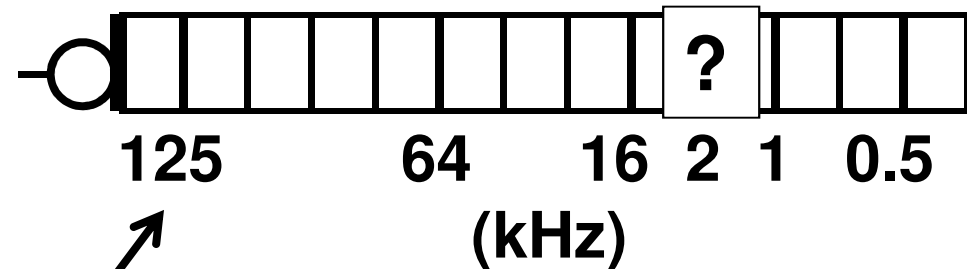


Hearing frequencies most affected by pile driving sound (i.e., highest TTS)

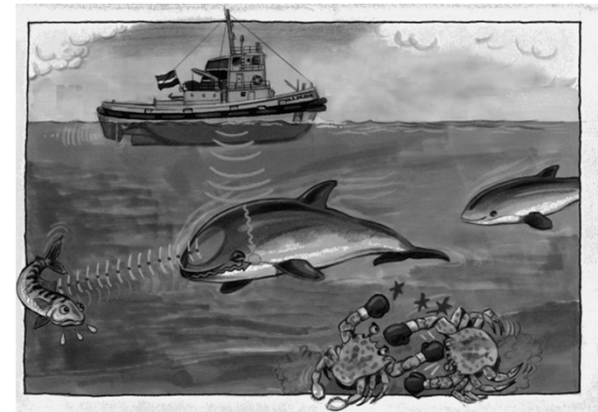


Pile driving

Filter bands in cochlea

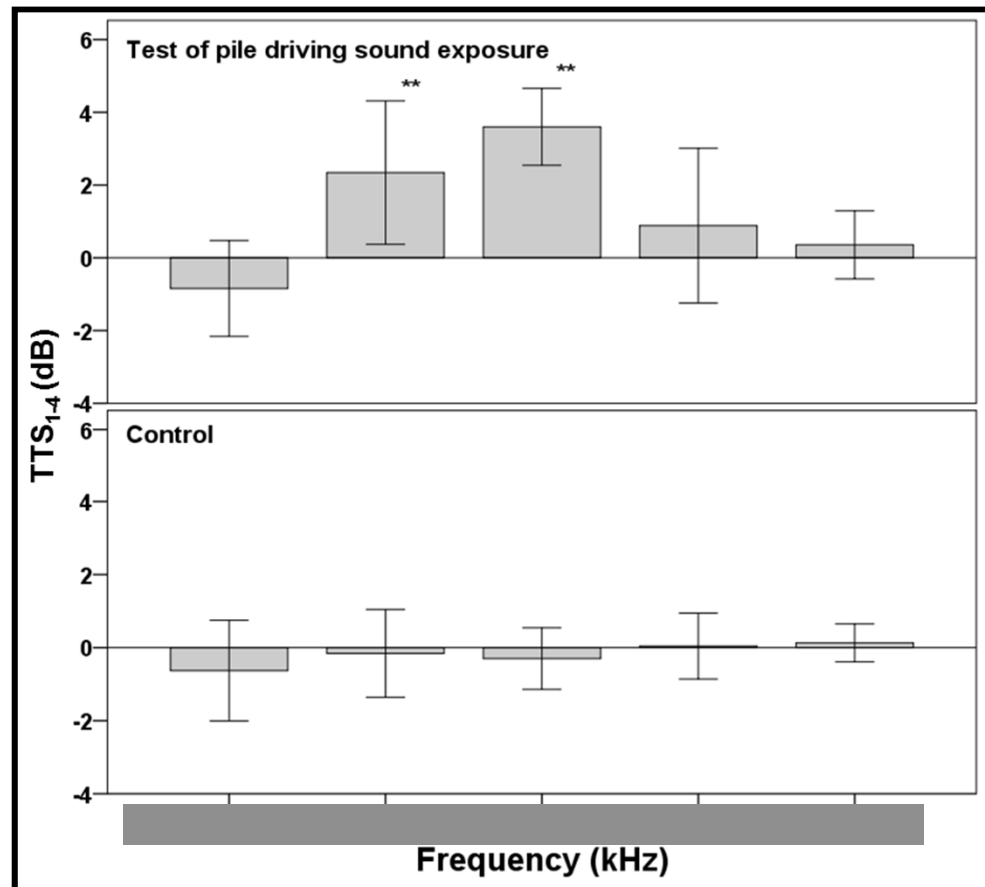


Porpoise echolocation



Results Part 1: affected hearing frequencies

- Data collection June-August 2013.
- 1 hour exposures to pile driving sounds.



- Report written and reviewed by peers.
- Quotation on request.
- No risk for funding agency (Budget & Results).

TTS in harbor porpoises due to pile driving sound

Part 2: TTS onset and growth (needed to extrapolate to estimate PTS)



a) Absolute TTS onset SPL

b) TTS growth due to exposure duration

c) TTS growth due to exposure SPL

Searching for funding.

Proposal available on request.

TTS in harbor seals due to pile driving sound

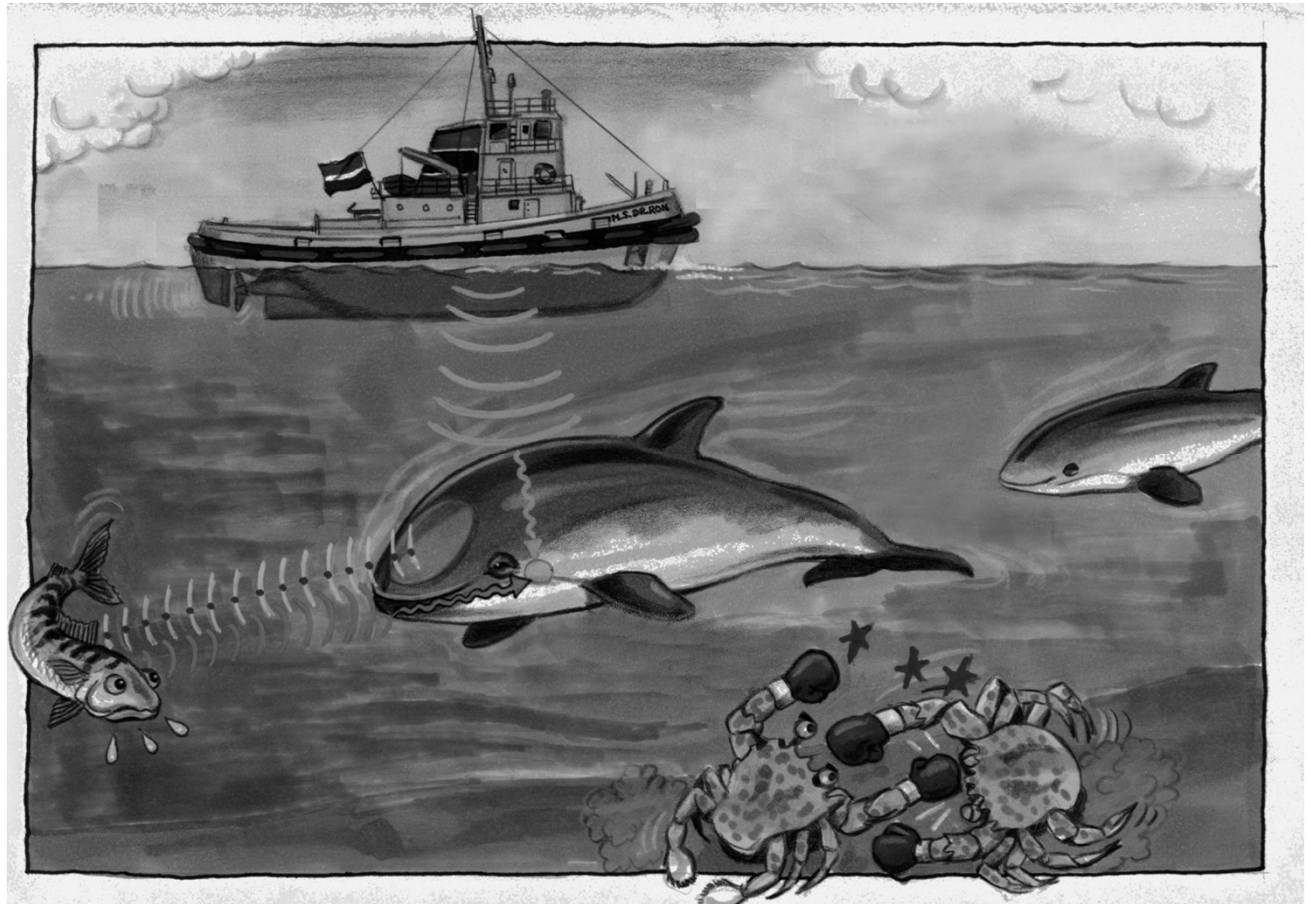
Part 1: affected hearing frequencies

- **Data collection June-December 2013.**
- **Maximum 3 hour exposures (less sens. than Hp).**
- **Searching for funding.**
- **Proposal on request.**



Ecological effects of TTS depend on:

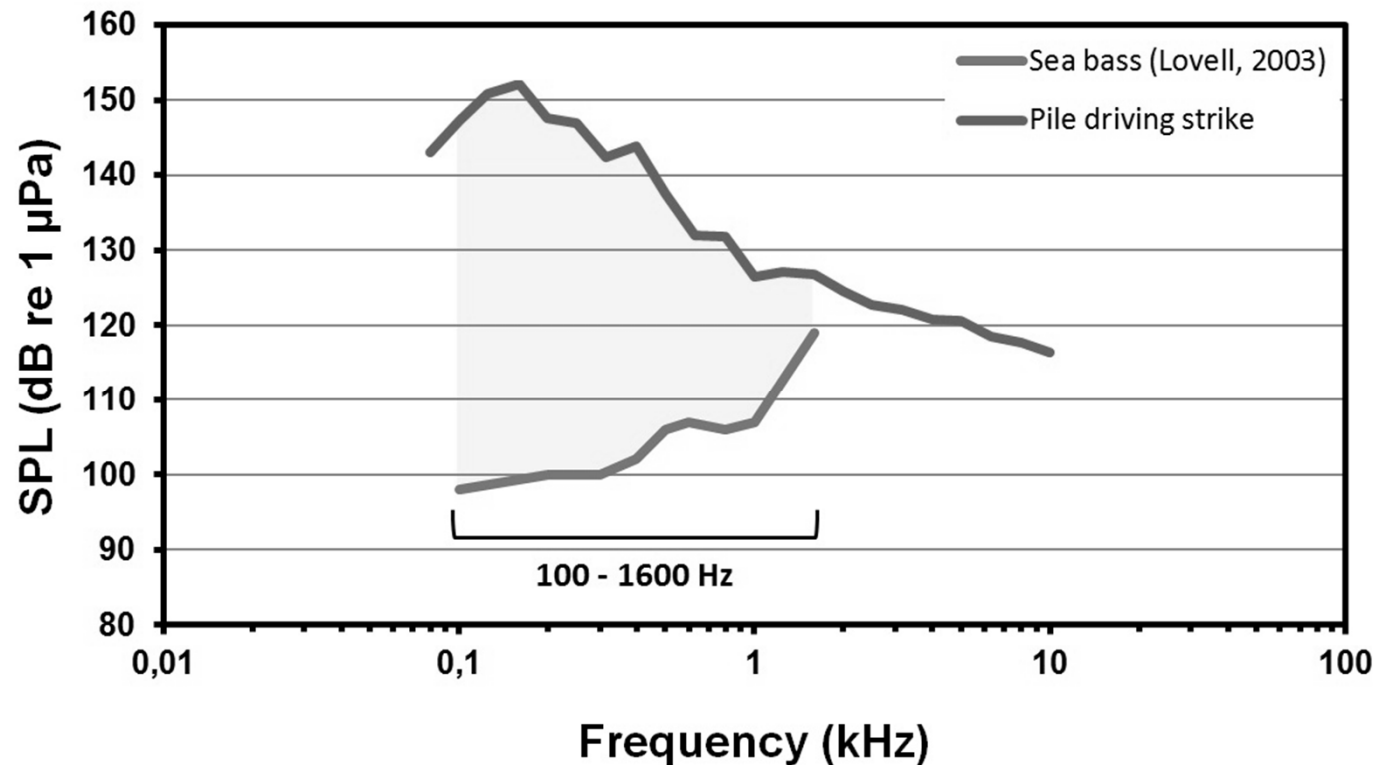
- TTS level (degree of reduction of hearing)
- TTS duration (during exposure)
- Recovery rate of hearing (after exposure)
- Importance of affected hearing frequency for a species



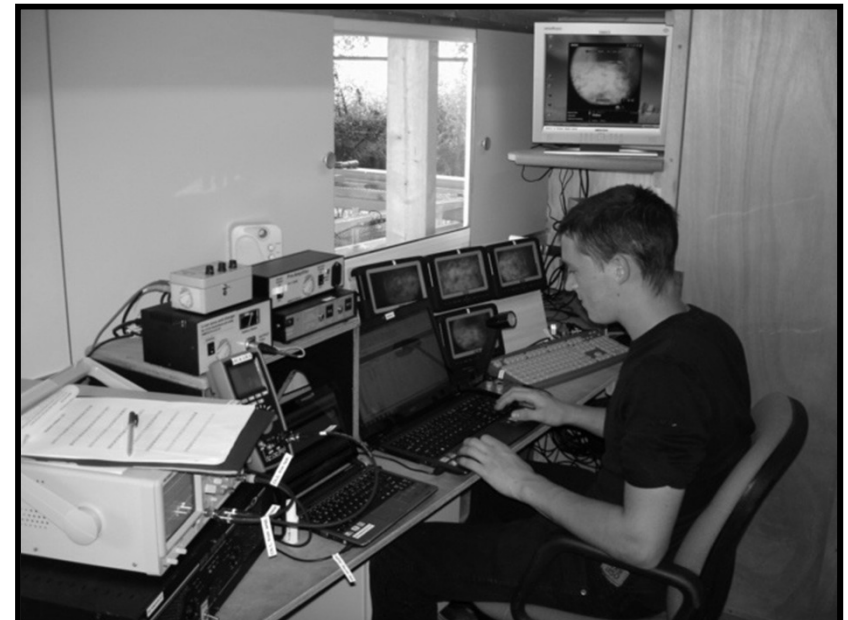
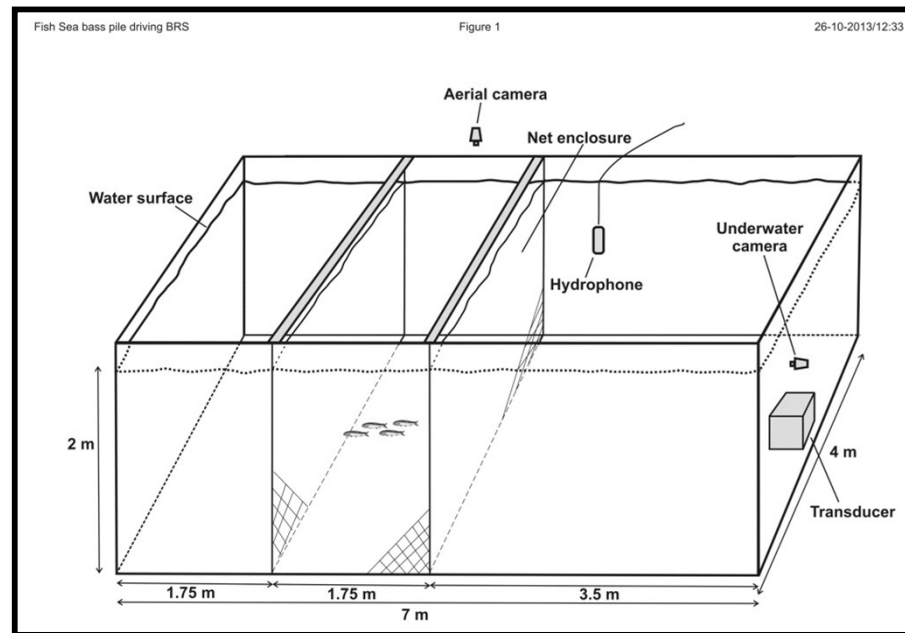
Effect pile driving sound on sea bass behavior

(Dose-response relationship)

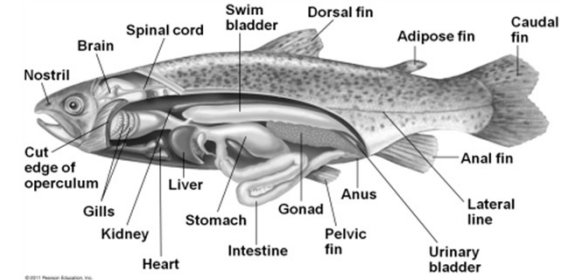
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Fish research: pool and equipment



Materials & Methods



- **Sea bass of 25 and 35 cm length.**
- **Schools of 4 sea bass per fish size.**
- **7 exposure levels (dose-response).**
- **A session consists of: 20 min pre-exposure.
20 min exposure.
20 min post-exposure.**

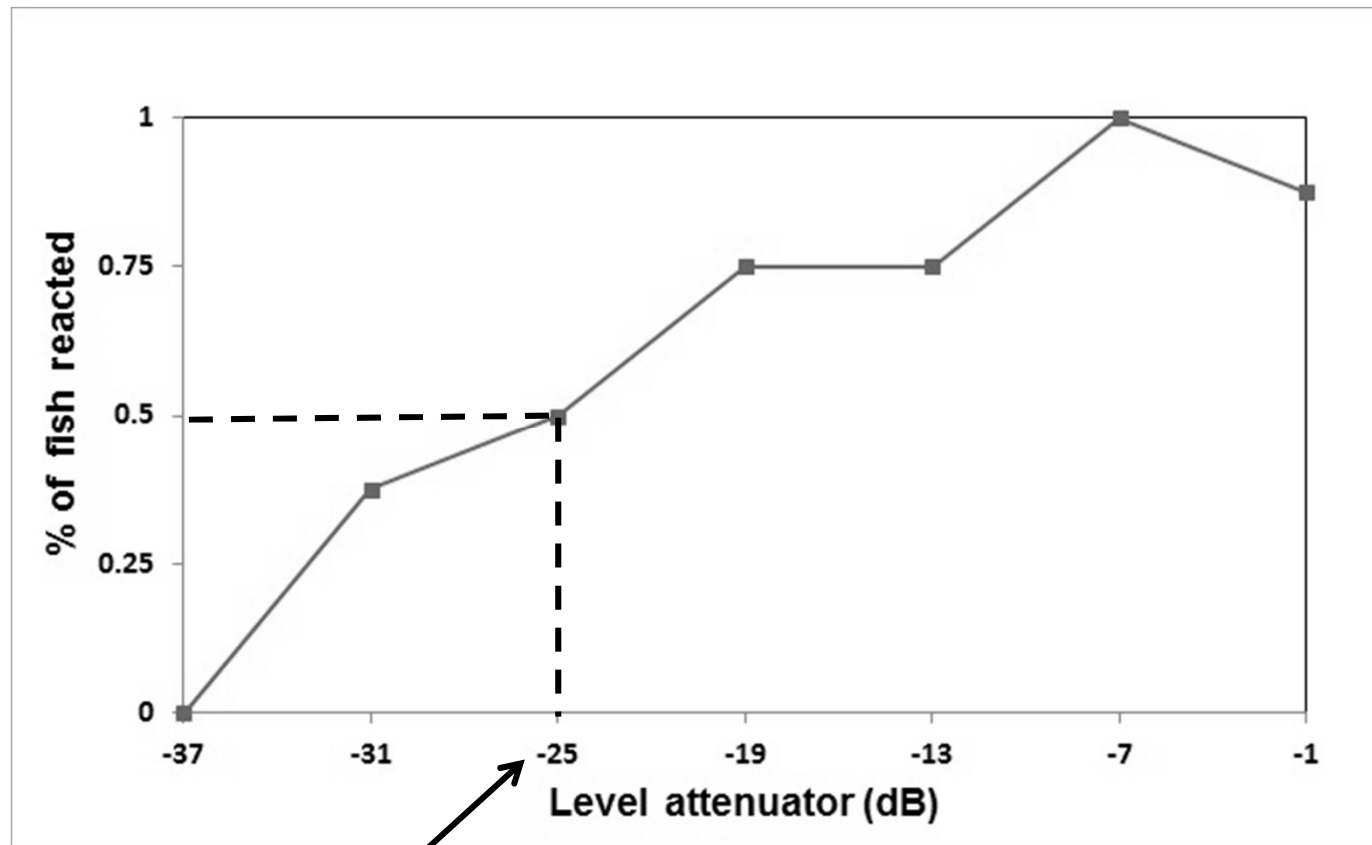


Example of a session (highest level)



Preliminary results (startle)

(1 school of four 25-cm fish)



Criterion level that can be used by regulators to calculate the area around a pile driving site in which the behavior of sea bass will be influenced.

Status sea bass pile driving project



- **Tests with 25-cm sea bass completed (5 months).**
- **Expected duration 35-cm sea bass: 5 months.**
- **Video analysis**
- **Quotation available.**
- **Funding for 2013 or 2014.**

Results of this study allow governments to evaluate the impact of pile driving on marine fish with swim bladders.



Research to reduce environmental impact of human activities at sea



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