

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



**Ron Kastelein**  
**SEAMARCO**



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

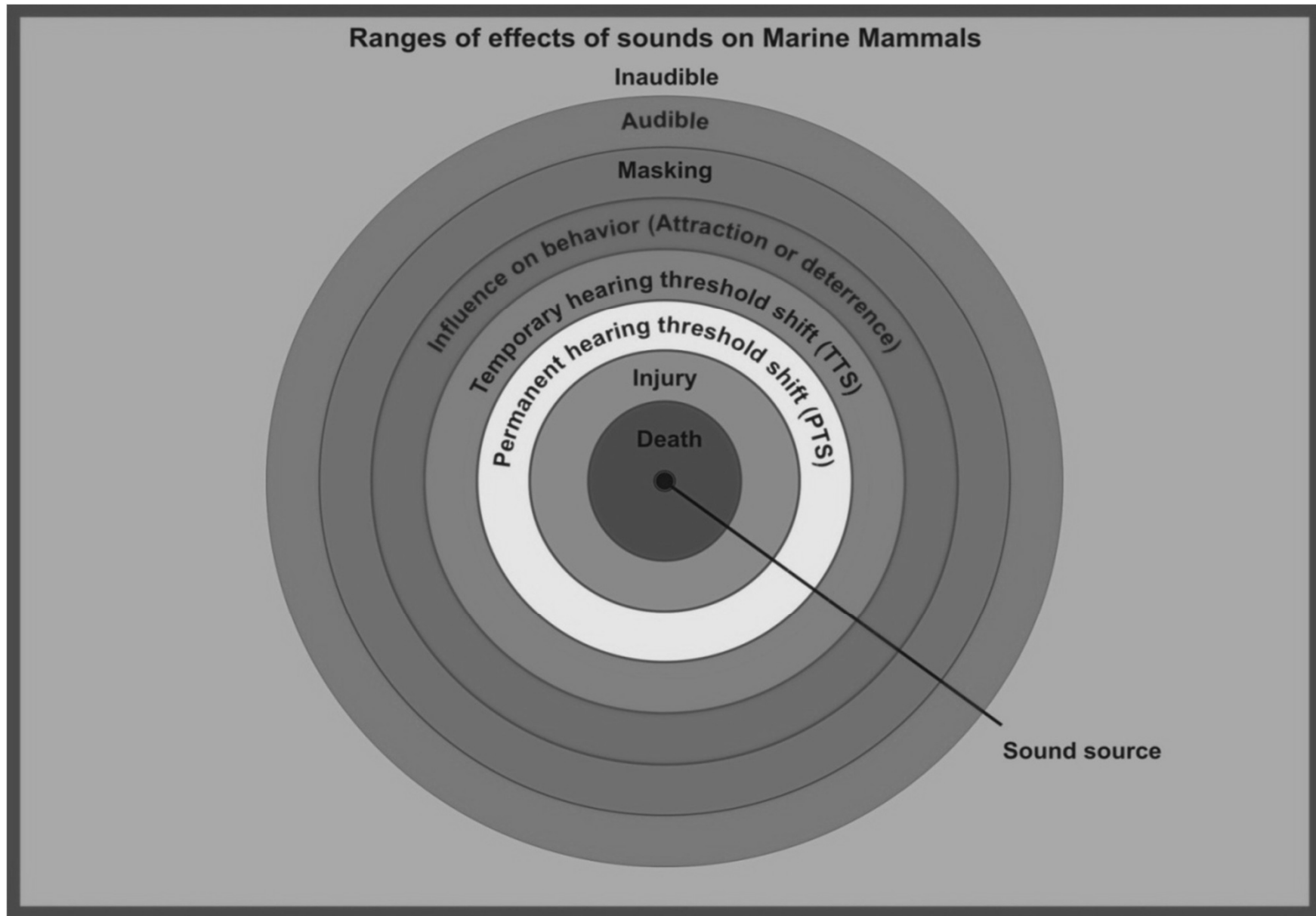
## **Marine animals use sound for:**



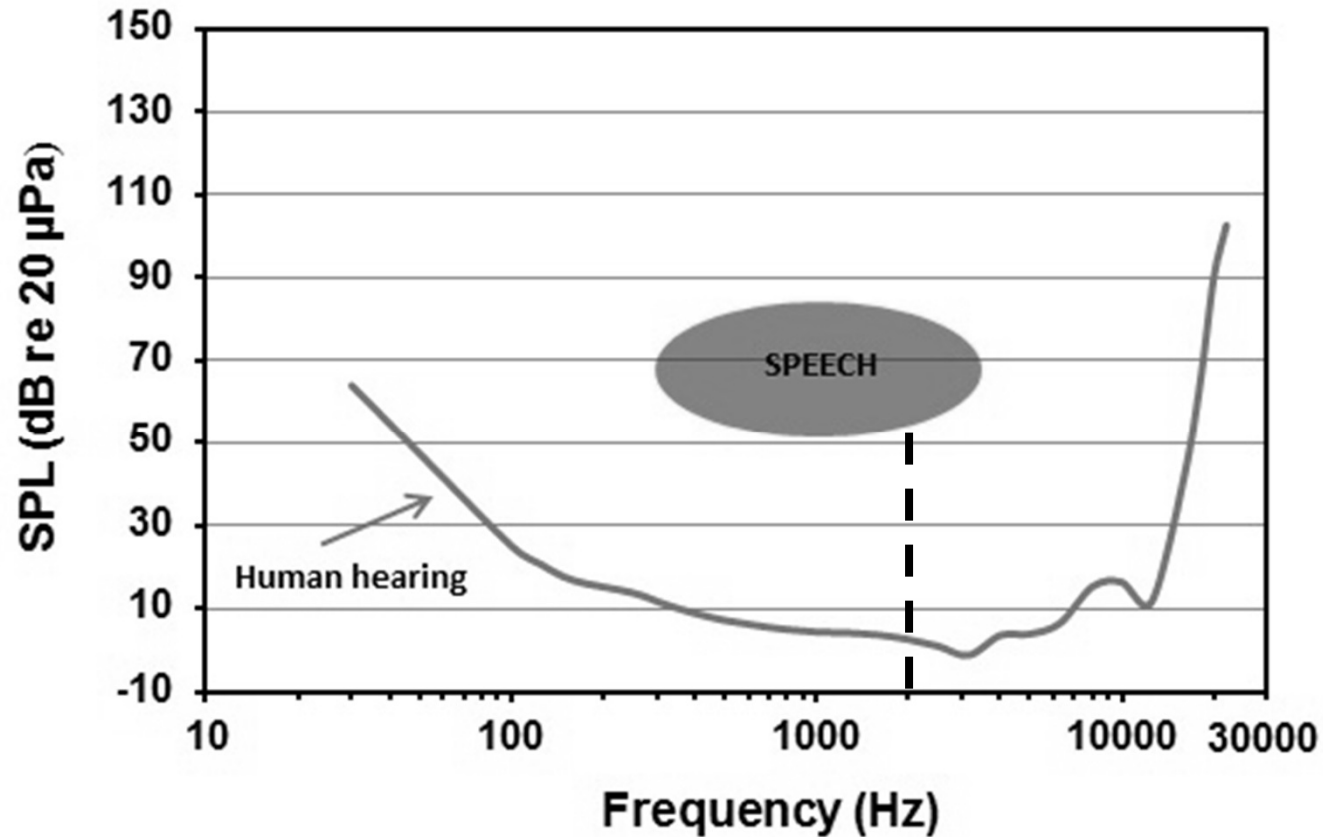
- **Communication (find partner)**
- **Navigation (just listening or echolocation)**
- **Food finding (just listening or echolocation)**
- **Avoiding predators**


**Anthropogenic underwater noise may reduce the efficiency of these activities**

# Potential effects of sound



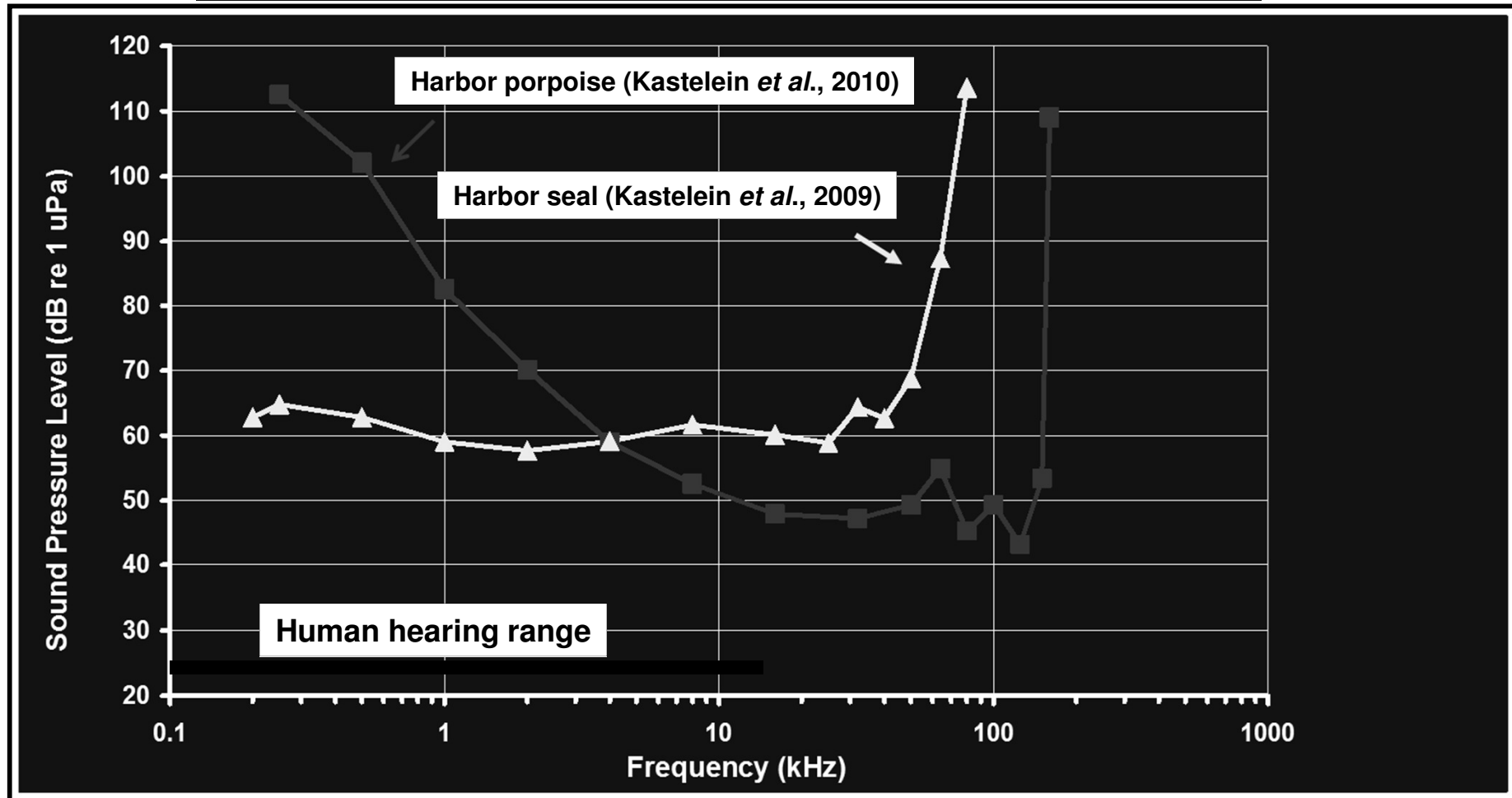
# Hearing thresholds for pile driving sounds



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

 2 kHz

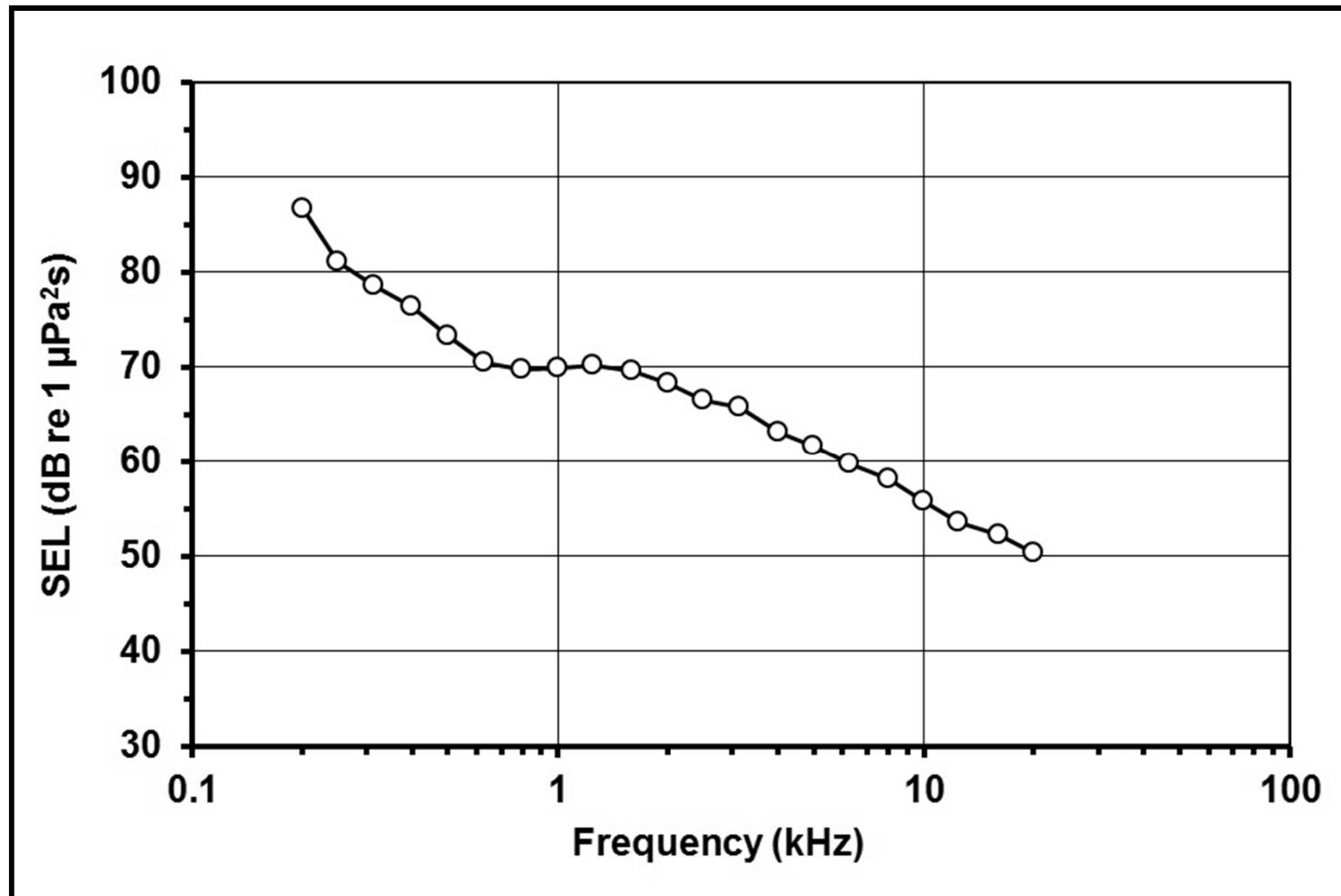
# Underwater audiograms for tones



**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 audiogram

# Harbor seal & harbor porpoise: pile driving detection

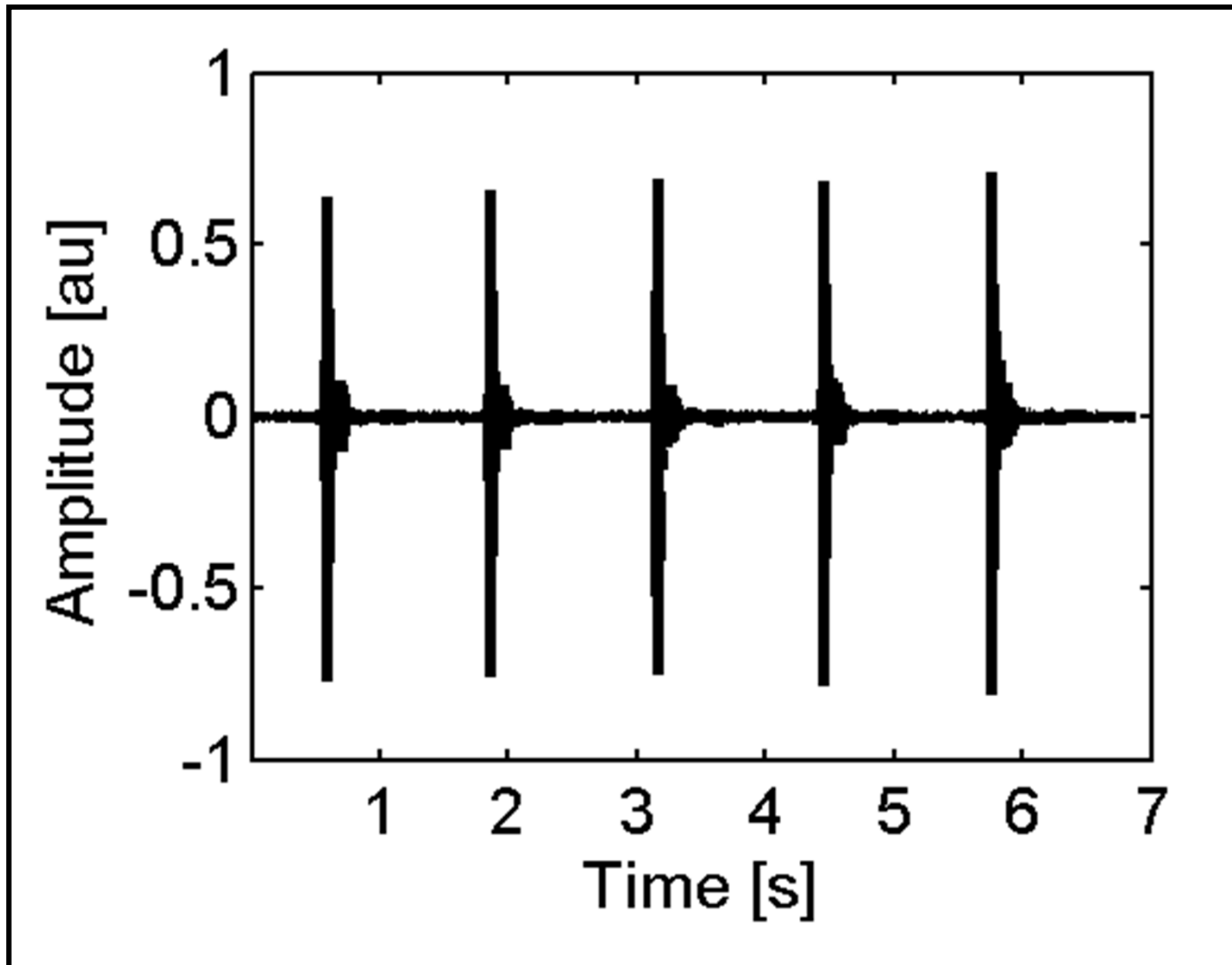


## Goals hearing studies:

- 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).

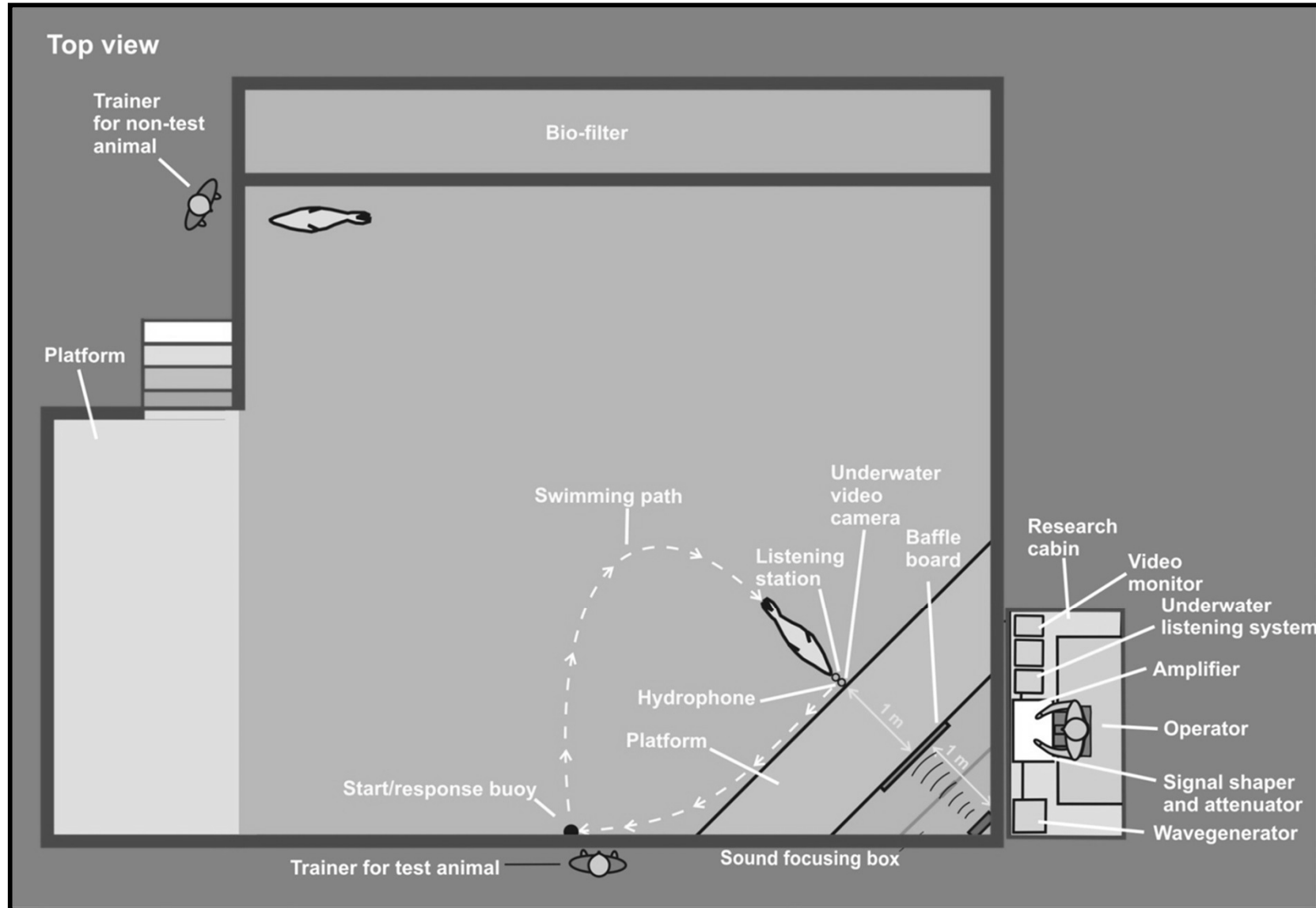
Input data for the Soriant tool to estimate effects of anthropogenic underwater sounds on marine fauna (developed by TNO)

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

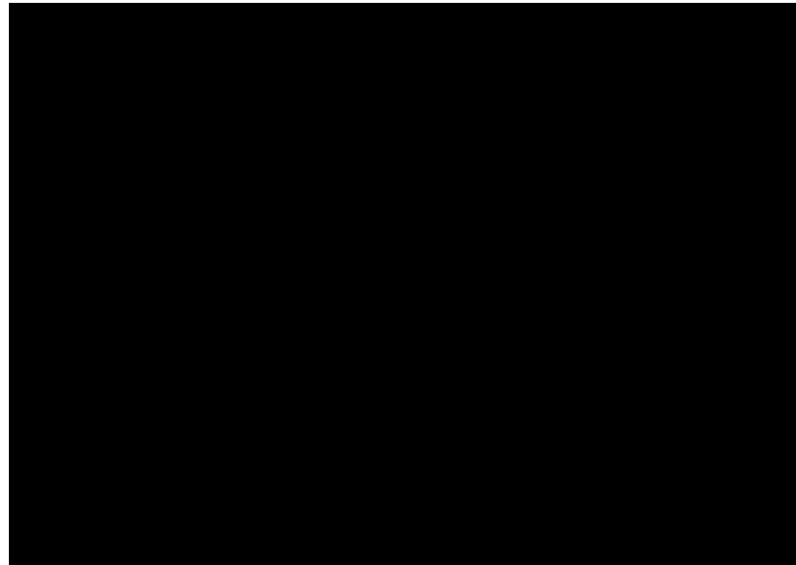




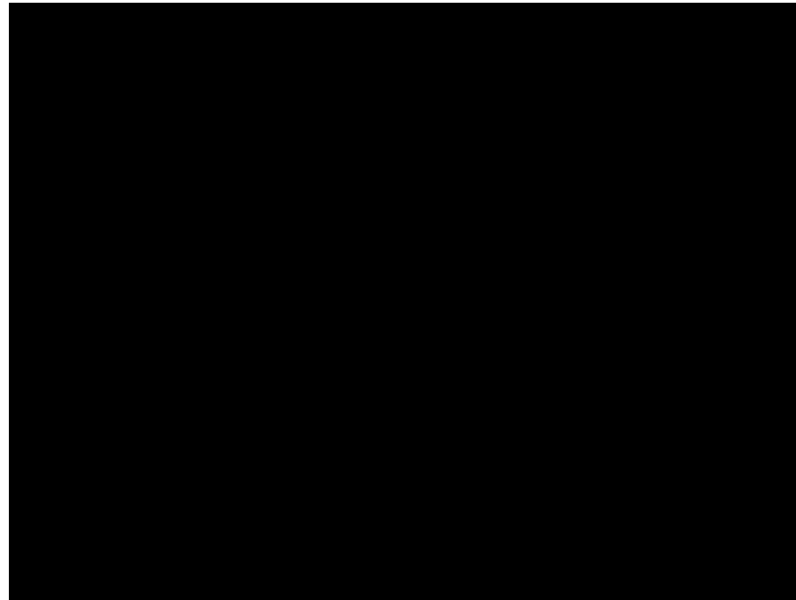
# Hearing thresholds h. seals for pile driving sounds



# Hearing study with harbor seals

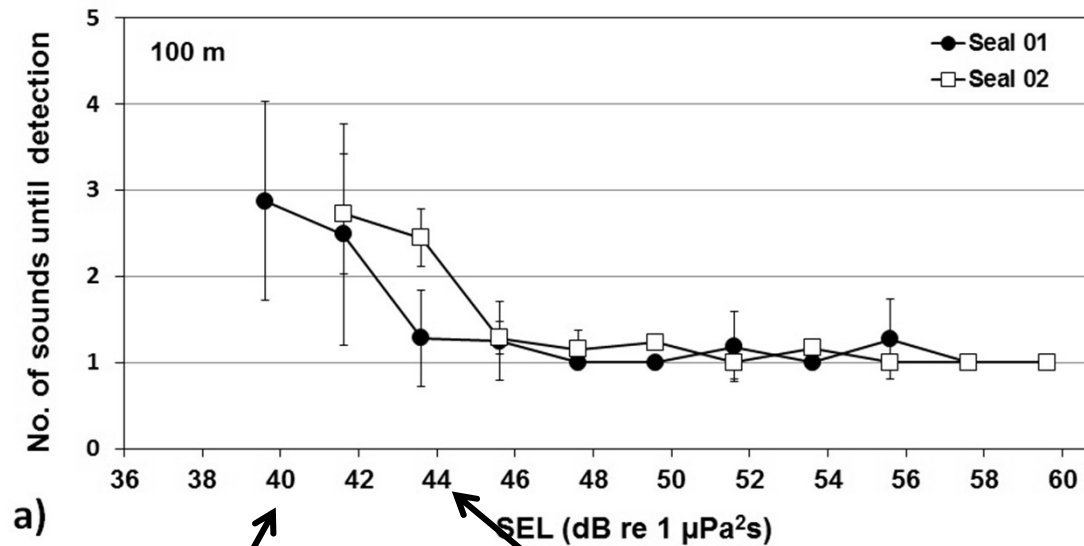


**Heard at  
first strike**



**Heard at  
4th strike**

# Results harbor seals

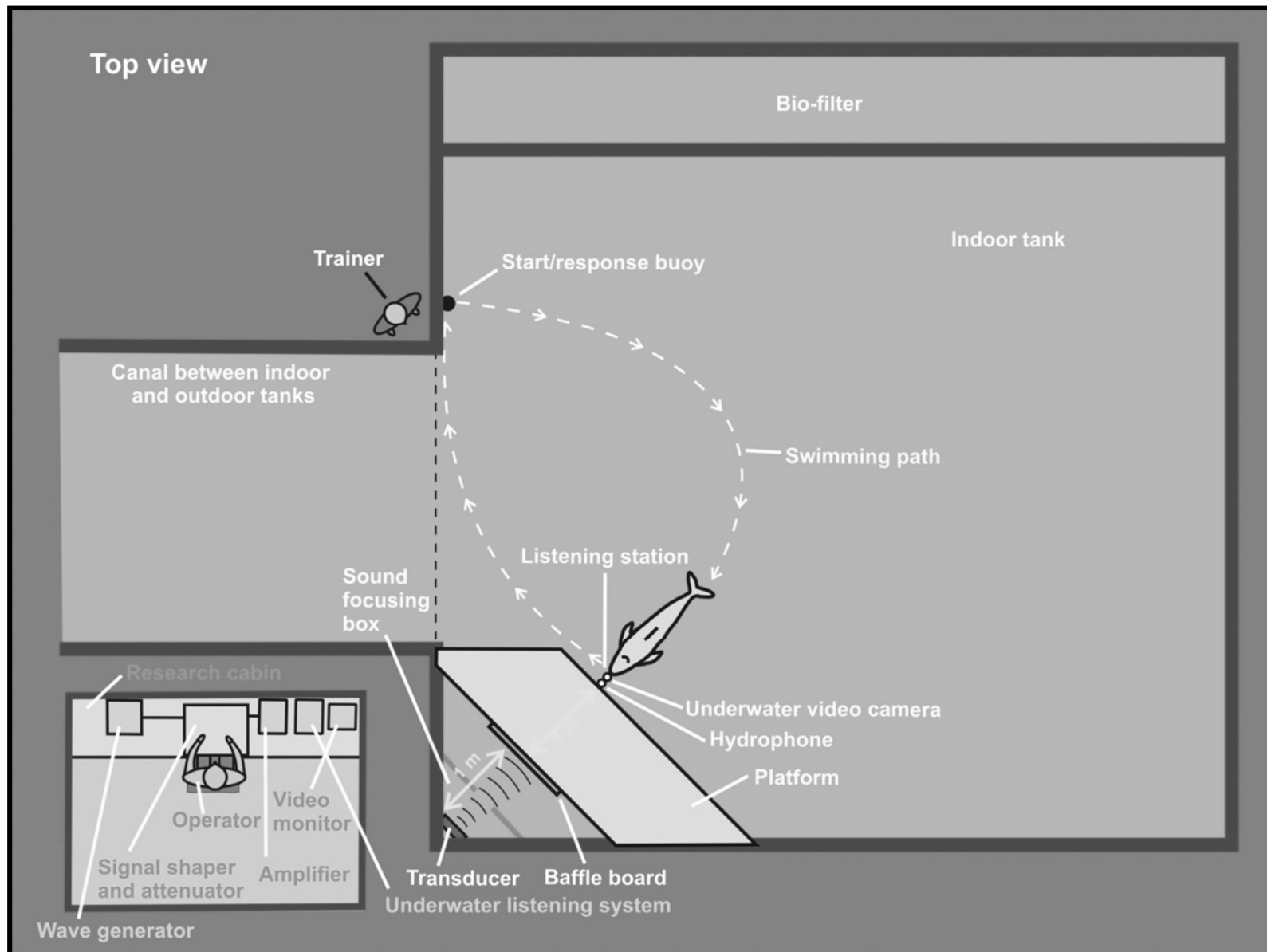


**Seal 01:**  
**50% det. thr. SEL any strike:**  
**40 dB re 1  $\mu\text{Pa}^2\text{s}$**

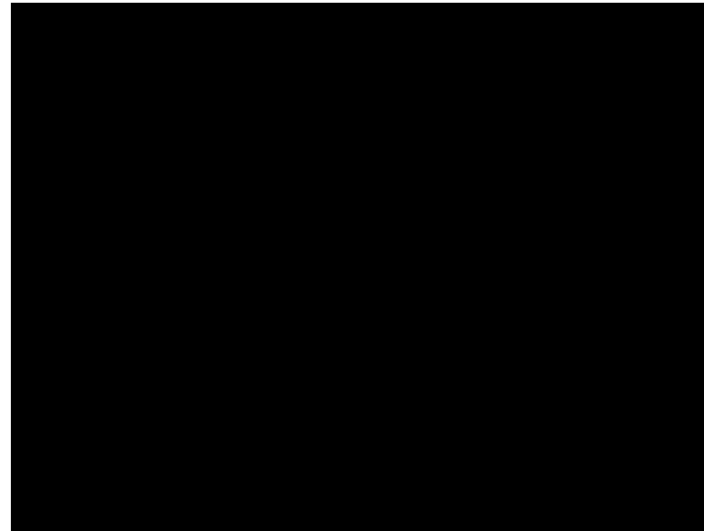
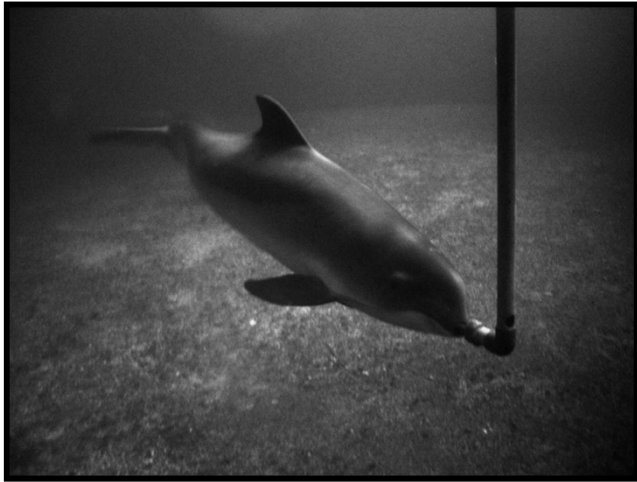
**Seal 01:**  
**50% det. thr. SEL first strike:**  
**44 dB re 1  $\mu\text{Pa}^2\text{s}$**

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>.

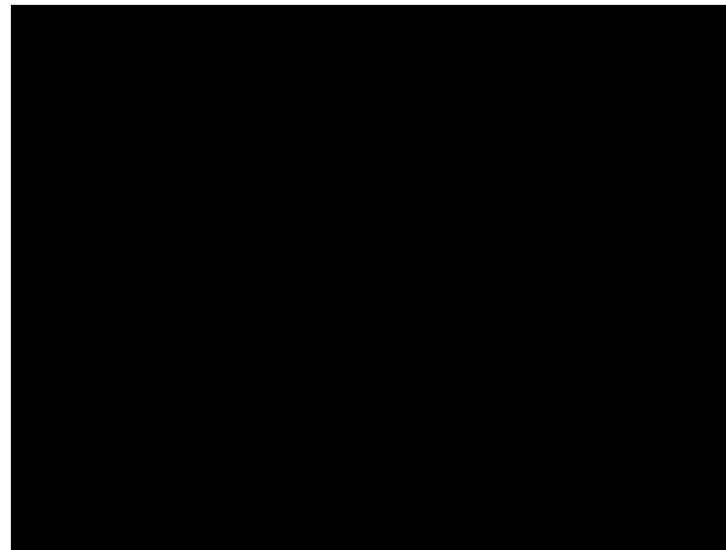
# Hearing thresholds h. porpoise for pile driving sounds



# Hearing study with harbor porpoise

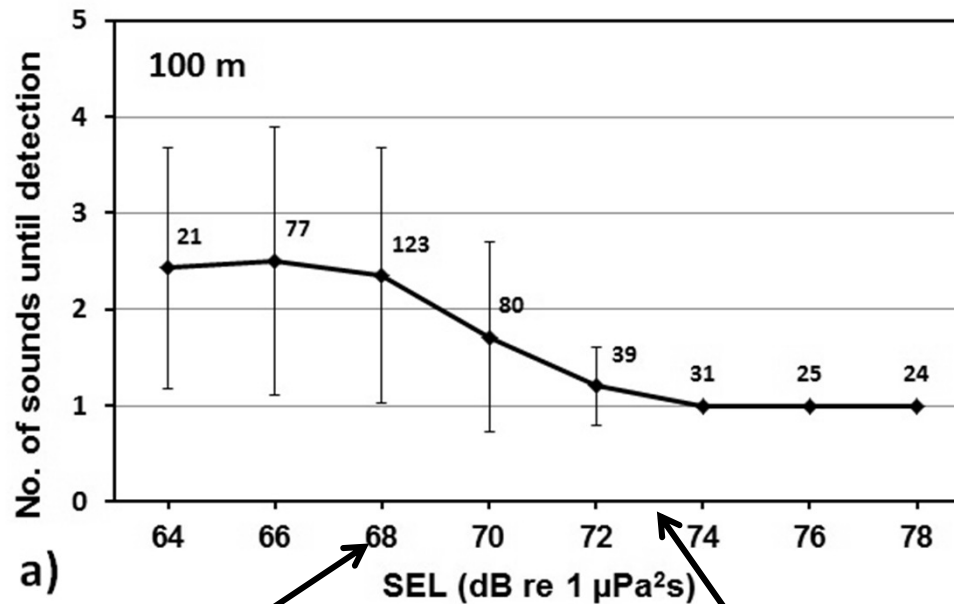


**Heard at  
first strike**



**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**

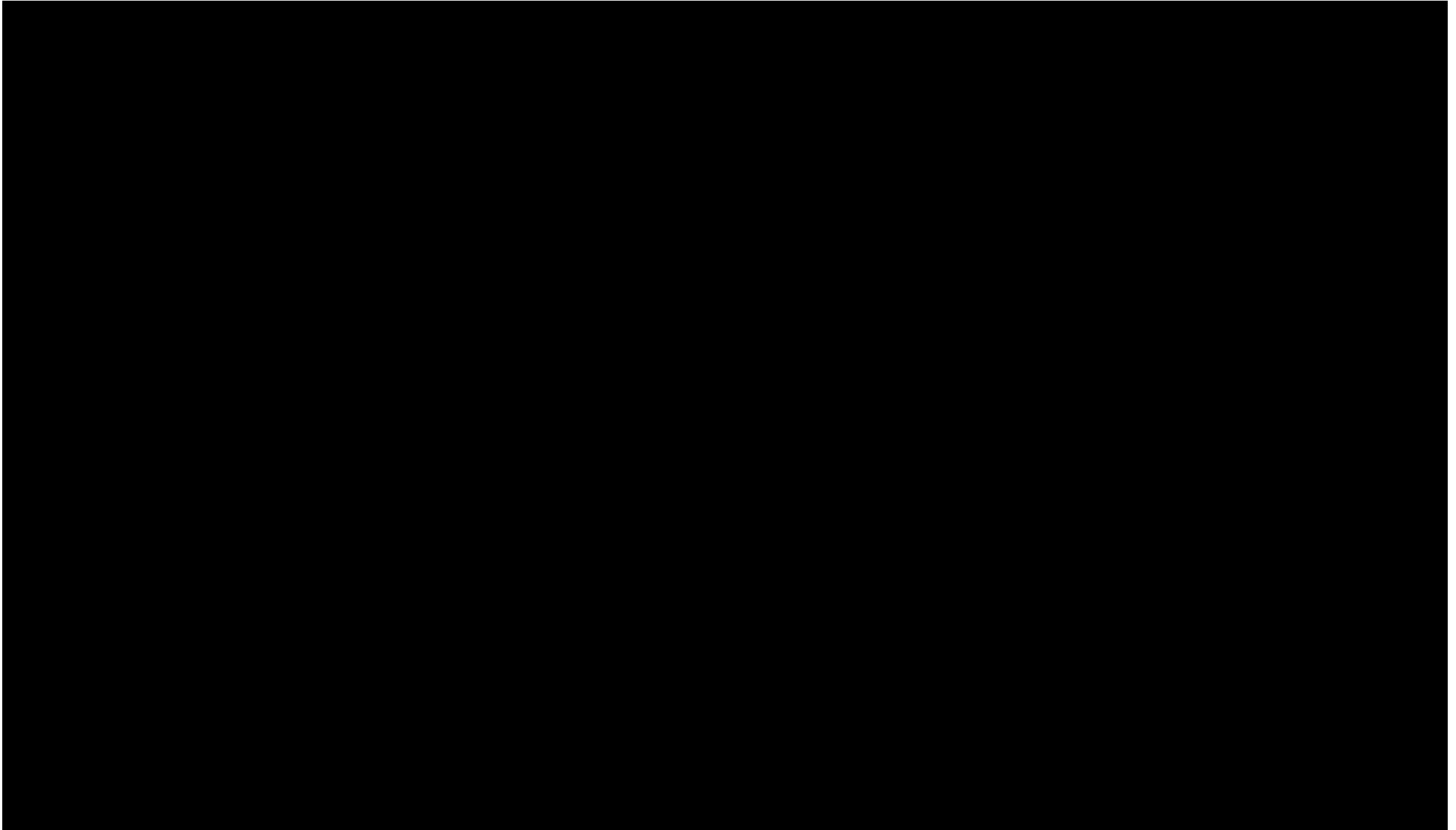
**Contact: Martine Graafland, RWS Zee en Delta.**



## **Behavioral response to pile driving sound**

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

**Example behavior during baseline period**

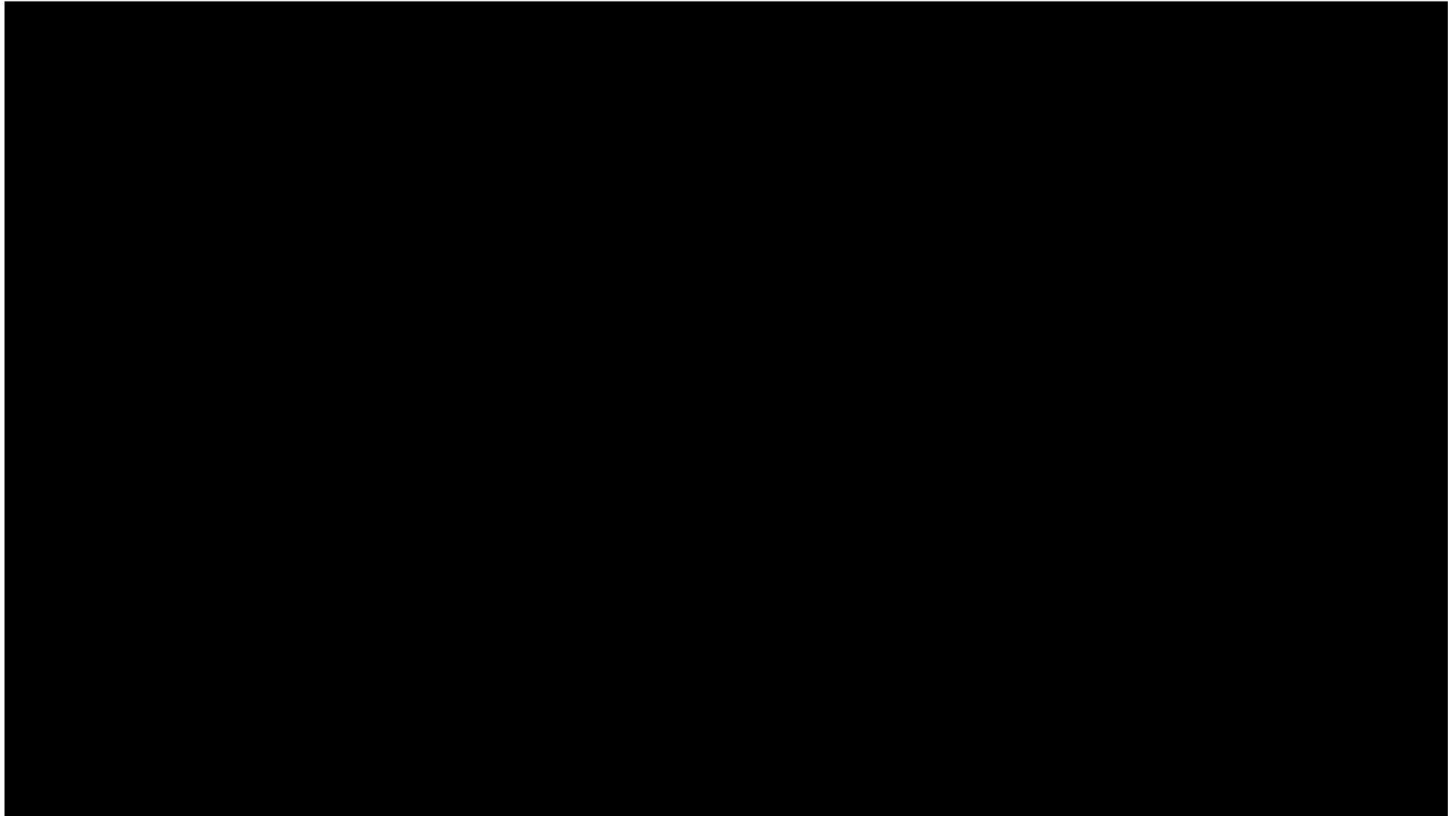




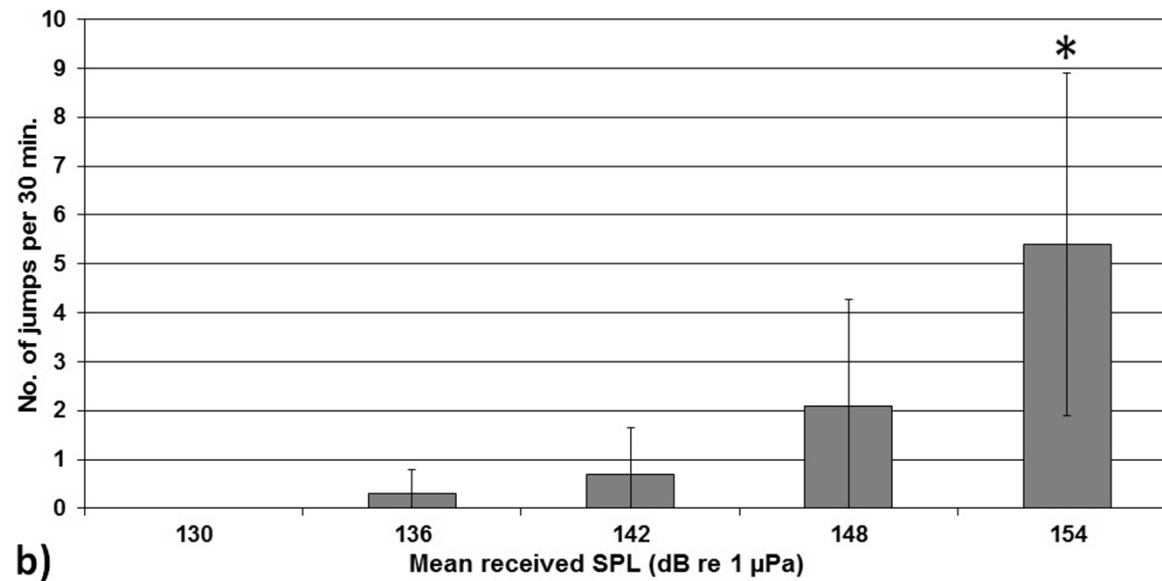
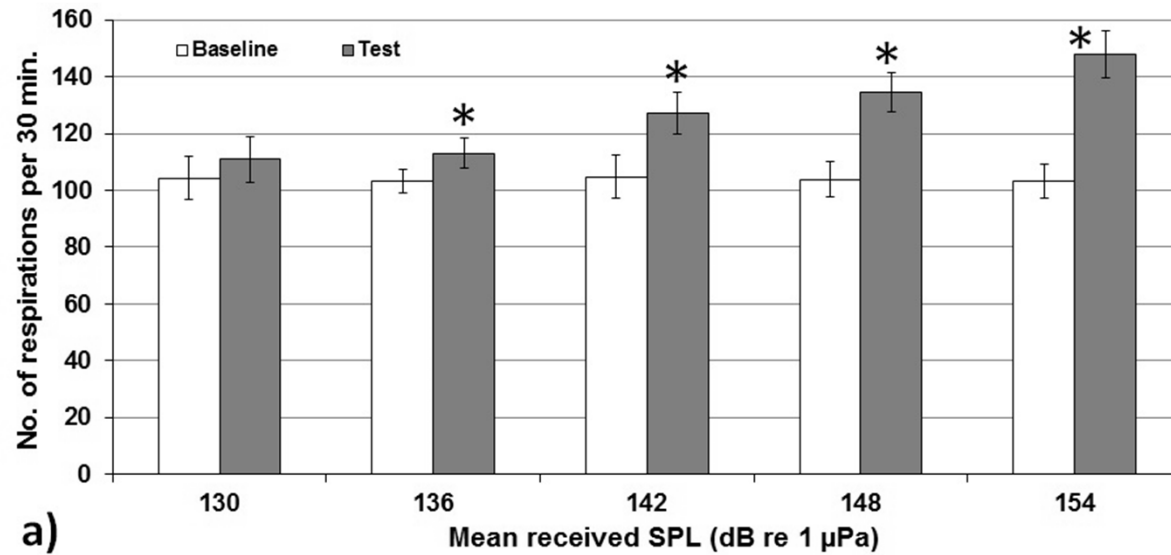


## **Behavioral response to pile driving sound**

**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

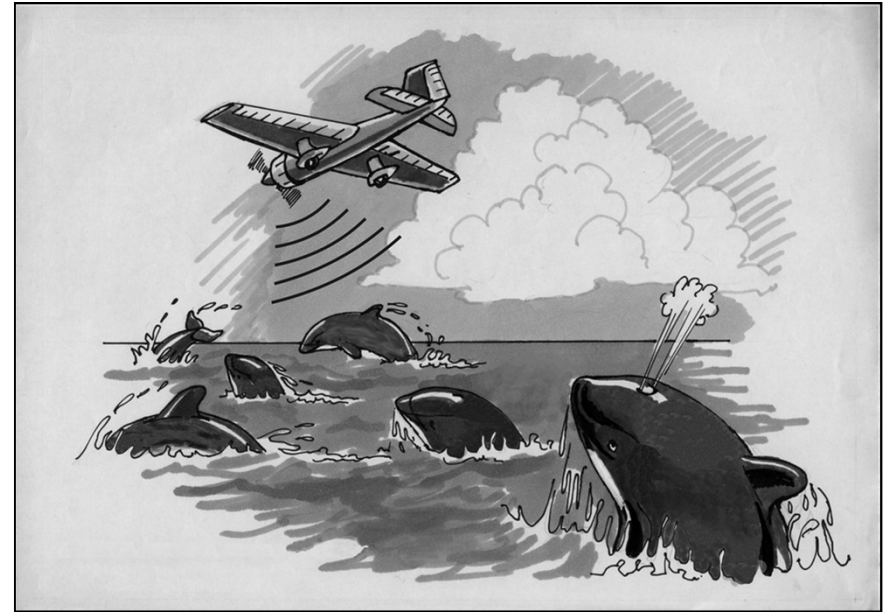


# Potential effects of u/w sounds

## 1) Effects on behavior

a) Use of space

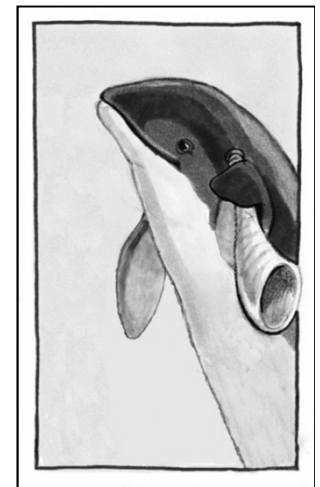
b) Activity level



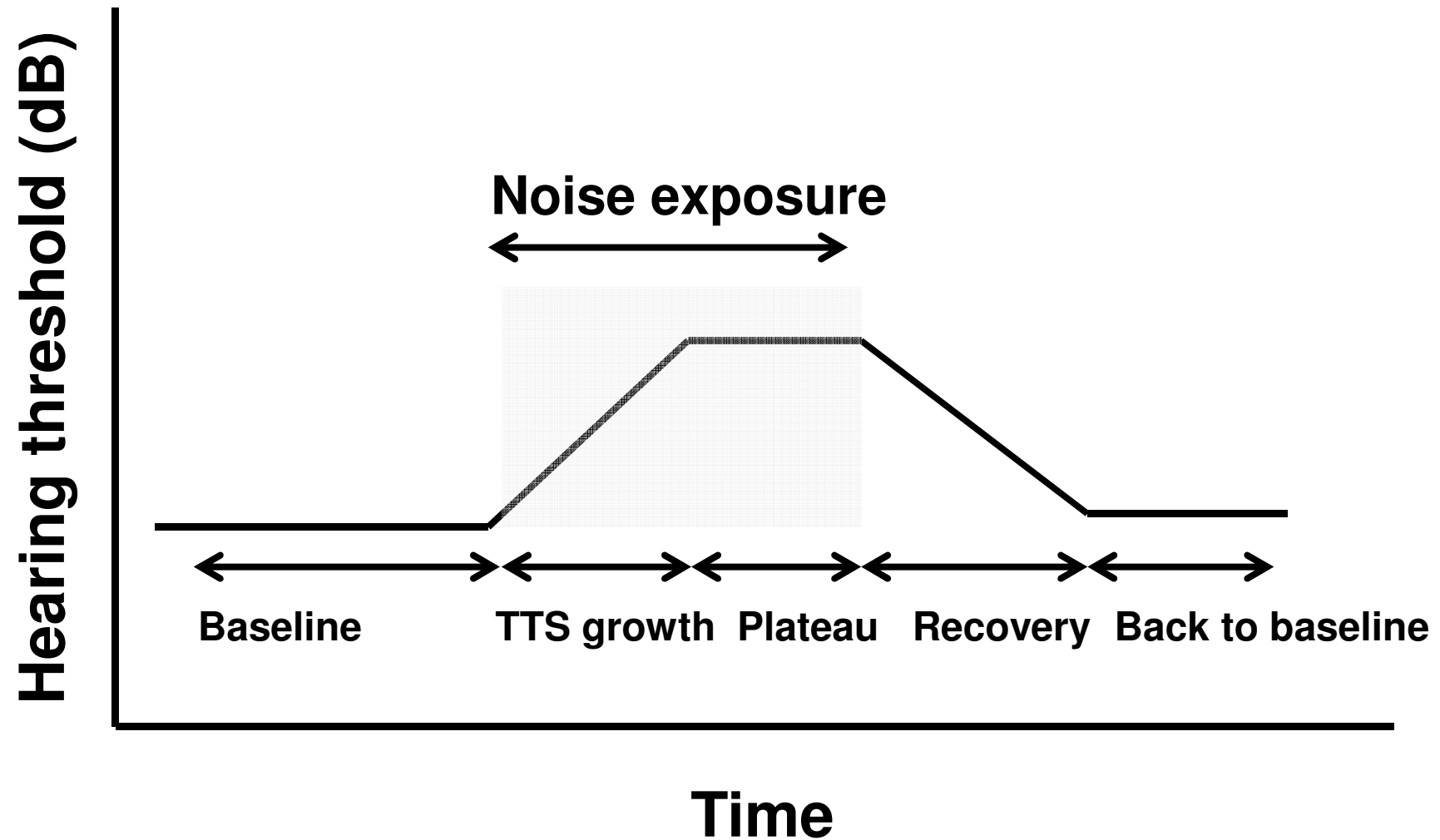
## 2) Effect on hearing

a) Masking (Listening and echolocation)

b) Effects on hearing sensitivity (TTS & PTS)



# Temporary hearing Threshold Shift (TTS)

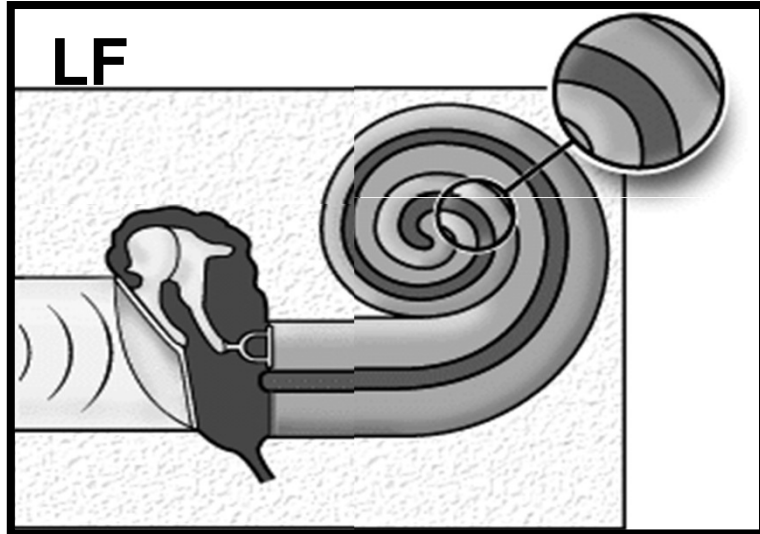


# TTS in harbor porpoises due to pile driving sound

## Part 1: affected hearing frequencies

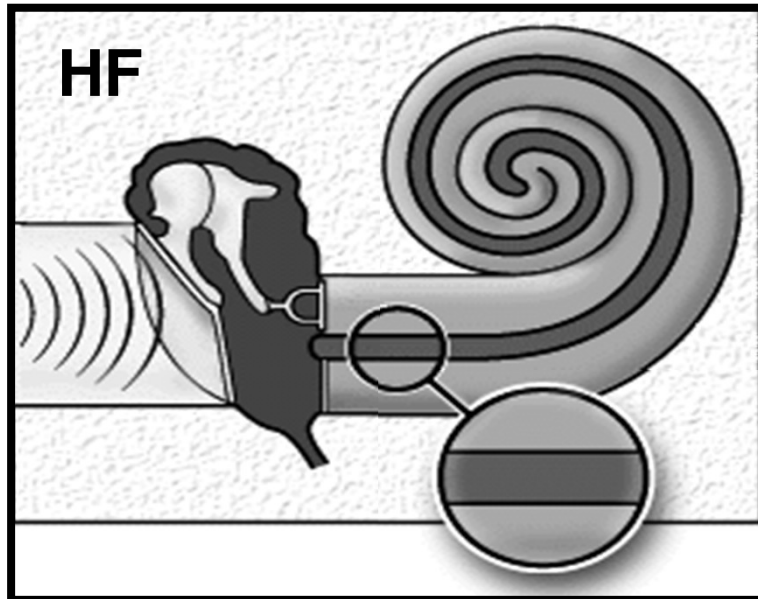
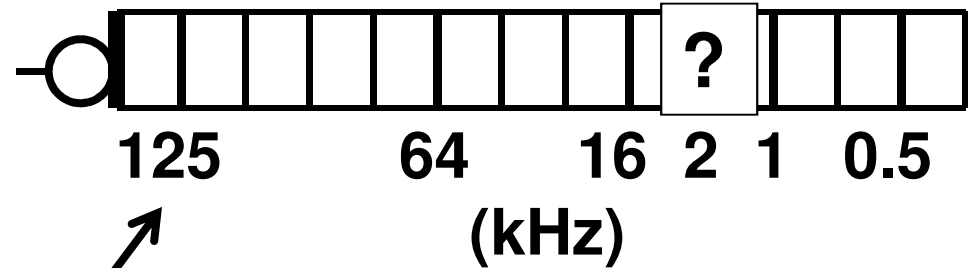


# Hearing frequencies most affected by pile driving sound (i.e., highest TTS)

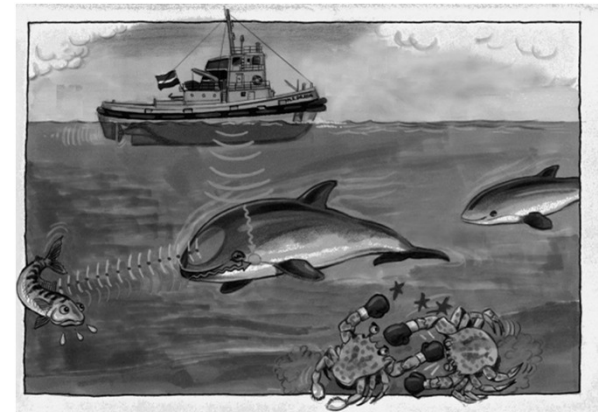


Pile driving

Filter bands in cochlea



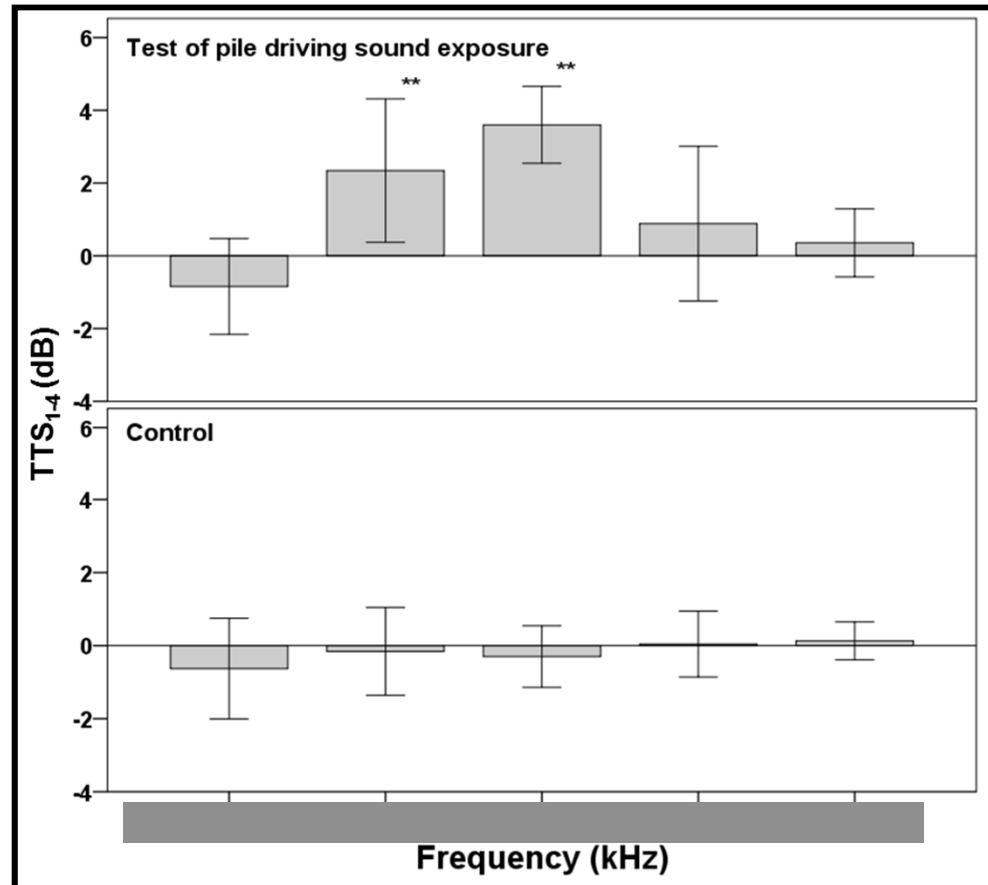
Porpoise echolocation





# 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**

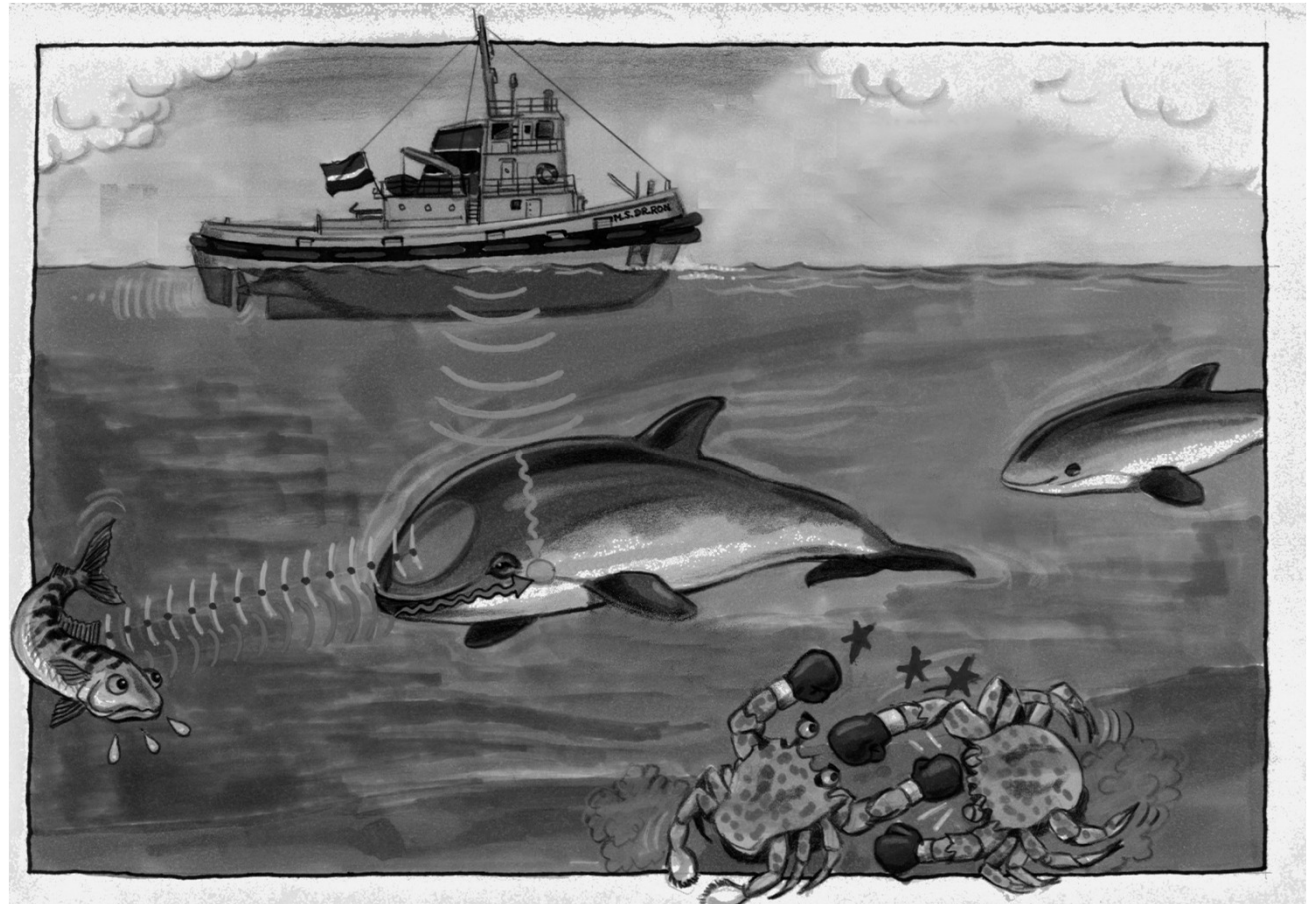
## **Part 1: affected hearing frequencies**

- **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:

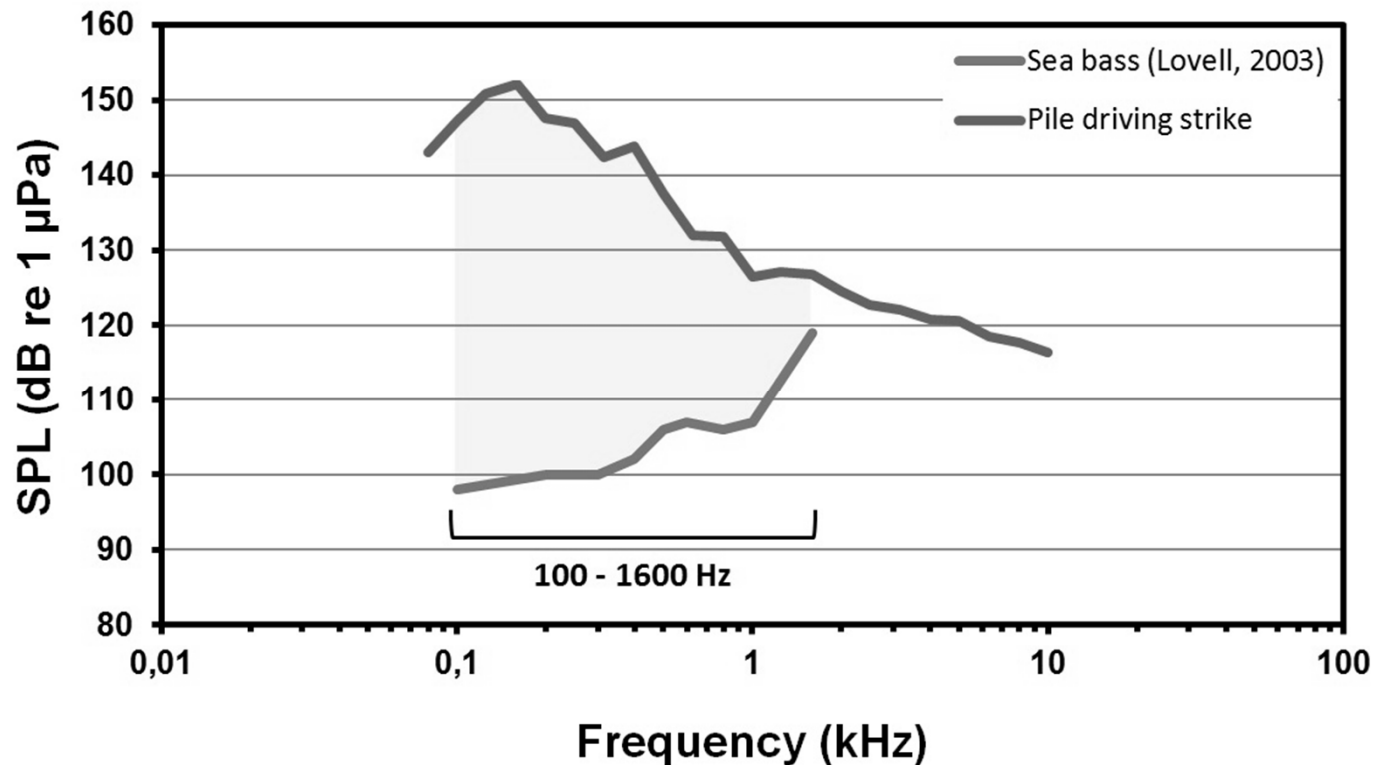
- TTS level (degree of reduction of hearing)
- TTS duration (during exposure)
- Recovery rate of hearing (after exposure)
- Importance of affected hearing frequency for a species



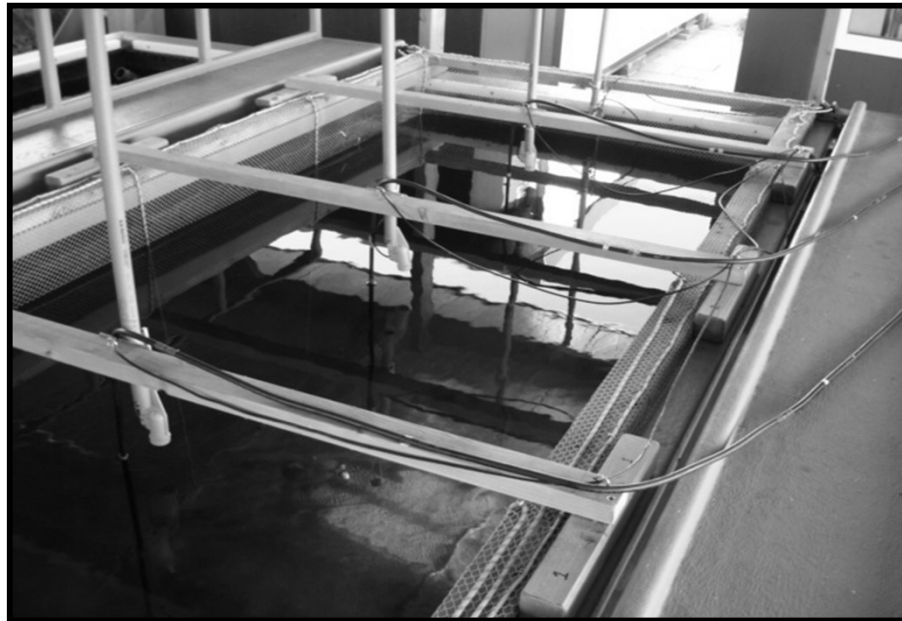
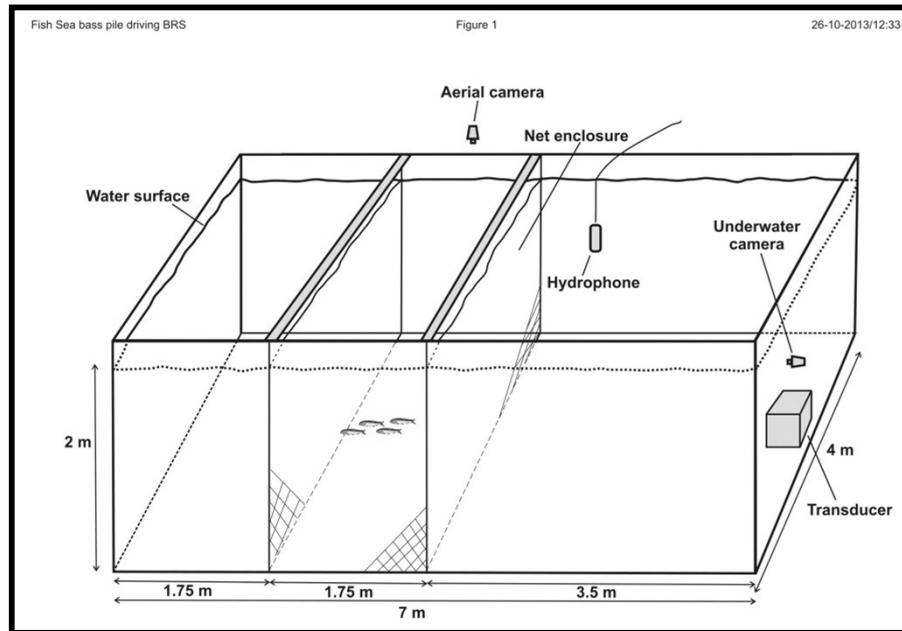
# Effect pile driving sound on sea bass behavior

(Dose-response relationship)

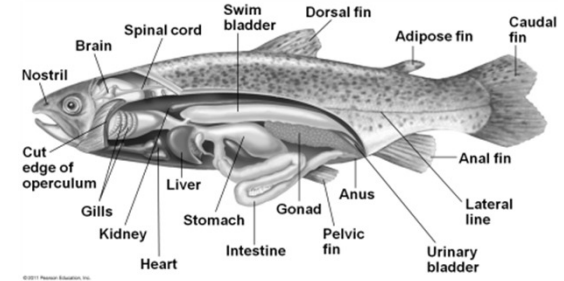
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SEAMARCO



# 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.**



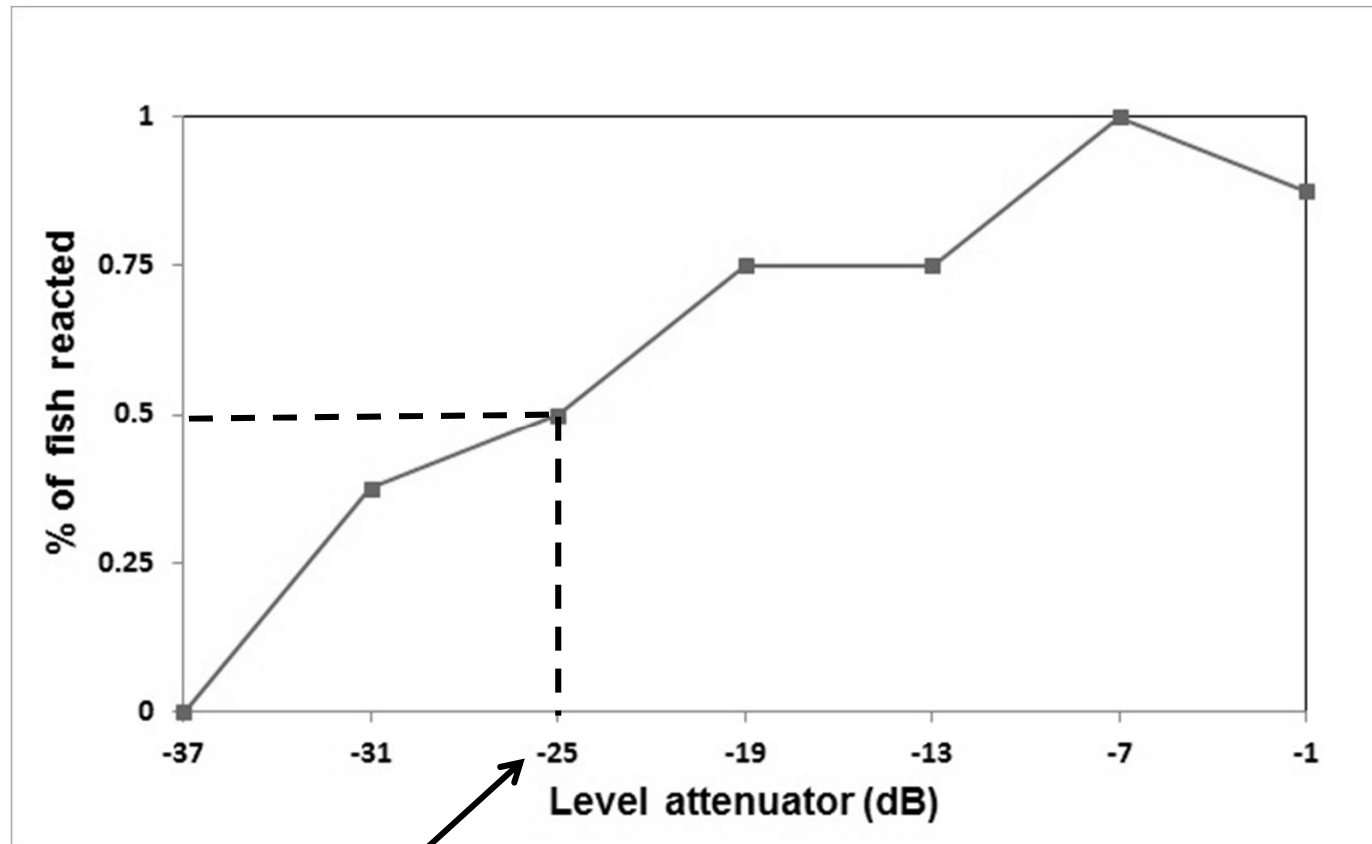
# Example of a session (highest level)





# 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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