Acoustic dose-behavioral response studies with harbor porpoises in pools and a floating pen

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SEAMARCO

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"Behavioral response studies"
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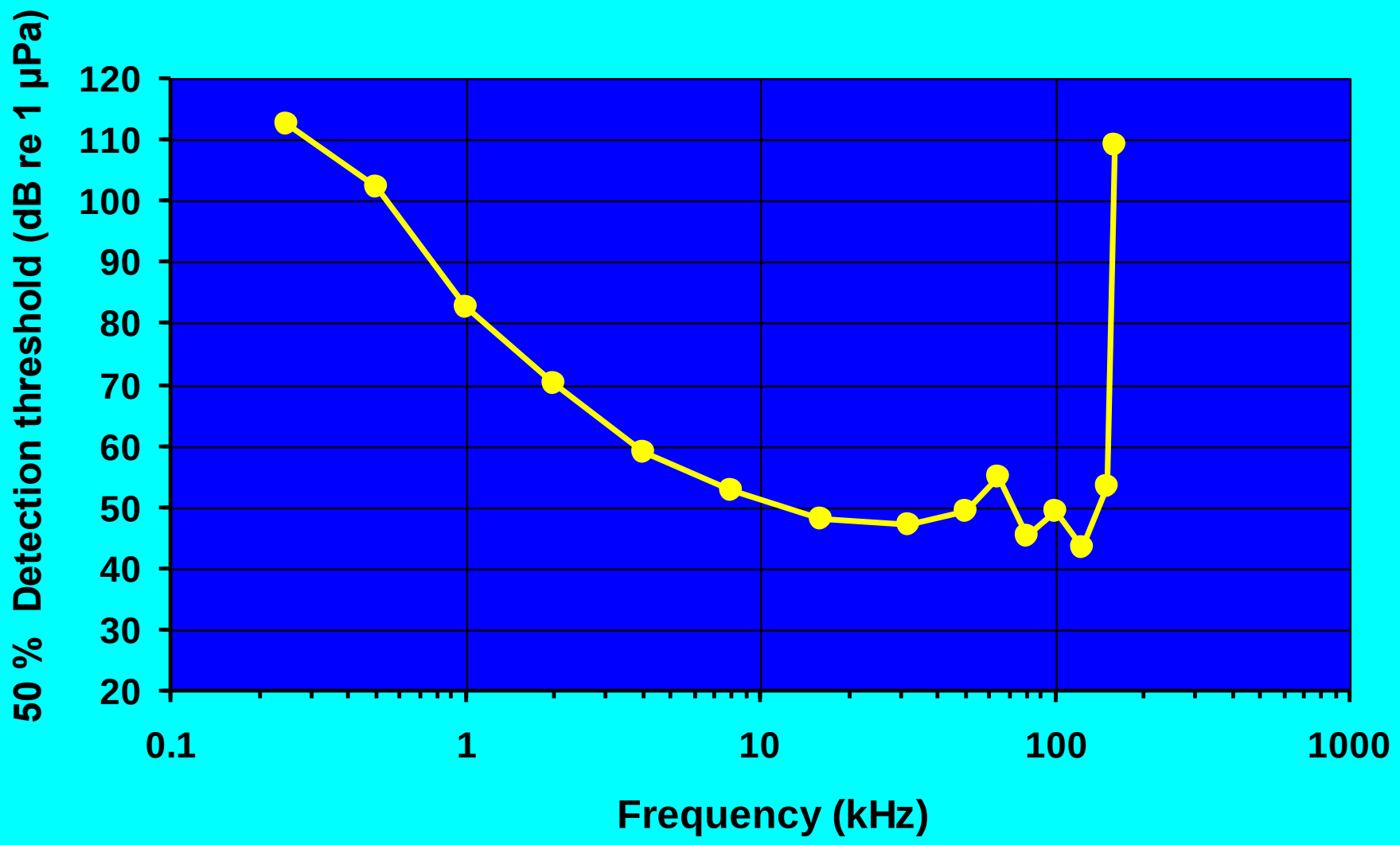
One of the most abundant marine mammal in the North Sea is the harbor porpoise (*Phocoena phocoena*)

Distribution area of the harbor porpoise

Results useful for regulators of many governments

Hp audiogram (hearing threshold curve)



Acute hearing over a very wide hearing range

Example of a clear behavioral effect

The name "harbor porpoise" was given because this toothed whale entered harbors

Vessels were driven by man and wind power

Industrial revolution: steam engines

Modern harbor of Rotterdam: no more porpoises

Anthropogenic activities producing underwater noise

Shipping

Dredging

Wind parks

Fisheries

Detonations

Seismic surveys

Oil & Gas

Pile driving

Sonars

What are the potential proxi effects of anthropogenic noises on marine fauna ?

- **Effects on hearing: TTS & PTS**
- **Effects on sound detection: Masking & Distraction**
- **Effects on behavior**

Why behavioral response studies (BRS) ?

Usually only a small number of animals is close enough near a high energy sound source to get a PTS.

However, a much larger number of animals respond behaviorally to high energy sound sources, as the behavioral threshold SPL is often lower than the SPL in PTS onset SEL_{cum}.

Sound source

↓

Propagation/background noise

↓

Location of the marine fauna

↓

Received S/N level and duration

↓

Hearing

↓

Behavior -physiology

↓

Population dynamics

Population Effects

PCAD & DEPONS models

Pool & floating pen studies

- Studies are relatively inexpensive & efficient
- High repetition of tests
- Especially good for comparing sound types.
- Behavioral response threshold SPLs in a well-defined context.
- In the wild there are a “million” contexts (impossible to test). Some may be close to those of the captive test conditions, many others will not.
- Both in the wild and in captivity, differences in response between individuals exist.

Behavioral response studies by SEAMARCO

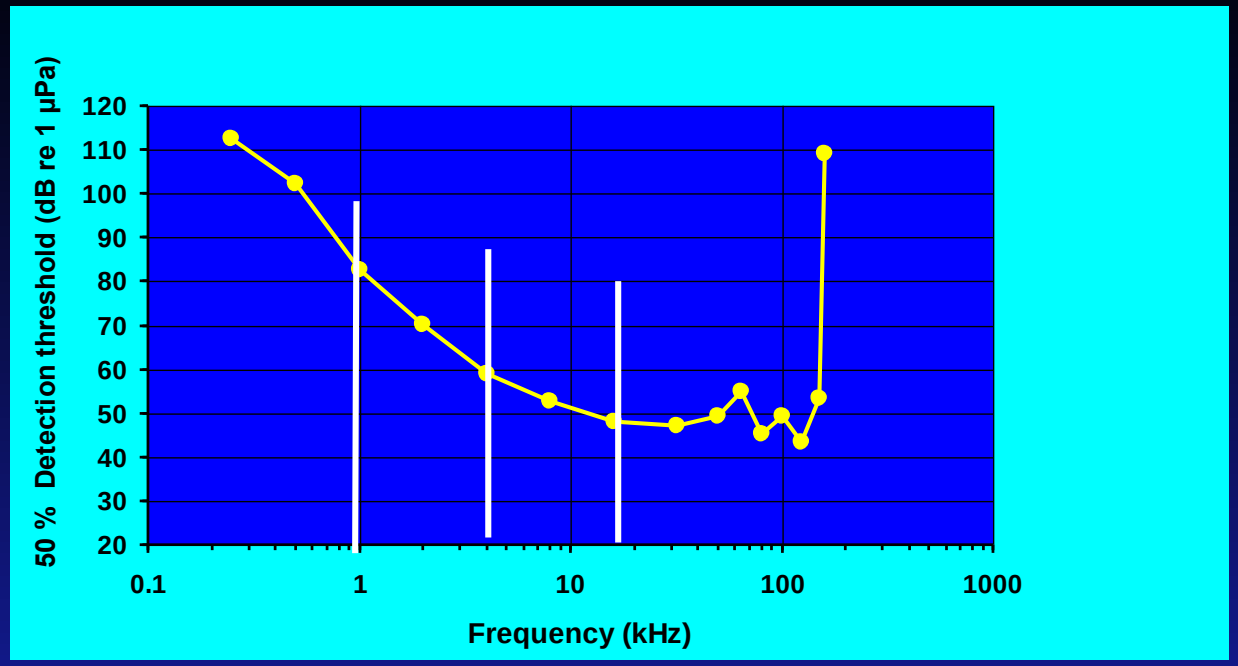
- Pingers to prevent accidental bycatch in fisheries
- Tonal signals (continuous, intermittent, ultrasonic)
- Acoustic mitigation (harassment) devices

- Data transmission signals (ACME; 12 kHz)
- Naval sonar signals (1-2 kHz, 6-7 kHz, 1.4 kHz)
- Offshore pile driving sounds (broadband,impulsive)

Determine optimal signal parameters of acoustic alarms to deter porpoises

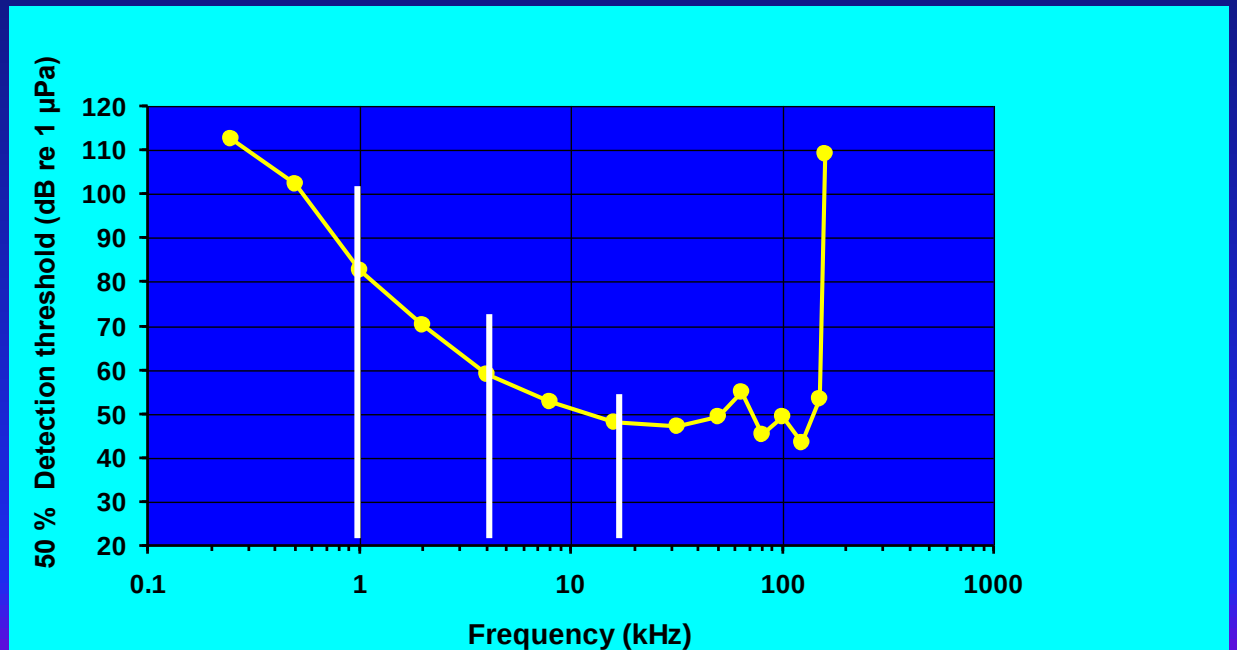
1994
Small pool
Lien (home-made) baleen whale pingers.
Small differences in sound signals (presence of harmonics) can elicit large behavioral differences.

Effect harmonics on audibility and perception



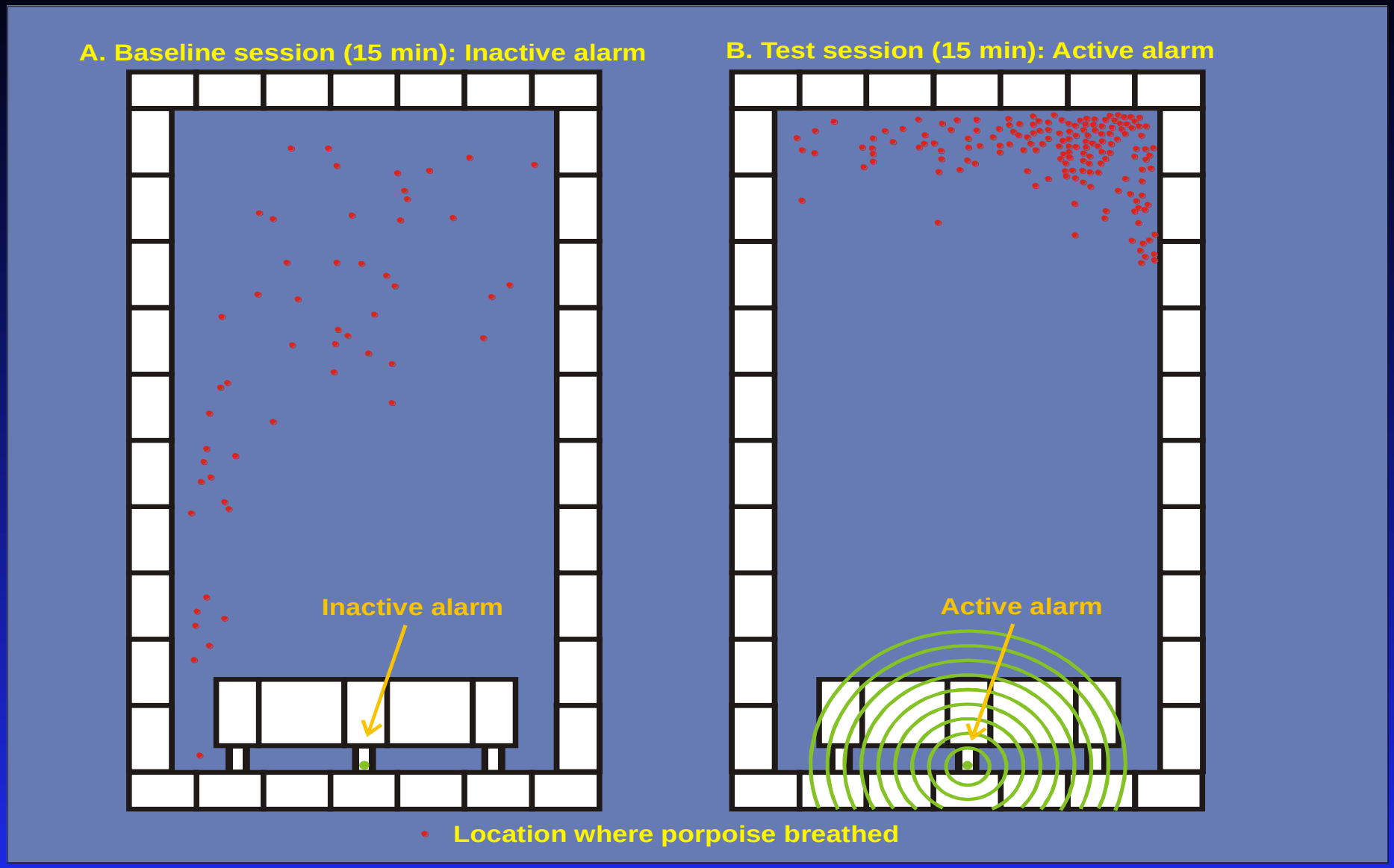
Important: Received levels of harmonics

Increase of audibility



Change in perception

1995-2002: studies in a floating pen

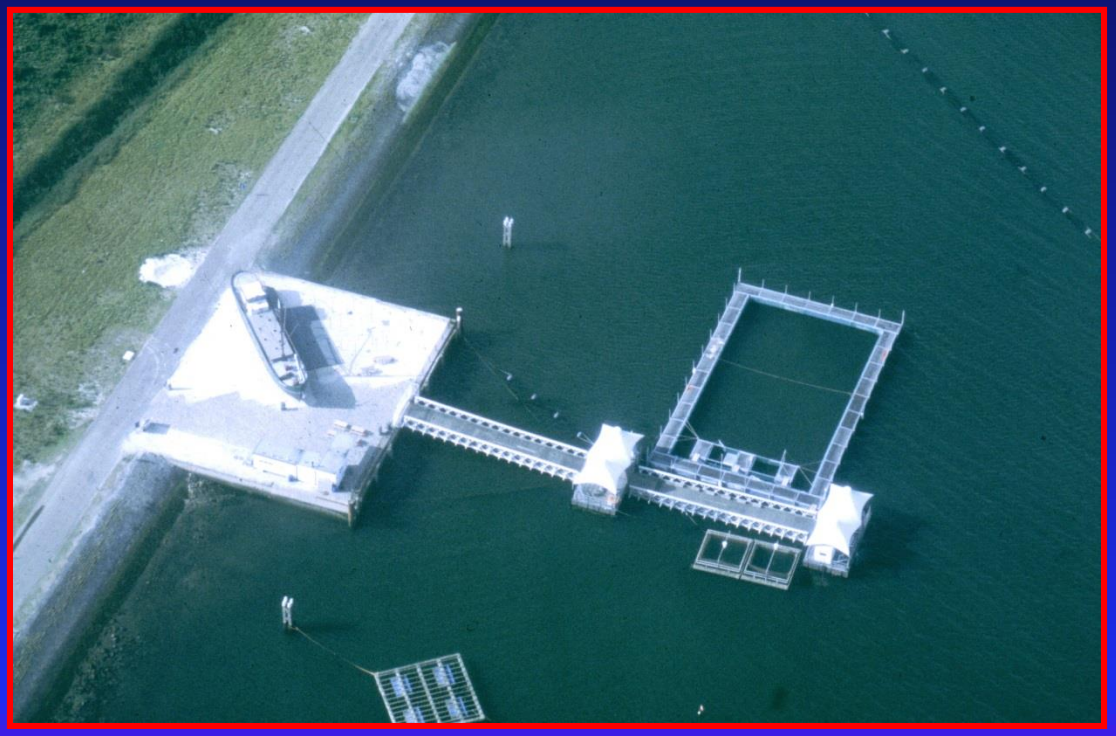


Search for optimal pinger sound characteristics

1995: Sweeps have a much stronger effect on the behavior of porpoises than clicks or tones

1996: 2-30 s for random pulse interval was too long

1998: Random pulse interval and pulse duration. Individual variation in behavioral reactions to sounds



1998, Effect of a “porpoise pinger” on another odontocete

Signals that deterred a harbor porpoise to the other side of the floating pen, had no effect on the behavior of a striped dolphin with good hearing

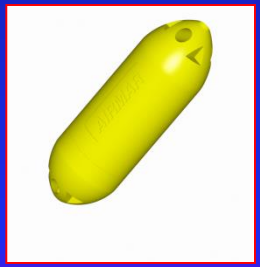
Conclusion: Pingers are, or need to be, species specific

2002

Floating pen

Ultrasonic pingers (70 & 120 kHz) deter porpoises well

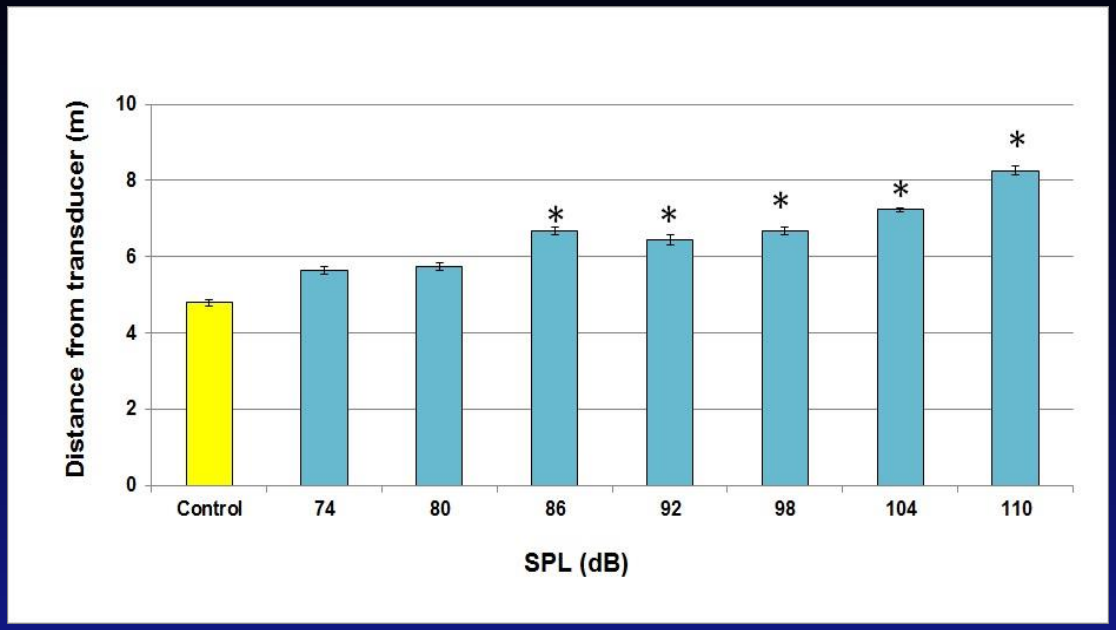
(no “dinner bell” effect in pinnipeds)

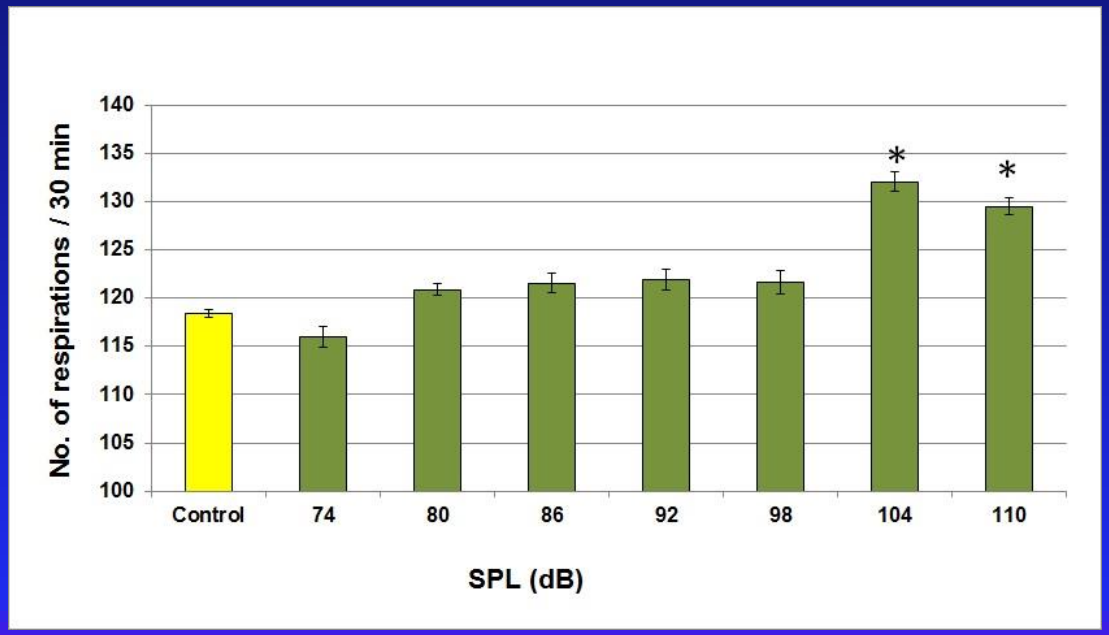


Acoustic Porpoise Deterrent (APD-01)
(developed by SEAMARCO for the offshore industry)

(Complex sounds in 70-150 kHz range)

2014, Behavioral Response Study (APD-01)





Deterring distance in a specific area in North Sea: 1.3 km. Far enough to prevent PTS when piling starts.

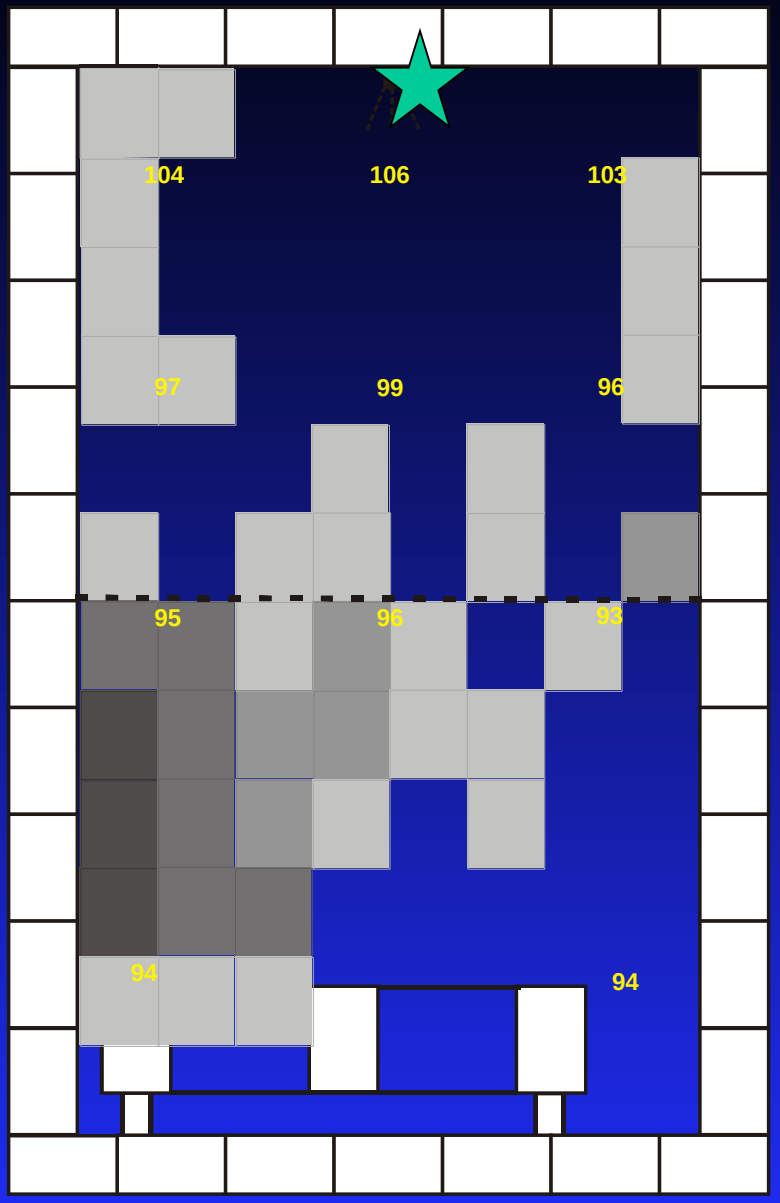
Status: Report in prep.

2010, BRS with Acoustic Mitigation Devices (AMDs/AHDs/ADDs) related to pile driving

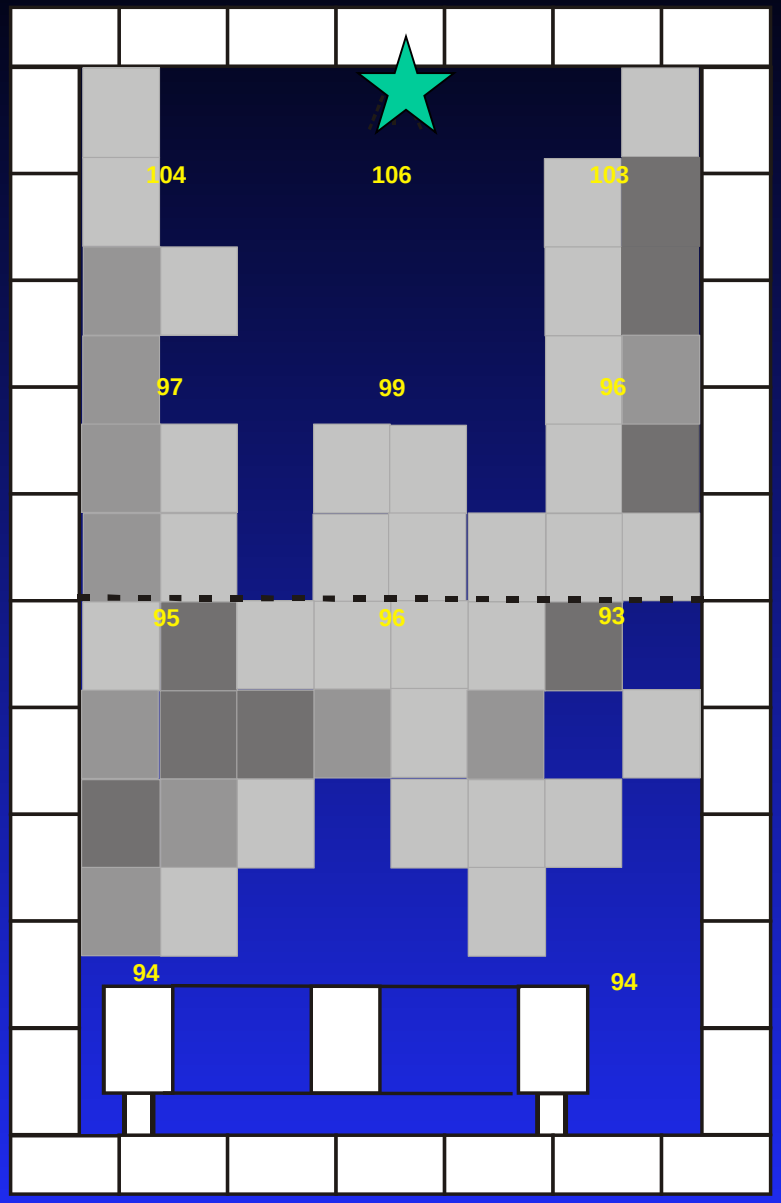
Conclusion: most commercial pingers do not what they advertise (both sound types, SPL and effects)

Avoidance threshold level for data transmission sounds

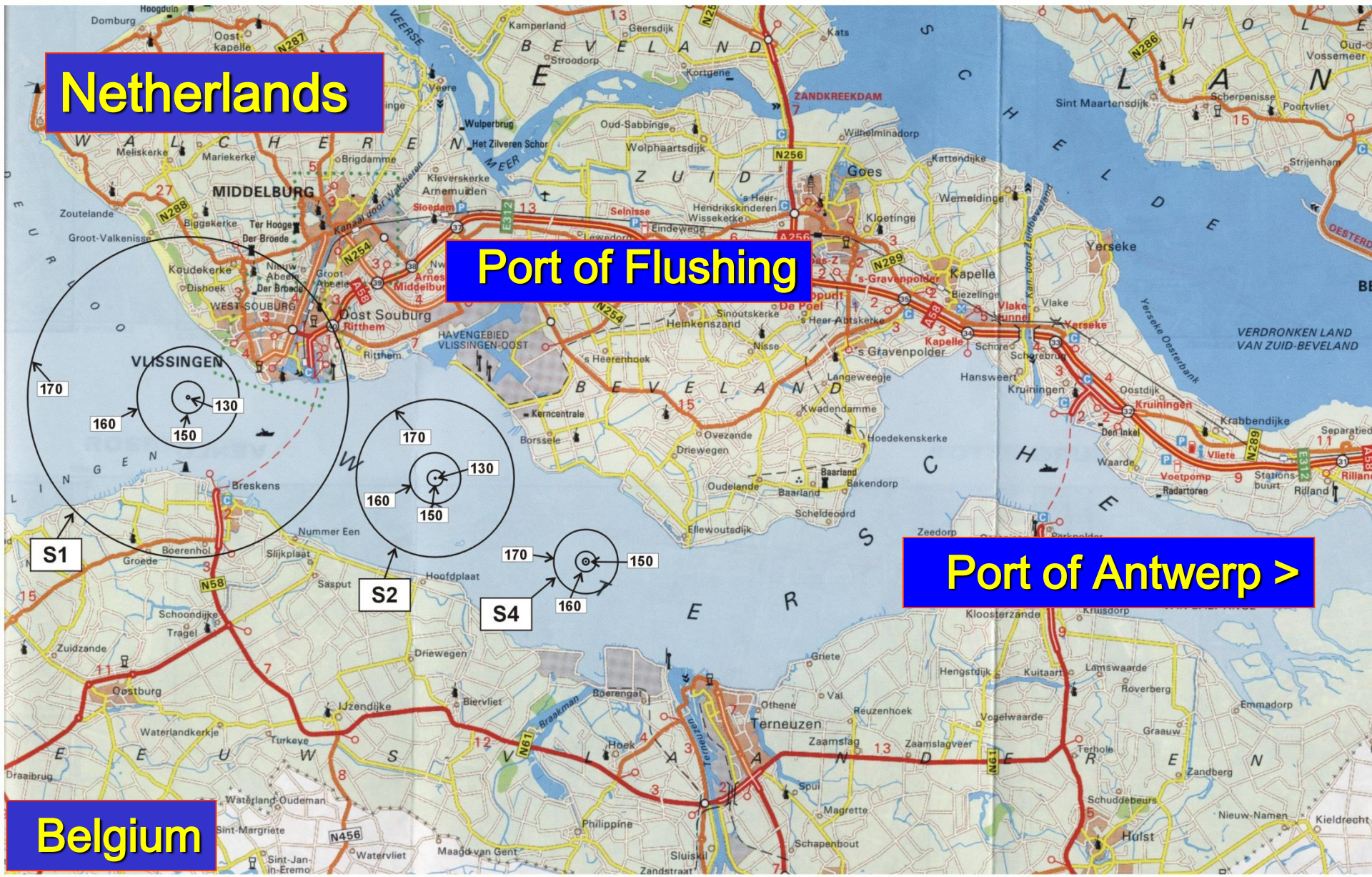
Animal 047, ACME Sound S1



Animal 064, ACME Sound S1



Individual variation



Avoidance zones of harbor porpoises for 4 Source Levels

BRS with naval sounds

Received levels of single sonar sweeps causing a startle response in 50% of pres. (LFAS: 1-2 kHz and MFAS: 6-7 kHz).

- Received levels of series of sweeps causing behavioral responses (LFAS: 1-2 kHz and MFAS: 6-7 kHz) (19% duty c.).

- Effect simulated Sea State noise on effect of series of 6-7 kHz up-sweeps (MFAS) on behavior.

- Received levels of series of 4 HELRAS signals causing behavioral responses (8% duty cycle).

BRS with 25 kHz naval sonar sounds

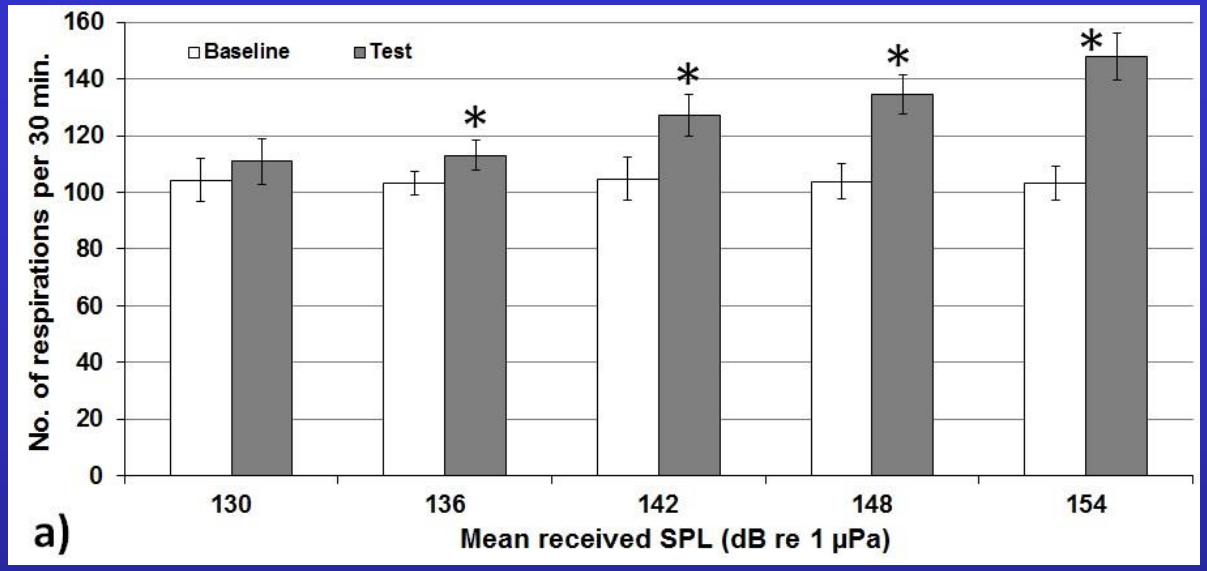
Specify parameters of duty cycle:

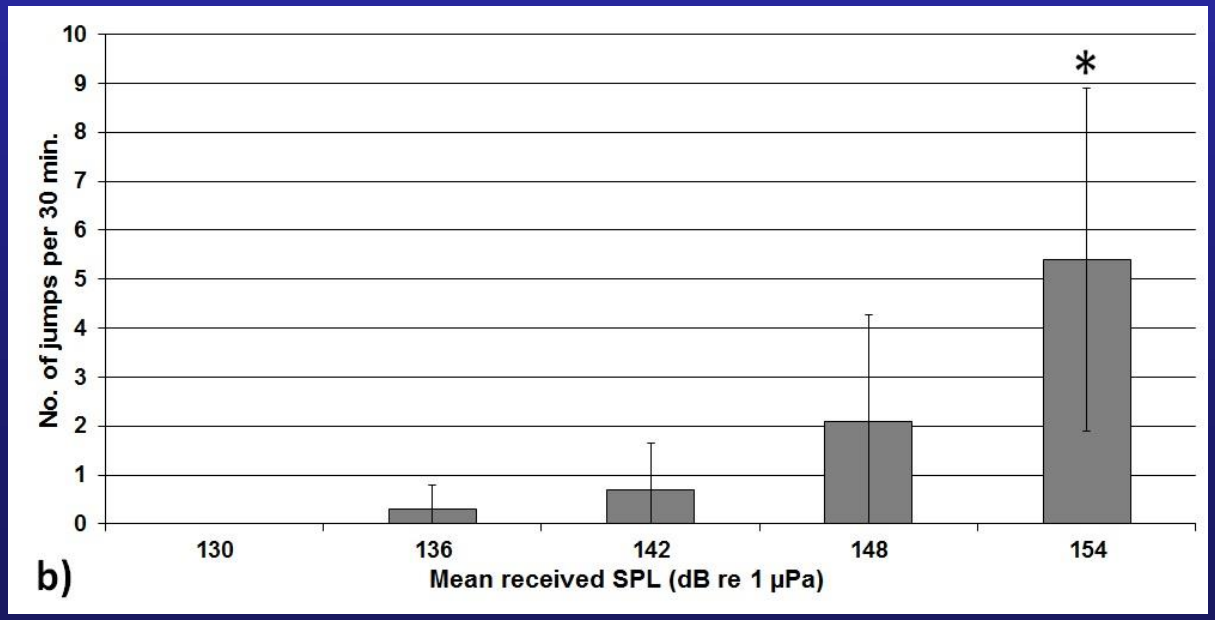
signal duration & interval

50% duty cycle

The lower series has more effect on behavior

BRS with pile driving sound





Conclusions BRS with pile driving sounds

Effects of pile driving sound on harbor porpoise behavior are expected to occur up to ~30 km under low background noise 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 (In some cases effect were not measured beyond these distances).

Importance of BRS results for regulation

Underwater sound criteria to reduce behavioral responses should:

- **Not only specify SPL, but also direction of sweep**
- **Specify the frequency (spectrum) of the noise (or weight the level).**
- **Differentiate between continuous sounds & intermittent sounds.**
- **If intermittent, specify the duty cycle. More importantly, specify inter-pulse interval.**

Importance of BRS results for mitigation

(behavioral effects, not necessarily effects on hearing)

(for harbor porpoises, possibly other odontocetes)

- **Use continuous sounds instead of intermittent**
- **If intermittent, increase the inter-pulse interval**
- **Use noise instead of tones or sweeps**
- **Lower the frequency (reduce level of harmonics)**
- **Produce down-sweeps instead of up-sweeps**
- **Prevent/reduce signal on- & offset transients**

Behavioral response studies with turtles and fish

(Van Oord, Dredging & Marine Contractors)

- 2009: Pool study at Blijdorp Oceanium (sea turtles)
- 2010: Field observations, Sweden (explosions-fish)
- 2011-2012: Field observations, Brasil (explosions-fish)
- 2011: Pool study at SEAMARCO, fine tuning sounds (Sea bass and Thicklip mullet)
- 2012: Pool study at SEAMARCO, fine-tuning sounds (Cod)
- 2012: Pool study at Arsenaal, test sounds on other species. (Sea bass, cod, Yellow tail Kingfish, sharks)

Acoustic Fish Deterrent-01

Reduced fish mortality by underwater explosions

Funding agencies:

Netherlands Ministry of Defense

(René Dekeling)

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Netherlands Ministry of Economic Affairs

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Van Oord, Dredging & Marine Contractors

(Heidi van der Meij & Erik van Eekelen)

Added after the talk was presented at the workshop:

BRS field studies should specify not only Received Level (RL) of the sounds, but all received signal parameters:

- **Harmonics**
- **Kurtosis**
- **Signal duration**
- **Inter-pulse interval**
- **On- of set transients**
- **Reverberations**

For instance the differences seen in effect of sonar sound due to behavioral state may possibly be explained by differences in received signal parameters received by surface and deep diving animals.

Thank you for your attention !

SEAMARCO

Research for marine conservation

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