Experimental validation of a species-specific behavioral impact metric for underwater noise.

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Need for metric

- Most underwater animals use sound; man made noise is pollutant with great capacity to effect their environment
- While lethal effects have previously received most attention, *behavioural effects* now considered by far most important
- However, marine species have greatly varying sensitivity to sound; how do we judge the significance of these effects of noise species-by-species?
- What is deafening for a dolphin?

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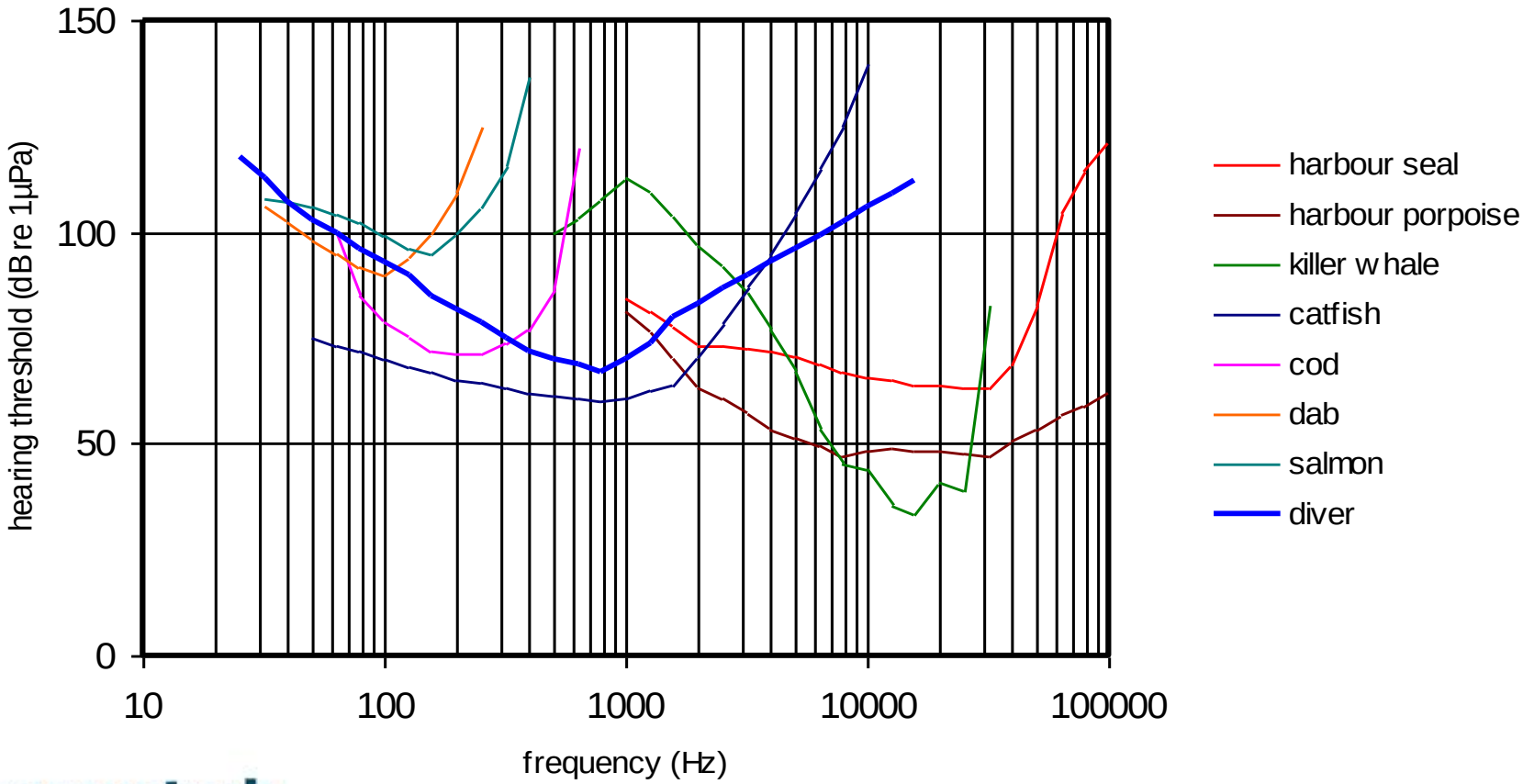
Hearing

Defined by audiogram, lowest level of sound that can be perceived by species as function of frequency



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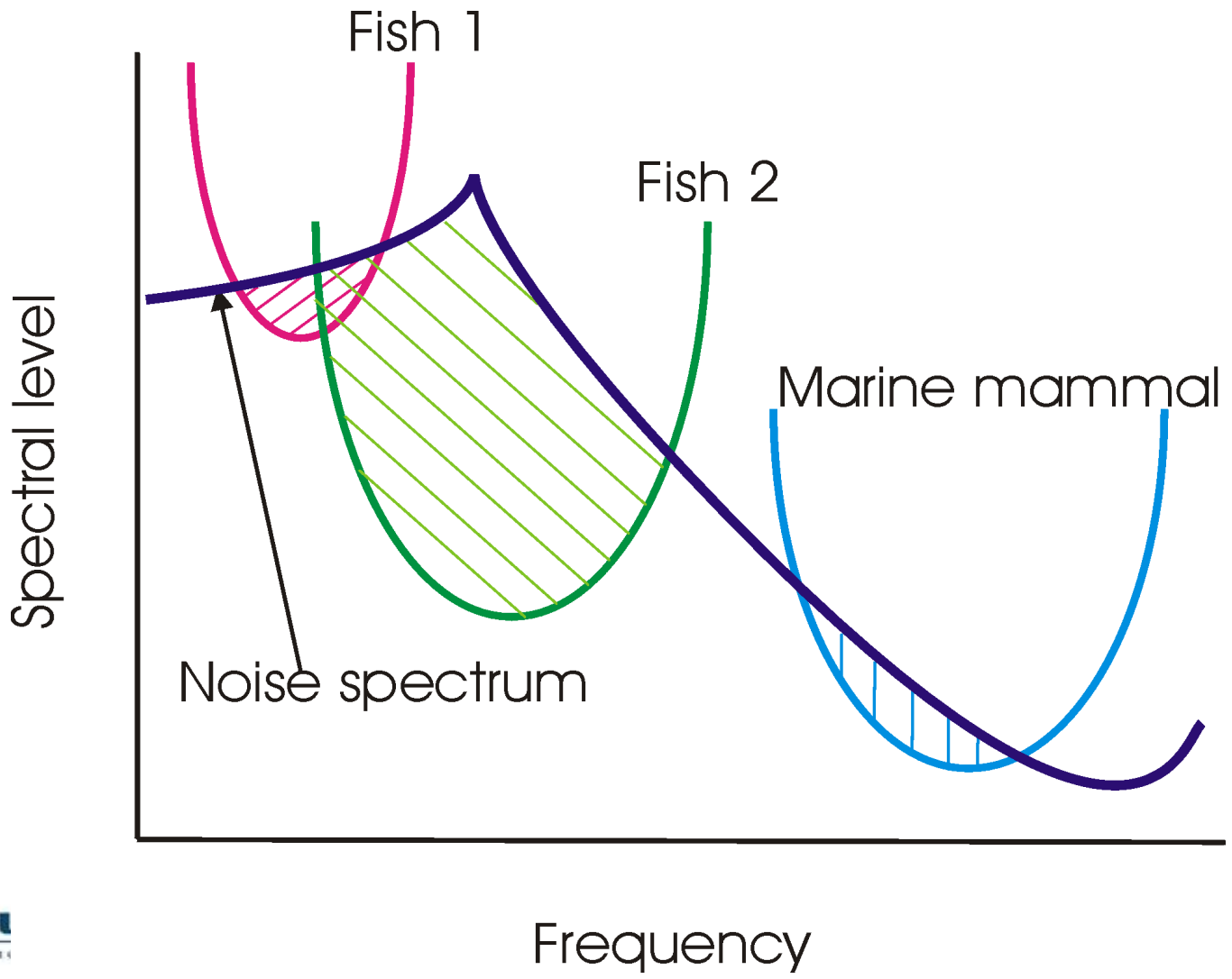
“Loudness” of sound



The dB_{ht} (*Species*): Concept

- Aimed at behavioural effects (chiefly avoidance) but also applicable to NIHL
- Measure of “loudness”
- Generic version of dB(A) for humans; incorporates weighting function based on hearing ability defined by audiogram
- Attractive to regulators (simple and objective regulations) and industry (“species sound level meter”)

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Some notes on dB_{ht} (Species)

- Reference for dB level is *species hearing threshold* (hence dB ht)
- Different for different species, must have species name appended e.g. 88 dB_{ht}(*Gadhus Morhua*) for cod, unless used generically ("levels of 90 dB_{ht} and above will generally cause avoidance….")
- Not a perfect scale – but much better than absolute sound levels. (e.g. some effects may occur lower in "nervous" species (for instance, the grazers) than in "bold" (predatory) species.)

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Experimental approach

- Subject fish with widely varying hearing to increasing noise levels of various types of sound; find percentage of each species which avoid noise at each level
- Data also available from fish exclusion system at nuclear power station
- Present as dB_{ht} level for each species, using published or measured audiogram
- Does avoidance depend primarily on dB_{ht} level?

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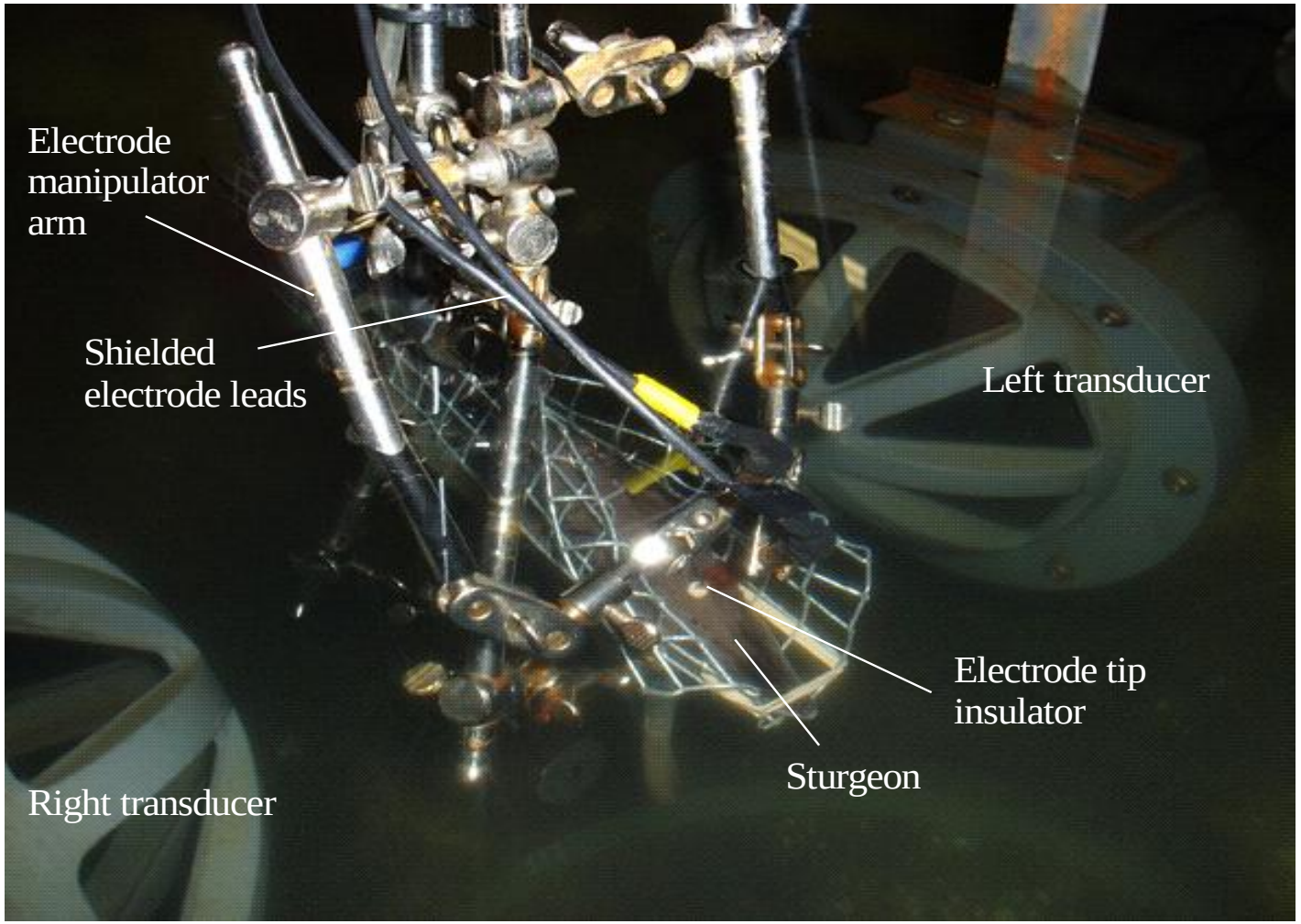
Audiogram measurements



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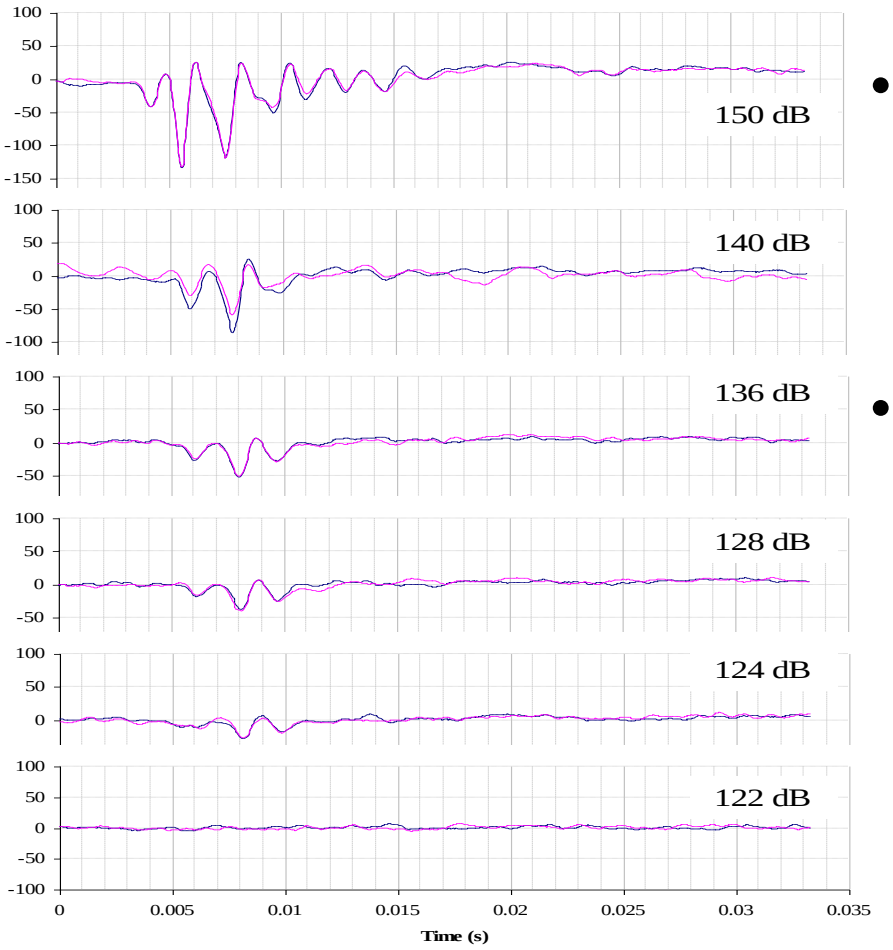
Auditory Brainstem Response



- Twin transducer system allows separation of pressure and particle velocity effects
- Threshold of hearing is estimated by finding the level of sound at which the brainstem auditory response just appears above noise.

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Reaction tests

- Two transducers and “ping-pong” measurements to avoid bias to one side; calibrated to International Standards
- Overhead camera; percentage avoidance using “blind” assessment
- Over 800 individual measurements (12 species, 12 levels, 6 signal types); still being analysed.

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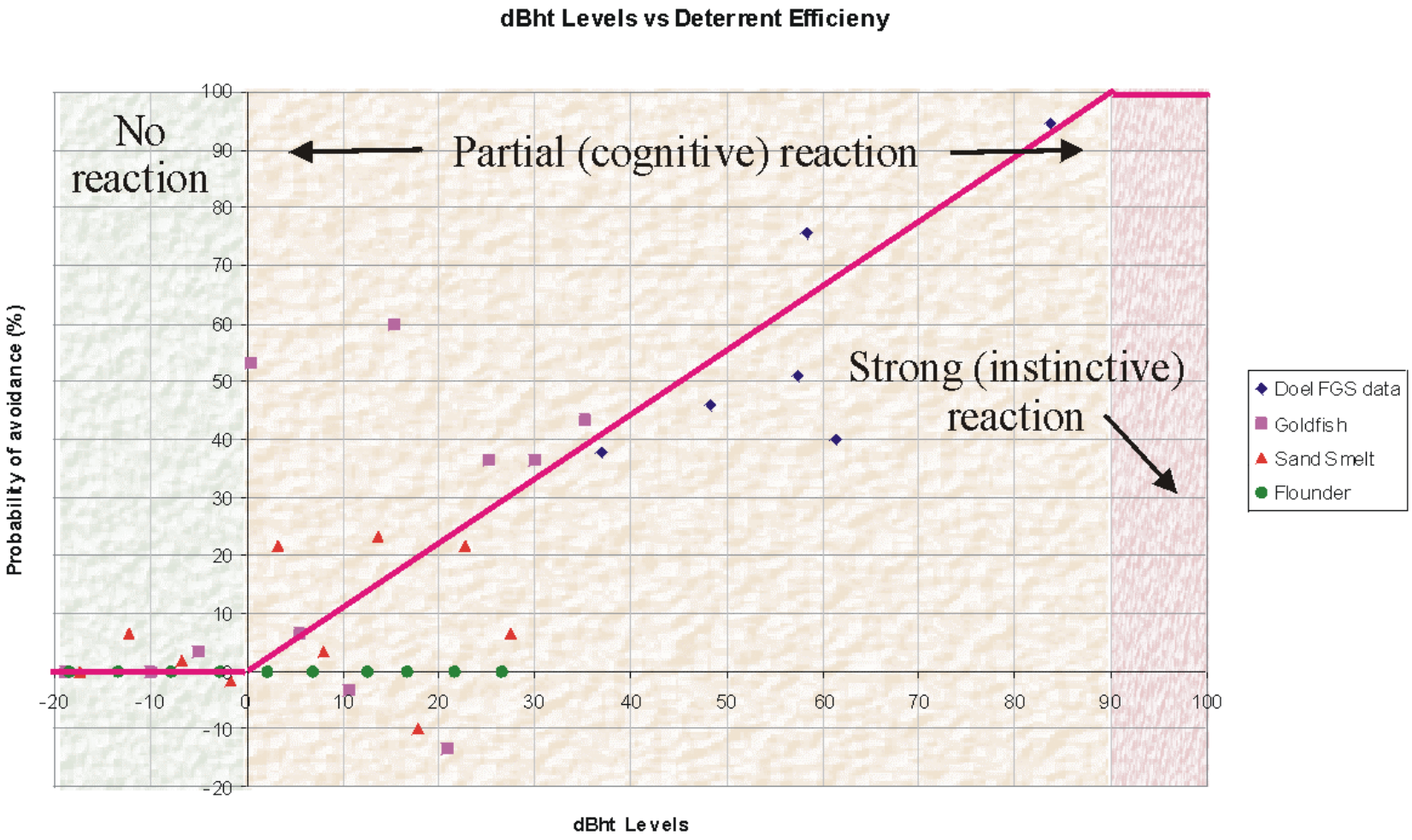
Reaction to noise



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General effects of noise

Level	Comment	Effects	Human equivalent
< 0 dB_{ht}	Animal can't hear it	No reaction	Soundproof room
0-90 dB_{ht}	Increasingly loud	Reactions primarily cognitive	e.g. office 50, workshop 70 dB_{ht}
90-130 dB_{ht}	Unbearably loud	Instinctive reaction (avoidance)	Roadhammer >100dB_{ht}
> 130 dB_{ht}	Deafening	Traumatic hearing damage	Gunfire near ear

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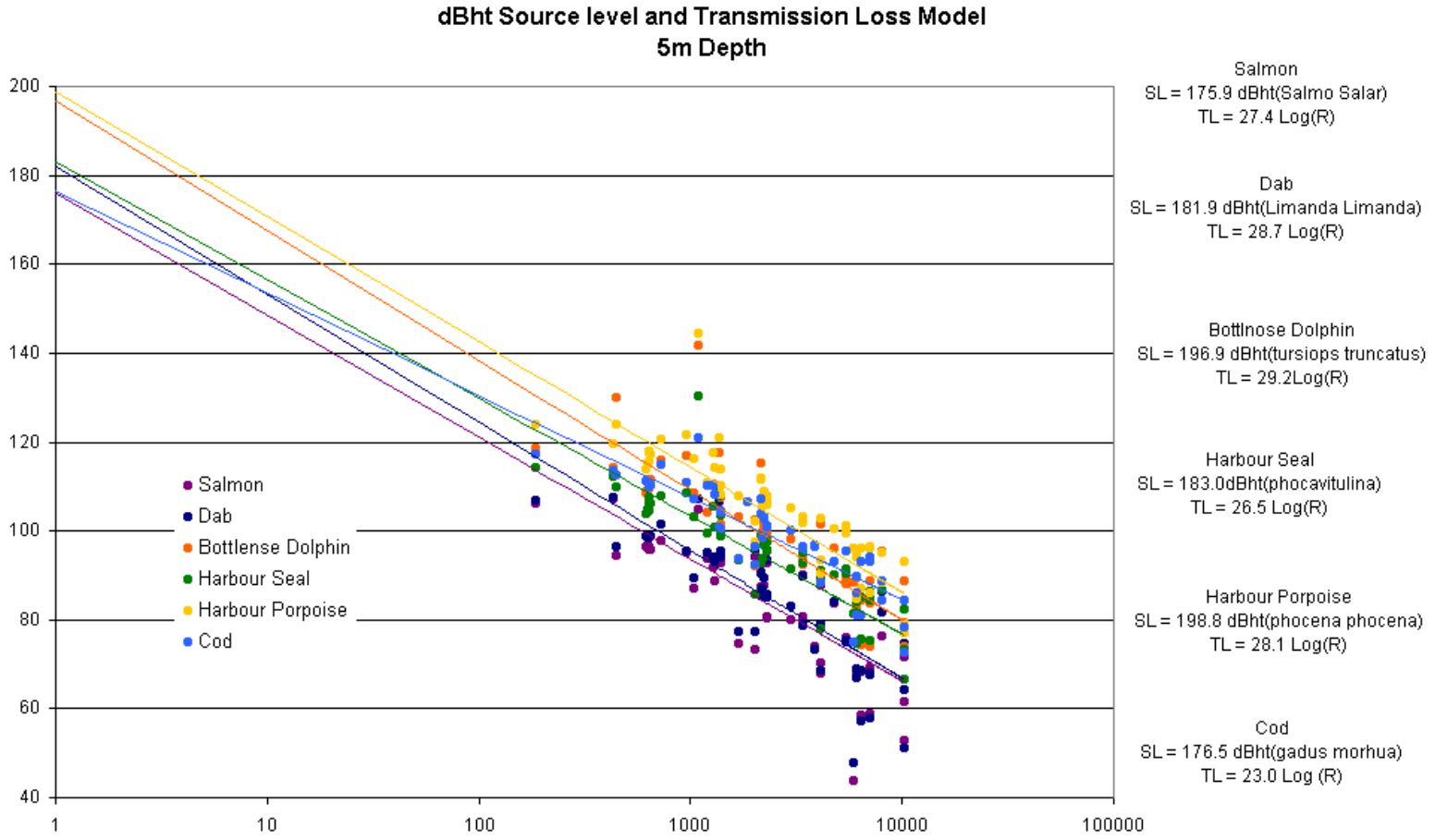
Behavioural effects of piling noise?



Pile hammering noise measurements at 5m depth

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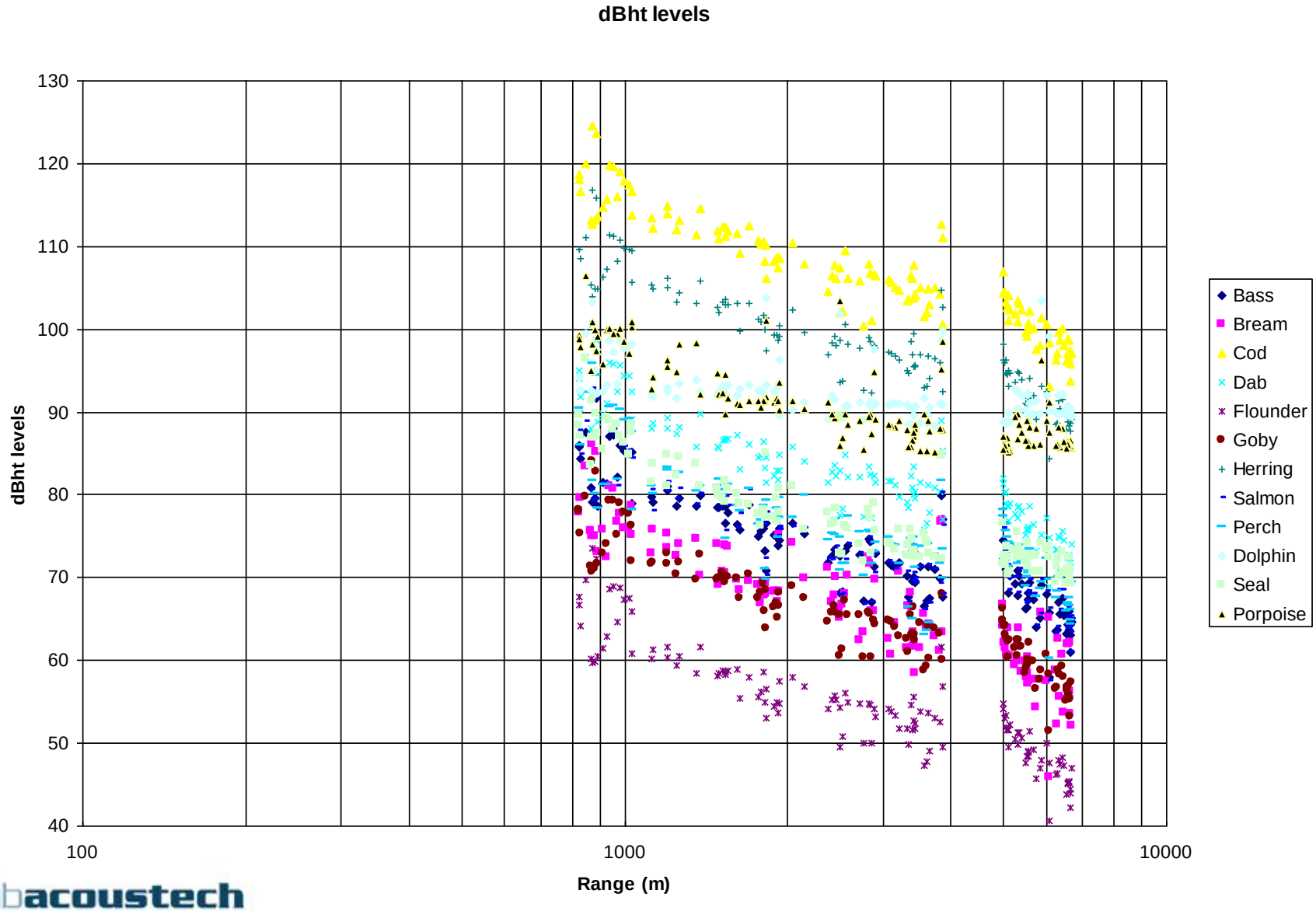
Behavioural effects of seismics?



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Other evidence?

- Piling: World's largest offshore wind farm was build on Horns Reef in the Danish North Sea in 2002; observations from ship surveys showed a significant change in behaviour of harbour porpoise on days with pile driving at distances up to 15 km from the wind farm

(Tougaard, J, Carstensen,J, Skov,H, Teilmann,J, and Henriksen, O D (2003). Effects from pile driving operations on harbour porpoises at Horns Reef offshore windfarm, monitored by T-PODs and behavioural observations. Report by National Environmental Reseach Institute, Frederiksborgvej 399, DK-4000 Roskilde,Denmark)

- Seismics: Significant study by Engås in 1992 confirmed that a 3-D seismic survey caused an immediate reduction in commercial catch rates in its vicinity of substantially more than 50%, while having lesser effects extending at least 20 km away and perhaps further

(ENGÅS, A., S. LØKKEBORG, E. ONA & A.V. SOLDAL (1993). Effects of seismic shooting on catch and catch-availability of cod and haddock. Fisken og Havet 1993(9): 117p.)

Summary

- Research and validation still in progress
- Data to date confirm the degree of behavioural effect induced by sound depends primarily on the dB_{ht}(*Species*) level
- Favourable reception by regulators industry - allows sorting out real problems from red herrings, and simple generic statements about behavioural effects (e.g. “sound above 90 dB_{ht} will cause strong avoidance reaction”)

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