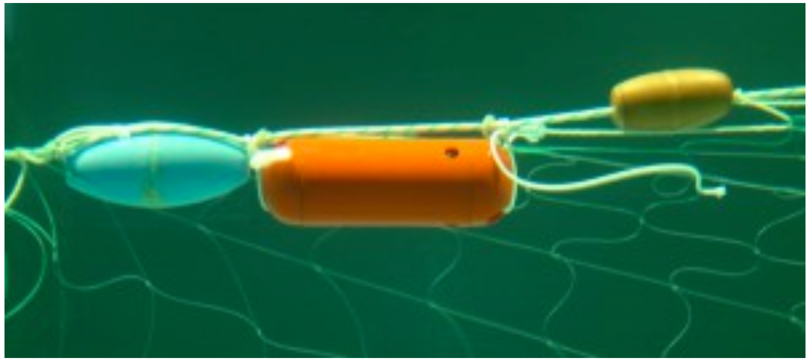
Auditory Processing in Whales and Acoustic Deterrence



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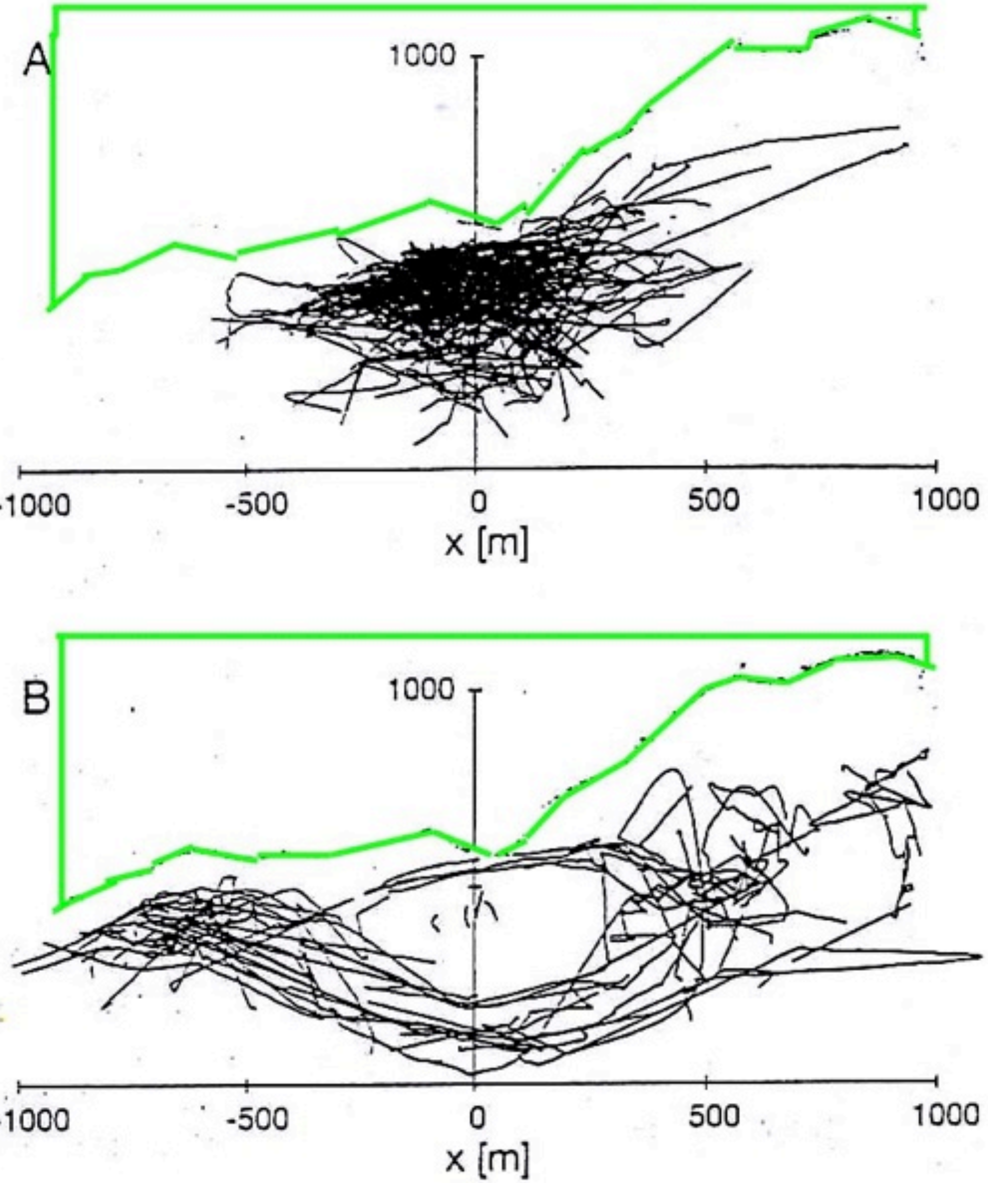
Outline

- Porpoises and Beaked Whales Show Strong Avoidance to low levels of ADD
- Delphinids and Baleen Whales Do Avoid, but at Higher Levels
- How to Design ADD for large whales based upon Hearing
- Appropriateness Depends Upon Setting

Responses of *Phocoena* to 145 dB pinger

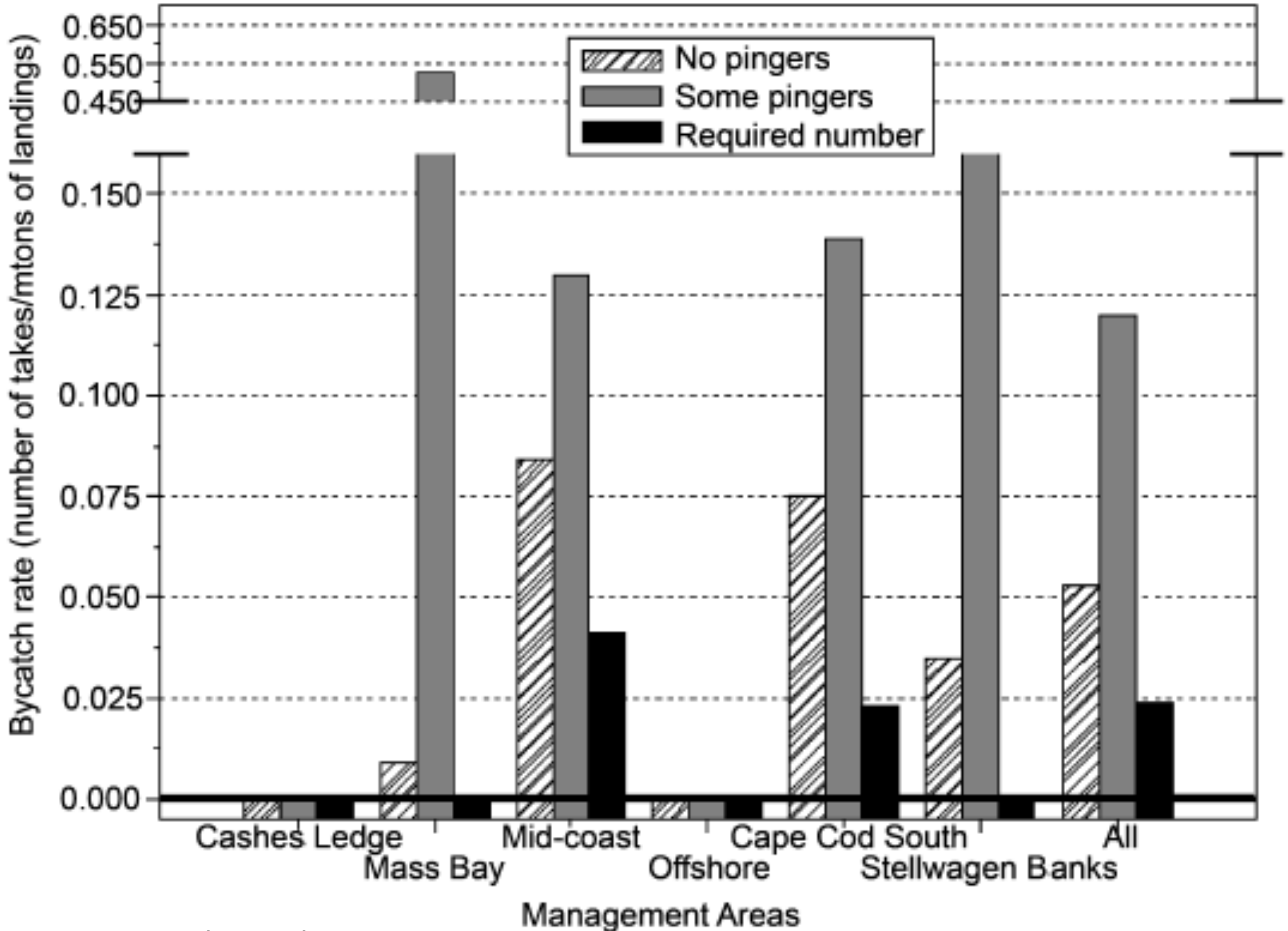
Control

Transmit



Culik et al 2001
Mar Ecol Prog Ser
211:255-260

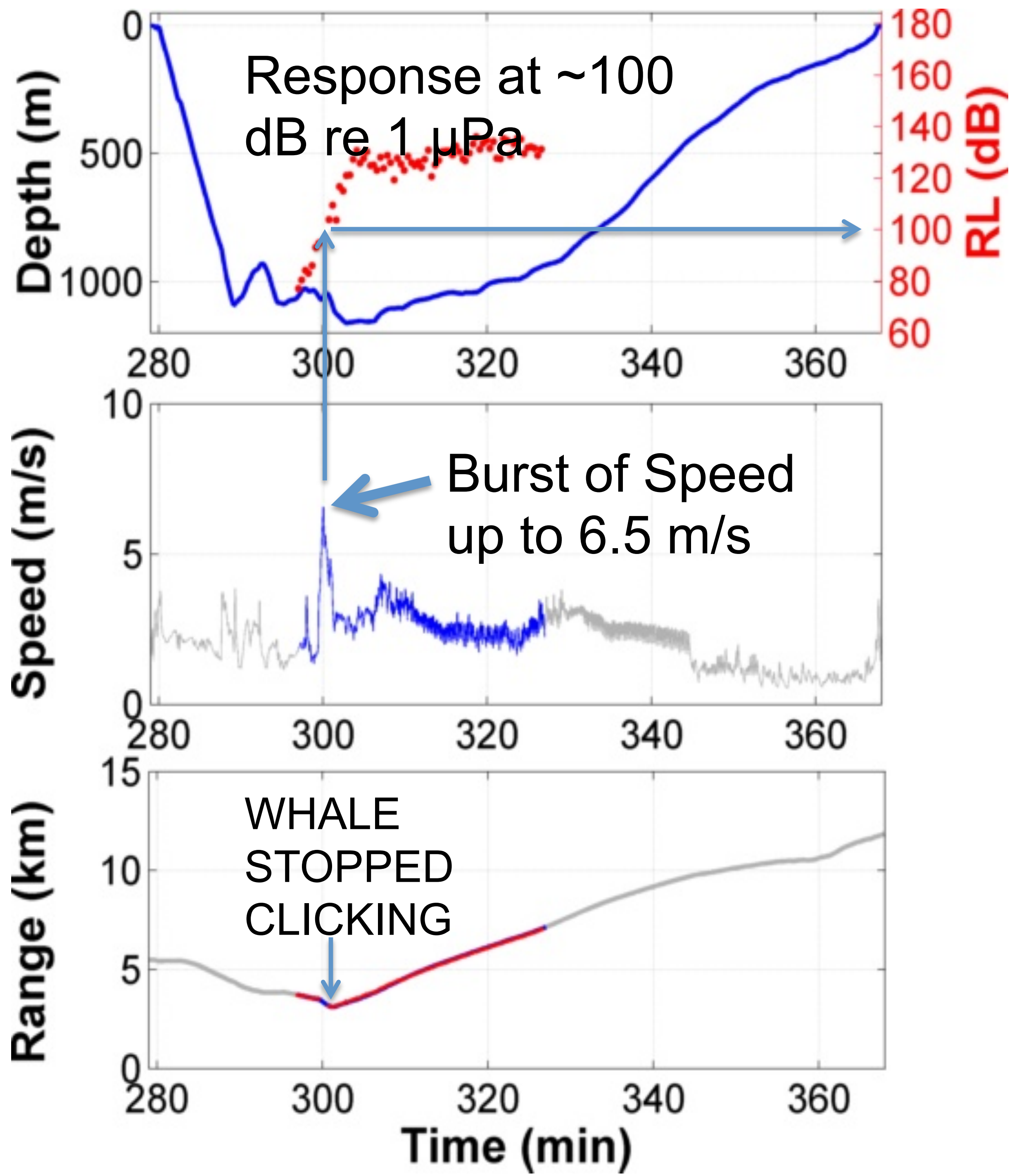
Pingers reduce bycatch of porpoises



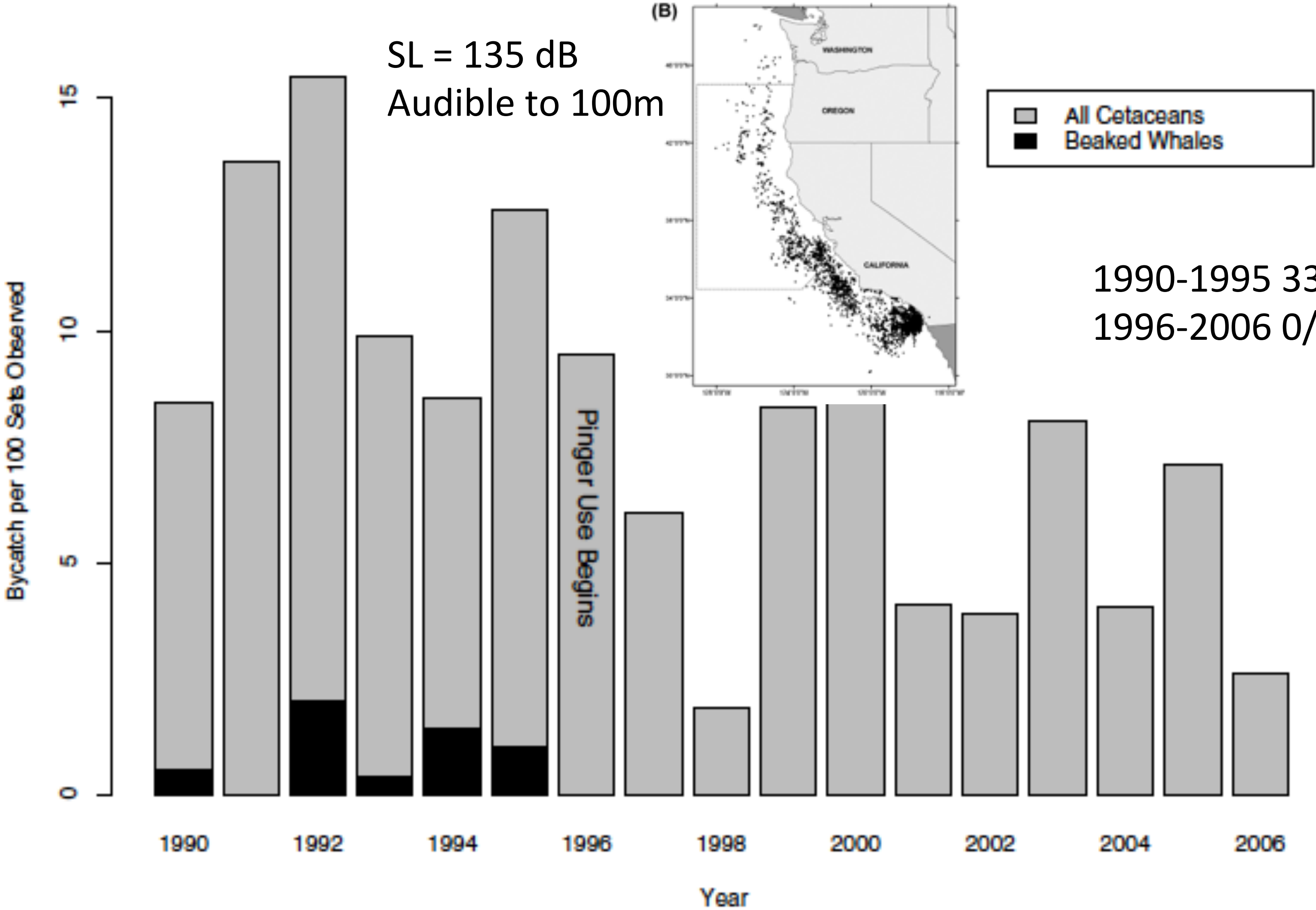
Palka et al. (2008) J Cet Res Mgmt 10:217-226

Cuvier's Beaked Whale Avoids Low Sound Level

Whale moved from <4 km to 12 km away from the source before surfacing



Pingers Stopped Bycatch of Beaked Whales



SL = 135 dB
Audible to 100m

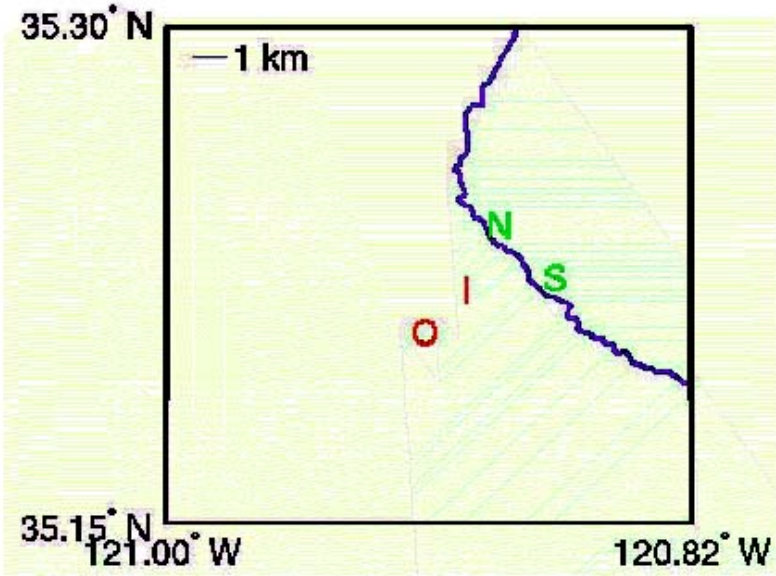
1990-1995 33/3303
1996-2006 0/4381

Figure 2. Bycatch rates (of individuals) of all cetaceans and beaked whales per 100 observed sets, 1990–2006.

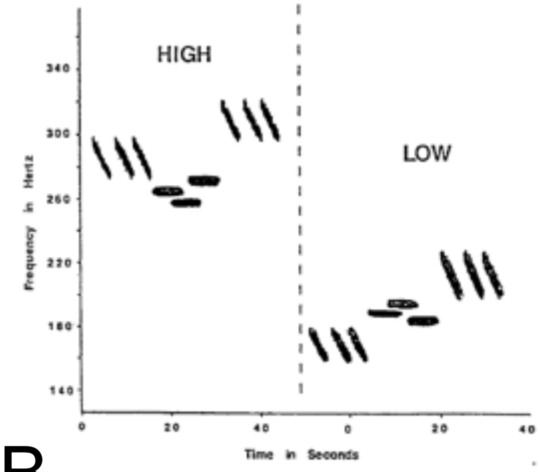
Caretta and Barlow (2008) MMS 24:956-961

Avoidance Responses of Gray whales migrating past the Central California Coast

- Dozens of whale groups migrating past site each day
- Land-based Observers track whales
- Paired Playback/Control Design
- Sound source moored offshore



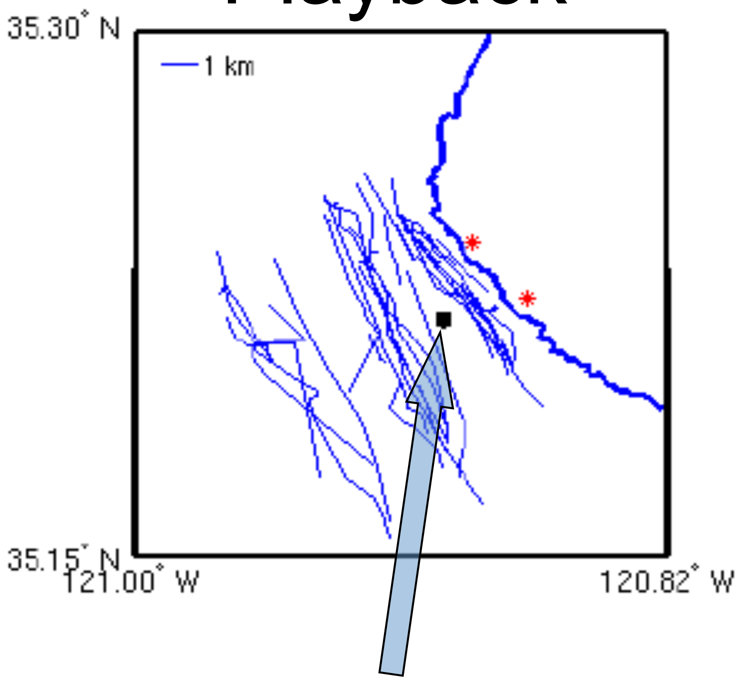
Responses of migrating gray whales to Low Freq Sonar



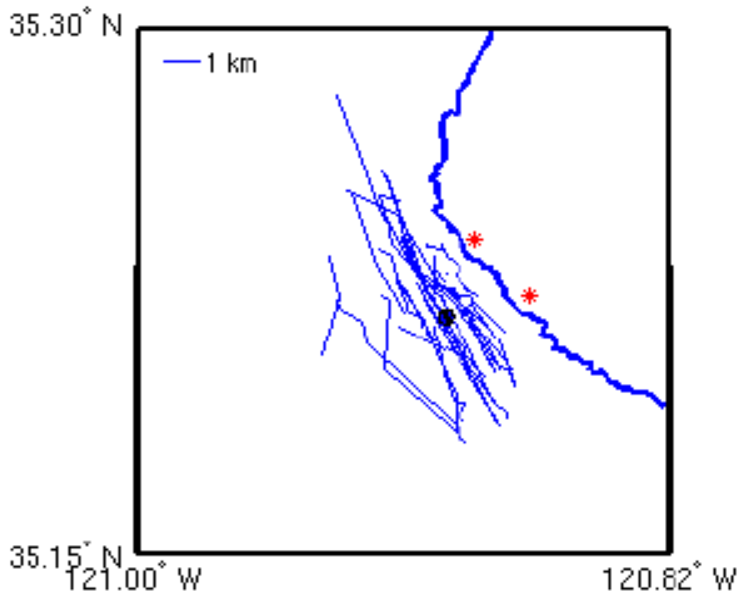
160-330 Hz, 42 s every 6 min

Inshore Mooring Source Level = 185 dB

Playback

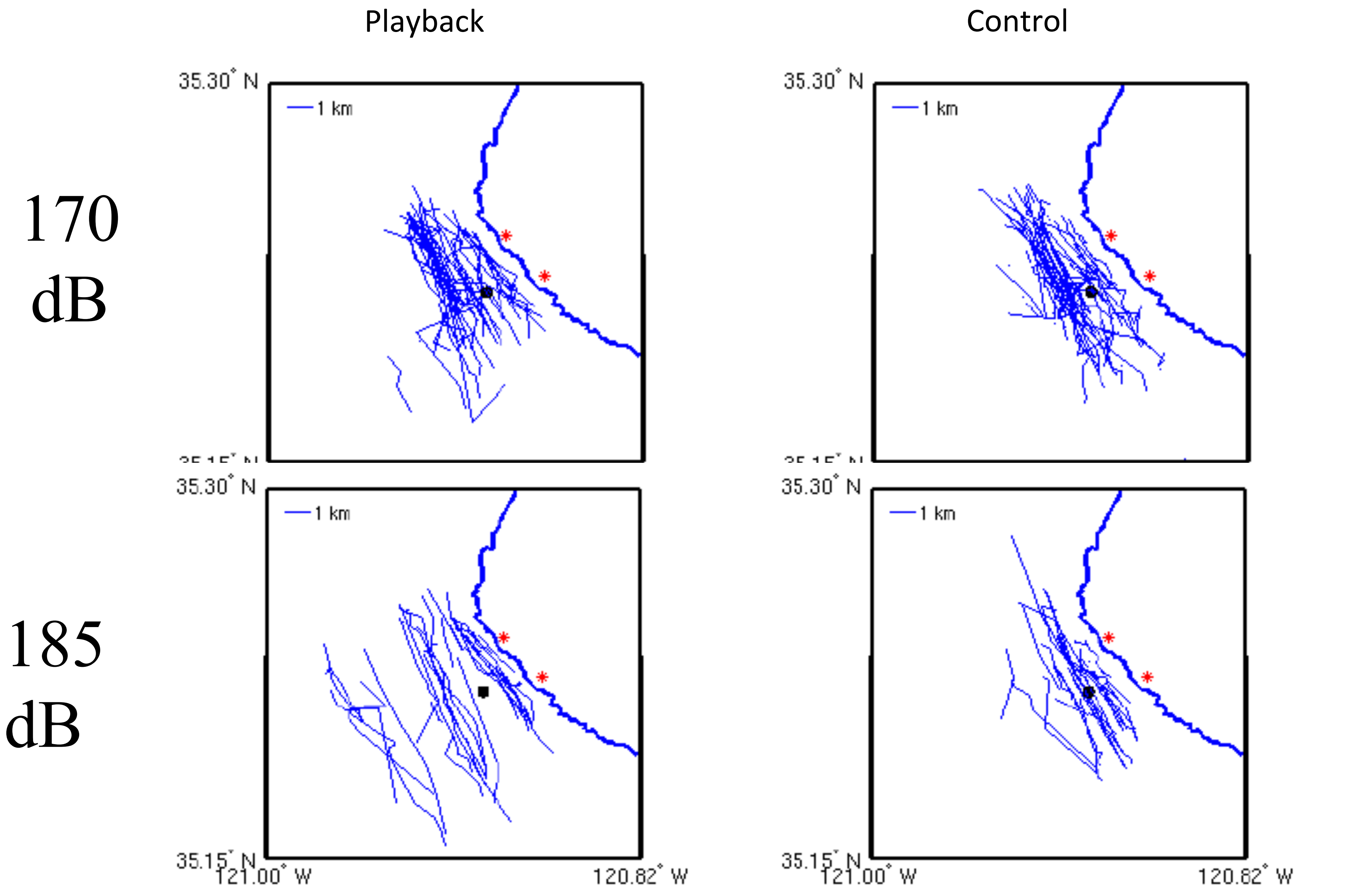


Control

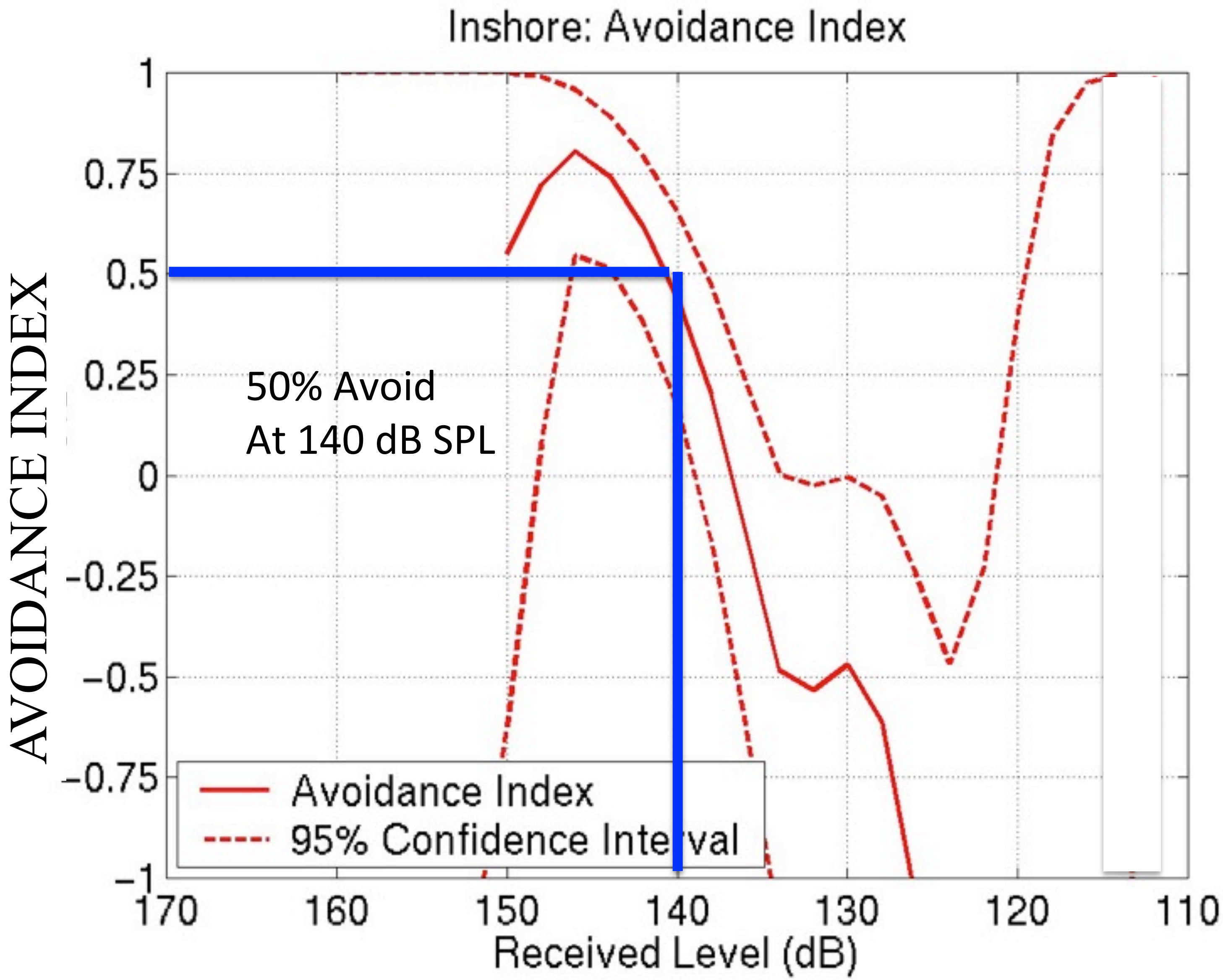


Whales avoid area near source

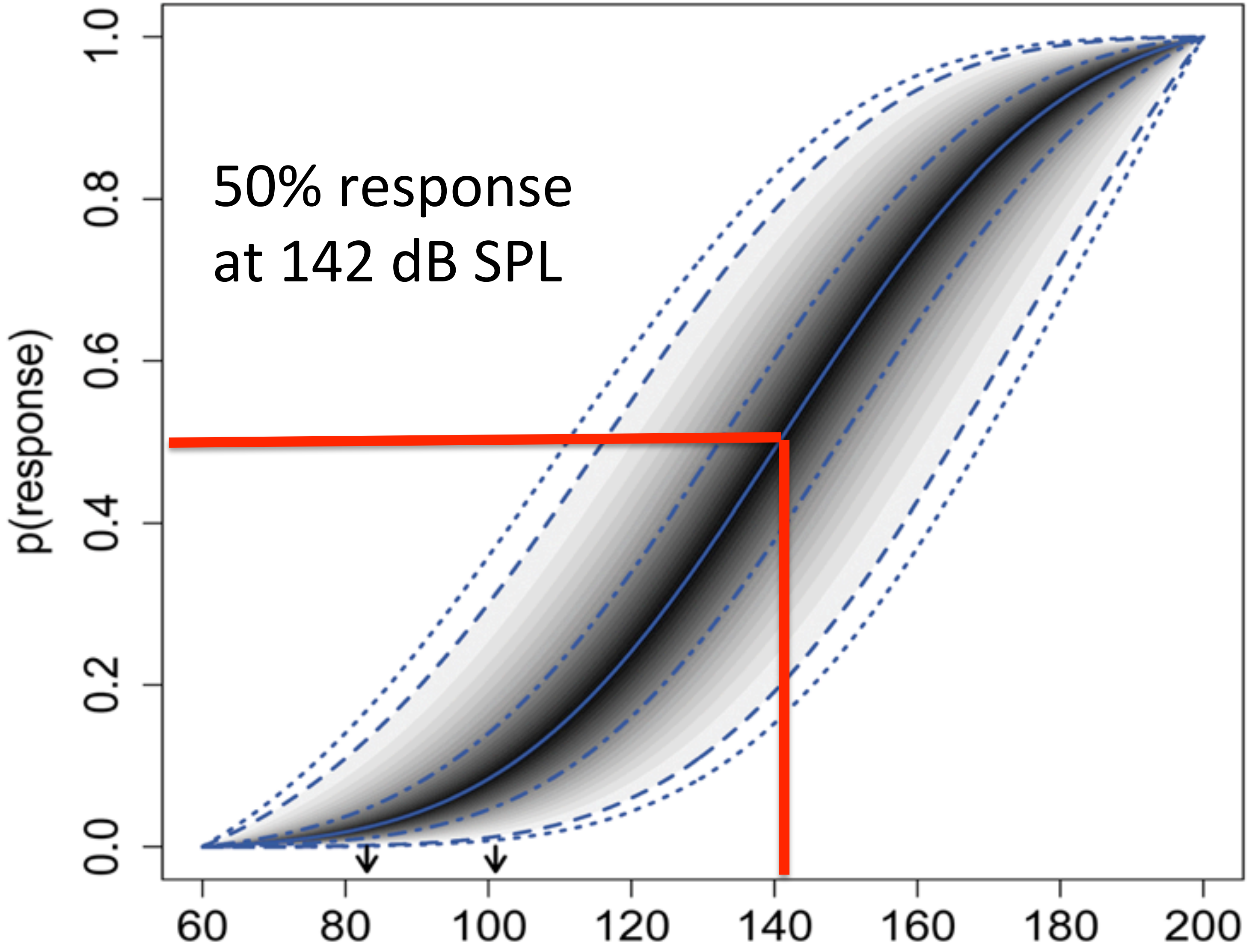
Response to Playback Scales with Source Level



Avoidance of gray whales to LFA sonar increases at higher received levels



Probability of Avoidance vs SPL for Killer Whale Response to Tonal Upsweeps 1-2 & 6-7 kHz

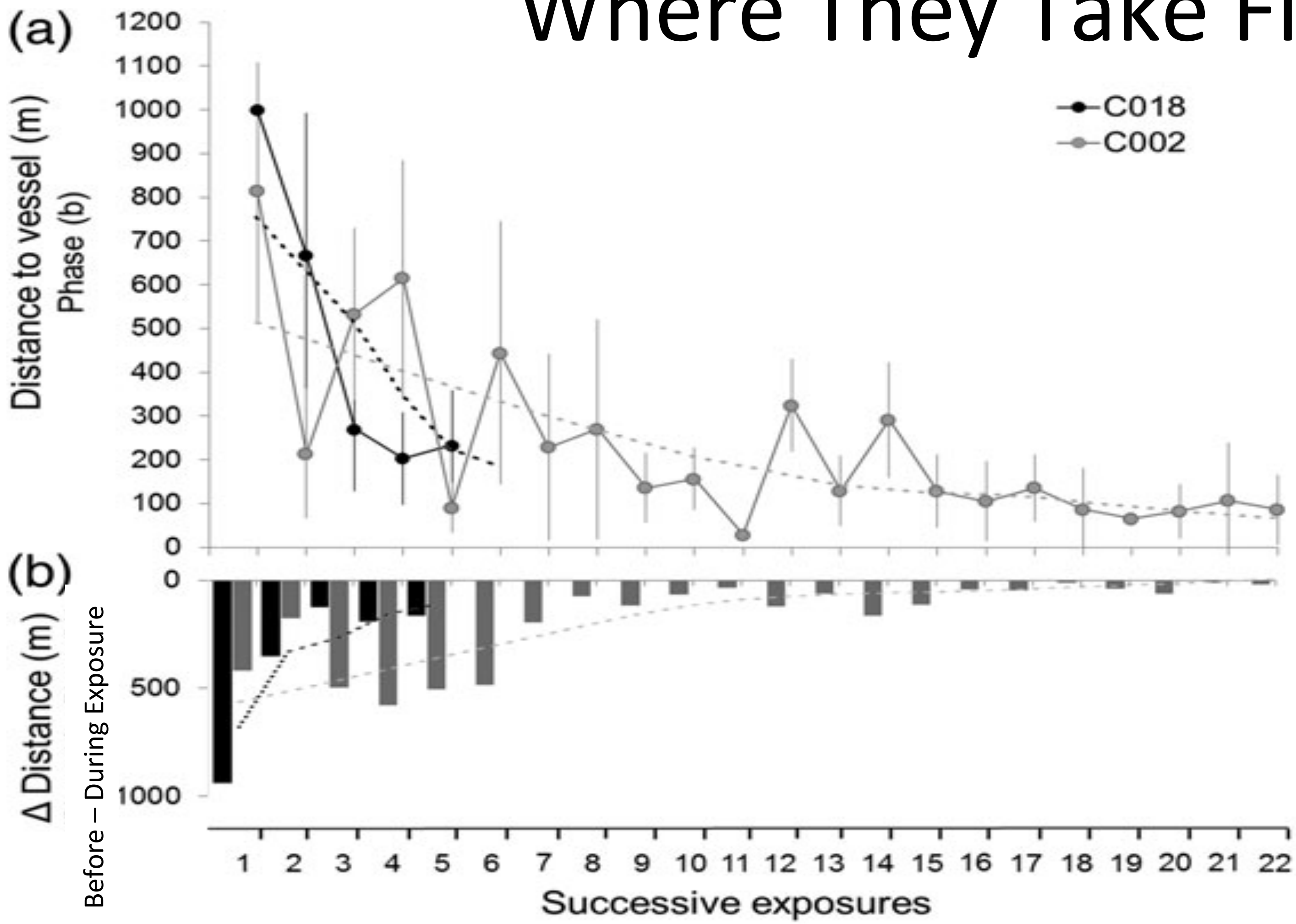


Miller et al. (2014) JASA 135:975-993)

Problem if ADD excludes non-target species from habitat

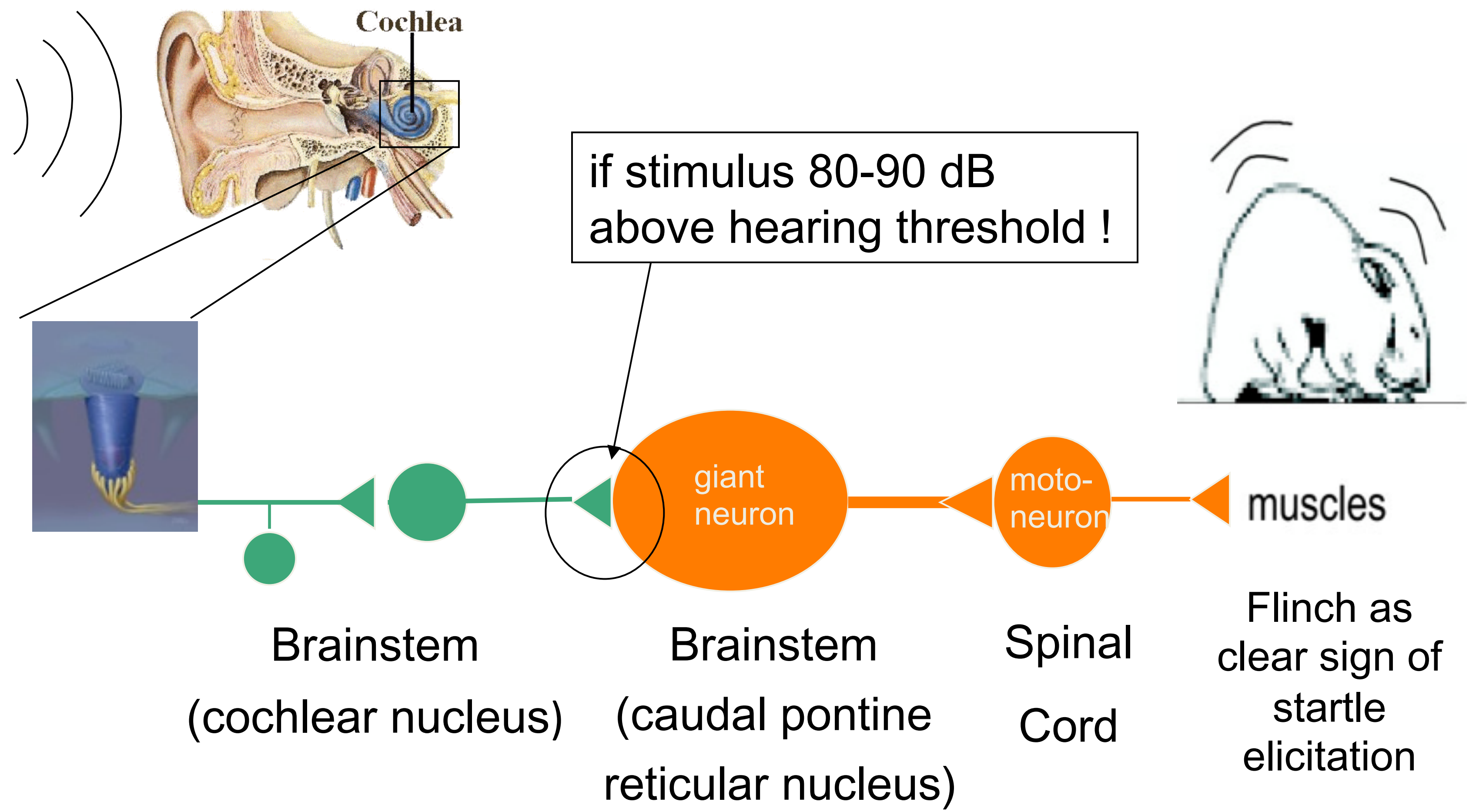
- Morton and Symonds (2002 ICES J Mar Sci 59:71-80) report that 4 AHDs (SL = 194 dB at 1 m) installed to reduce depredation by seals caused killer whales to avoid tens of km2 for 6 years until AHDs were removed
- Most ADDs operate above the frequencies that fish hear well (below 1 kHz). If ADD frequencies are lowered, this might affect catch rate of fish

Habituation of Killer Whales to AHD (SL = 195 dB) Attached to Longlines Where They Take Fish

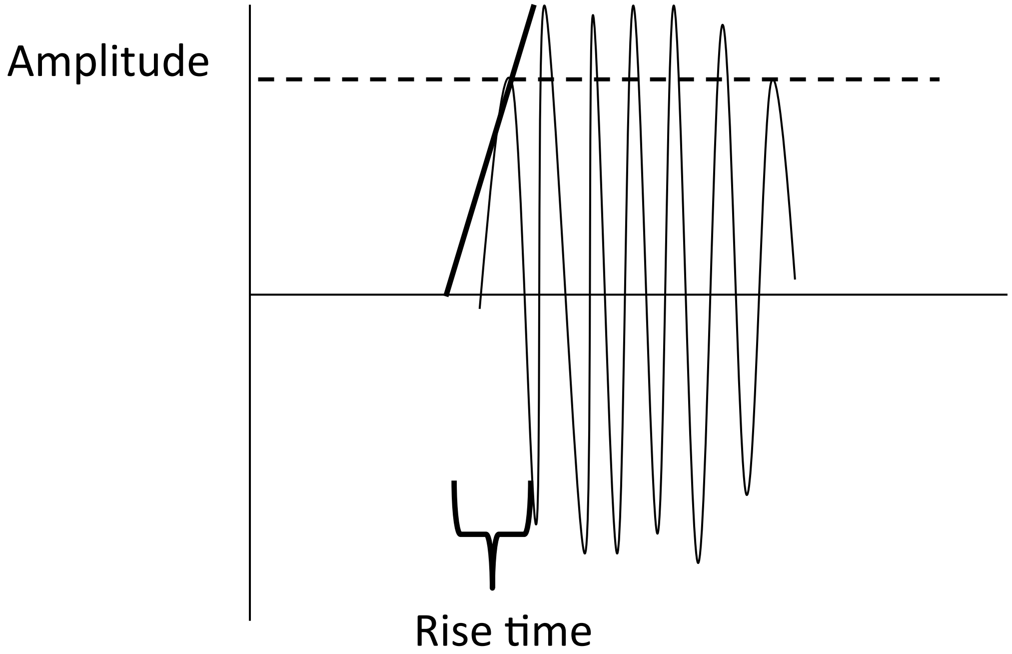


Tixier et al. (2014) ICES J Mar Sci doi: 10.1093/icesjms/fsu166

Acoustic Startle Reflex

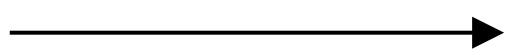


Acoustic Startle Reflex: Rise-time



Startle threshold (80-90 dB above hearing threshold)

(Pilz & Schnitzler, 1987 *J. Comp. Psychol.* 101:67-72



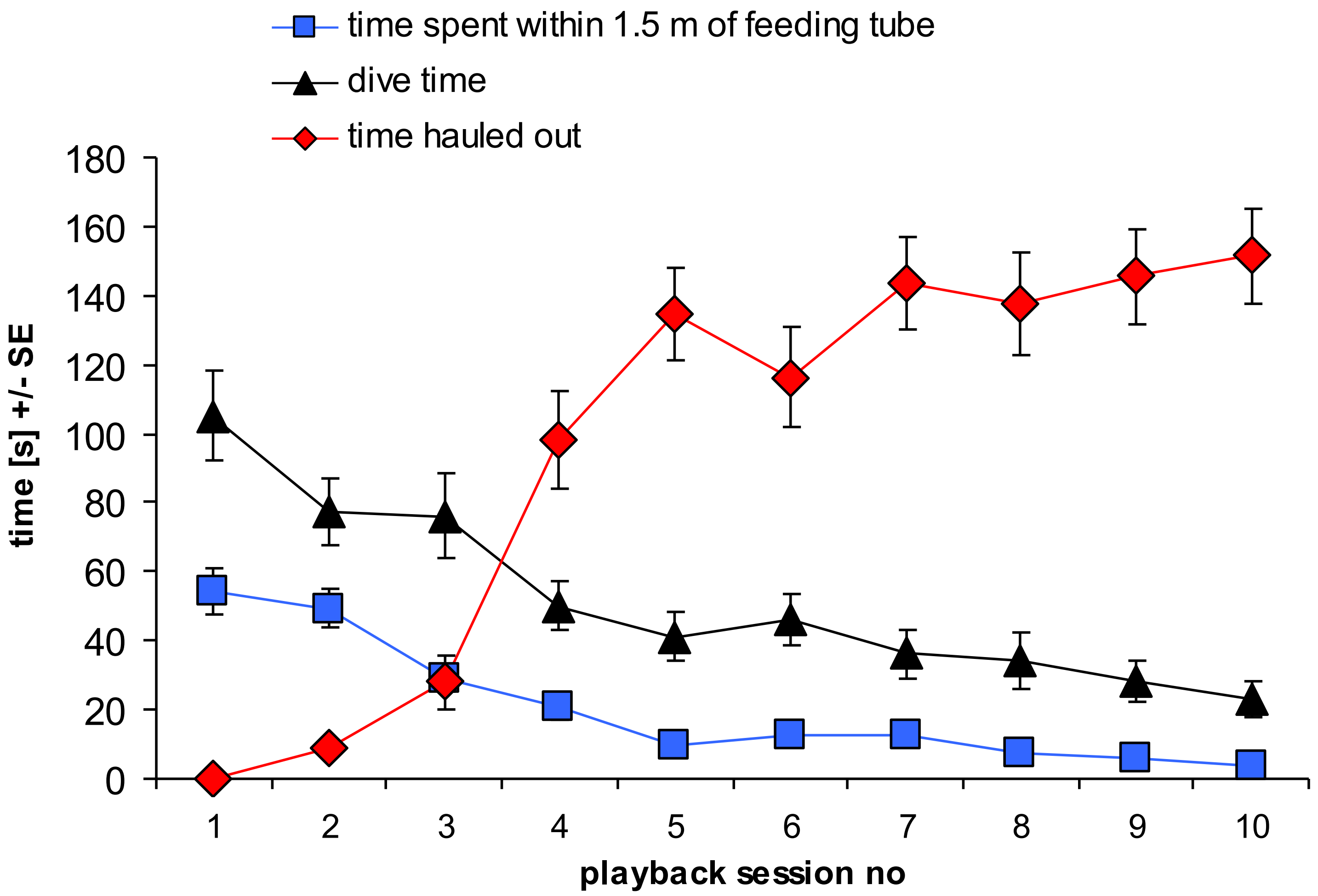
Reflex elicited if sound exceeds startle threshold within 15-20msec of its onset

Fleshler (1965) *J.Comp.Physiol. Psychol.* 60:200-207.

Video of seal response

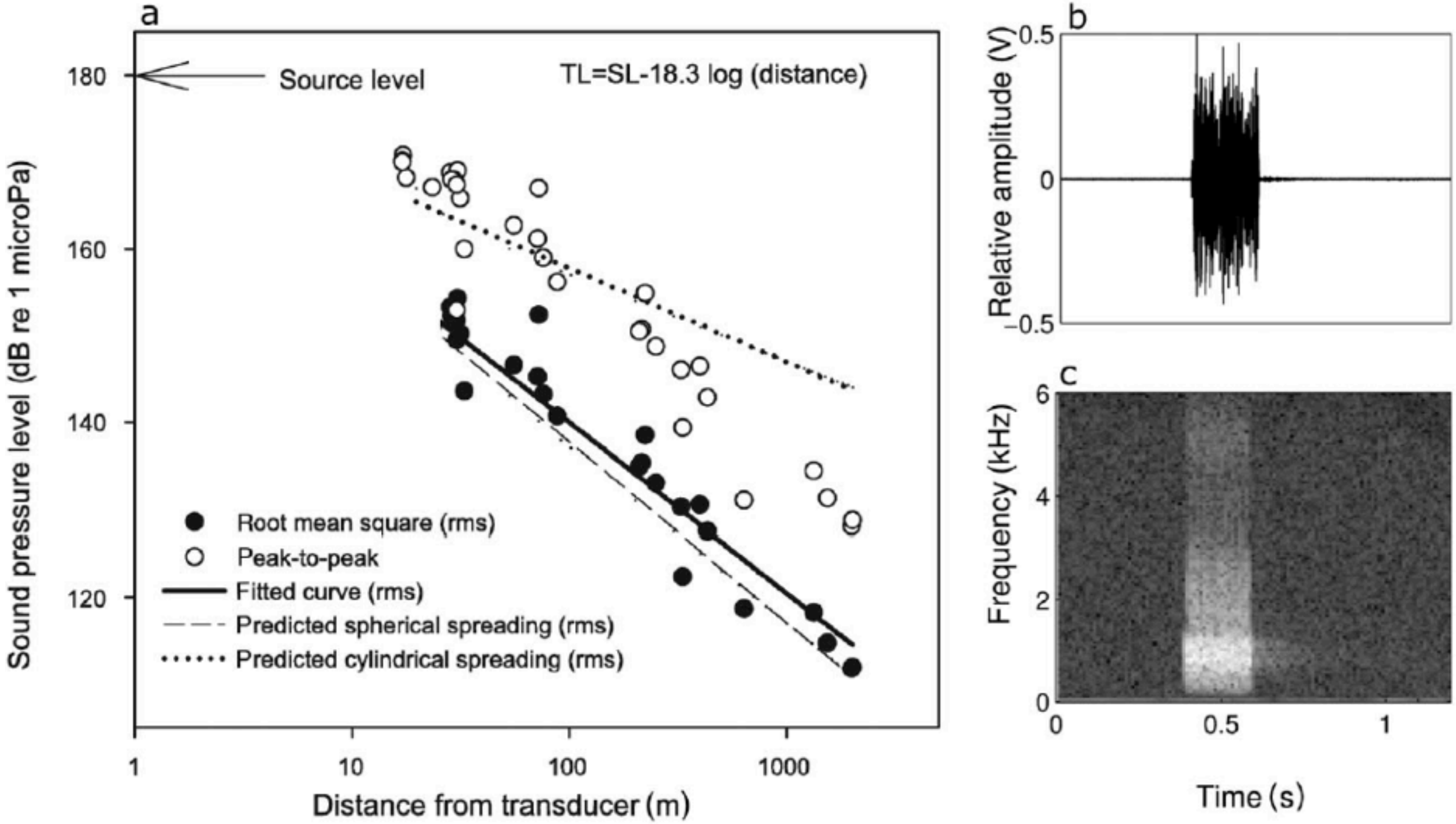
Behavioural responses associated with the startle reflex show sensitization in seals

Animals that showed signs of a startle response (flinch) sensitised (n=5)



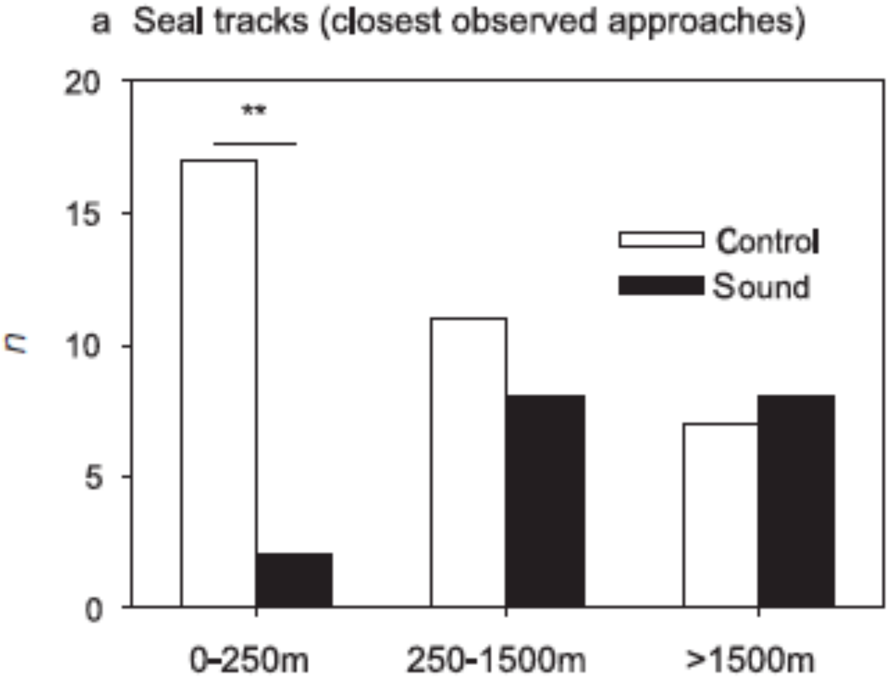
Götz & Janik (2011) BMC Neuroscience 12:30

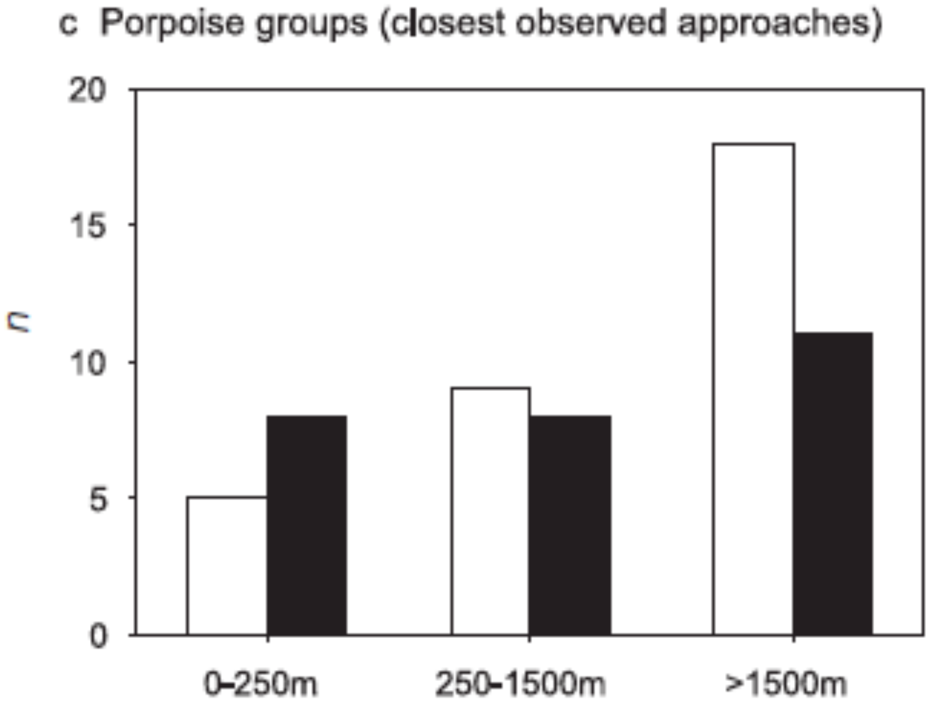
Application of Startle Response Stimulus for Seal ADD



Goetz & Janik 2015 Animal Conservation doi:10.1111/acv.12141

Seals Avoid ADD With Little Effect on Porpoises





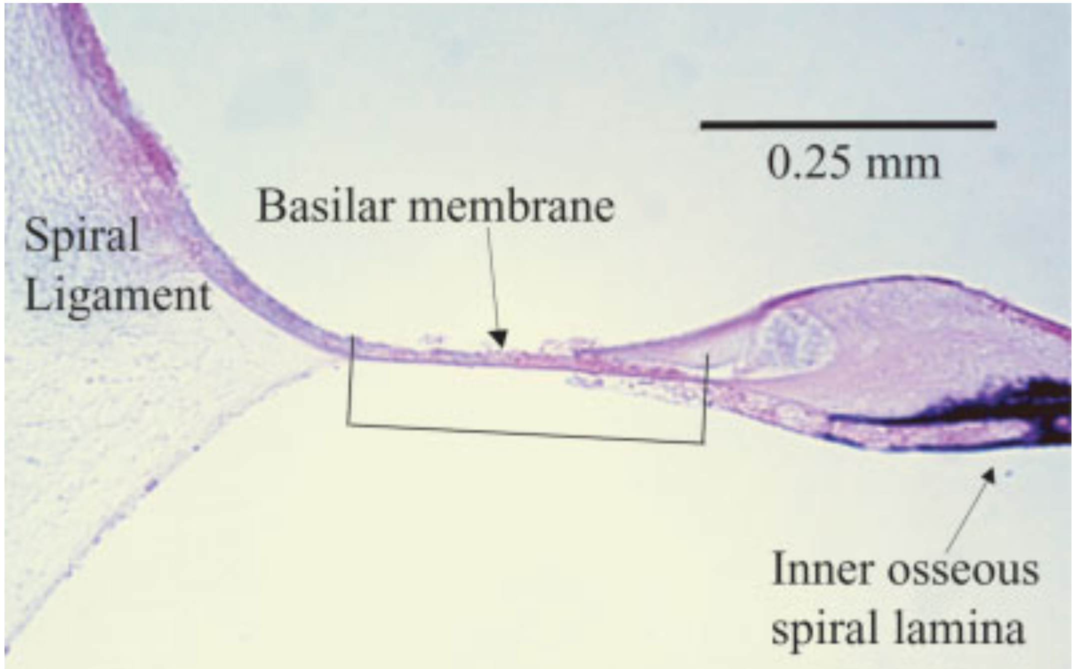
Exposure Durations Posing Risk to Hearing for 180 dB Source 1-2 kHz at 1% duty cycle

- For SPL = 180 dB; 1% duty cycle
- $RL_{@20m}$ = SL – 20 log (range) =180 – 20 log(20) = 154
- Sound Exposure Level (SEL) = SPL + 10 log (t_{sec}) – 10 log(100) = 154 – 20 + 10 log (t_{sec})

Species	Temporary Shift SEL	Time at 20 m	Permanent Shift SEL	Time at 20 m
Seal	183 dB[1]	22h	197 dB[1]	23d
Porpoise	190 dB[2]	4d	210 dB[1]	460d
Delphinid	195 dB[3]	14.5d	215 dB[1]	4y

1. Finneran and Jenkins (2013) 2. Kastelein (2013,2014) for 1.5 kHz tone

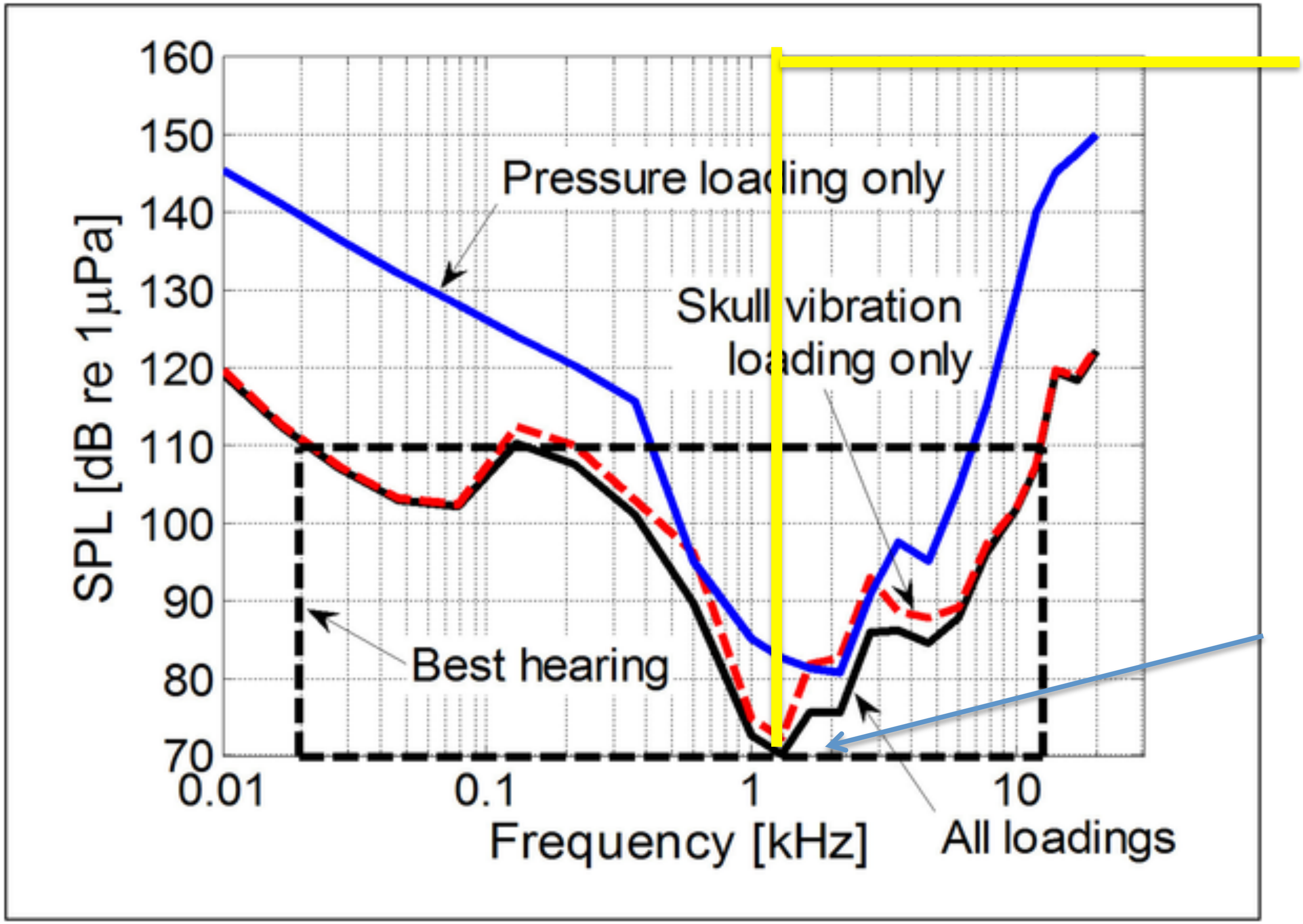
Frequency Range of Hearing Estimated from Mechanical Properties of Basilar Membrane



Position apex to base	Thickness/width	Predicted Freq (Hz)
2%	0.0012	12
50%	0.0125	1440
90%	0.05	18.28

Parks (2007) Anatomical Record 290:734–744

Predicted audiograms for a fin whale calf.



90 dB above Sensation Level suggests SL = 160 dB @ 1m For ASR based ADD

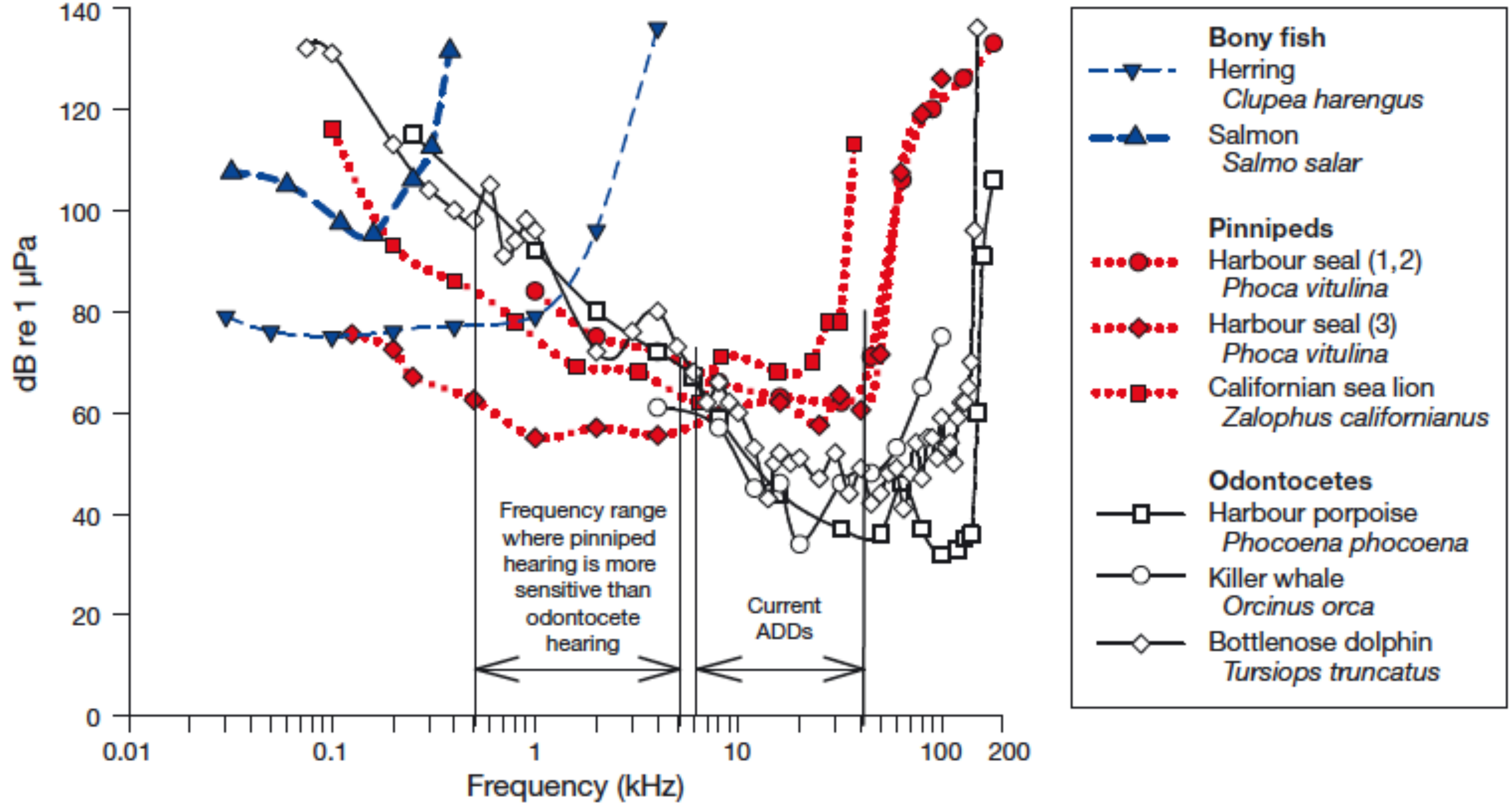
Actual Sensitivity Copied from Delphinid Audiograms

Cranford TW, Krysl P (2015) Fin Whale Sound Reception Mechanisms: Skull Vibration Enables Low-Frequency Hearing. PLoS ONE 10(1): e0116222. doi:10.1371/journal.pone.0116222
http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0116222

Audiogram is Essential for Design of ASR ADD

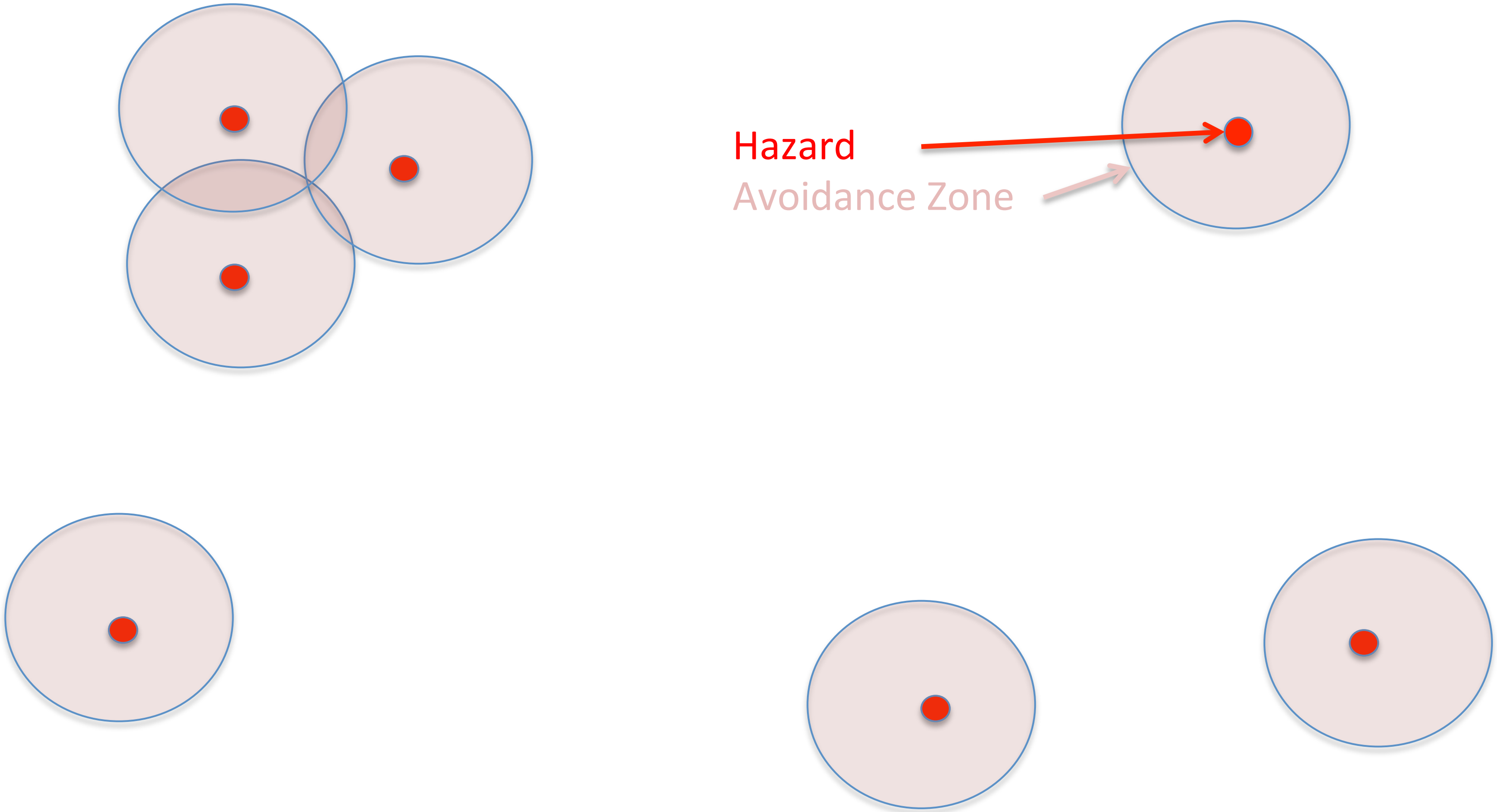
- Cranford & Krysl (2014) fin whale audiogram is estimated from a model with sensitivity equal to odontocete audiogram.
- Actual estimate of sensitivity needs validation in a baleen whale
- Janik and Gotz are planning to study levels of sound that evoke startle response in baleen whales
- Dtag hydrophones will record sound level. Accelerometers will record startle

Select ADD frequency for target species



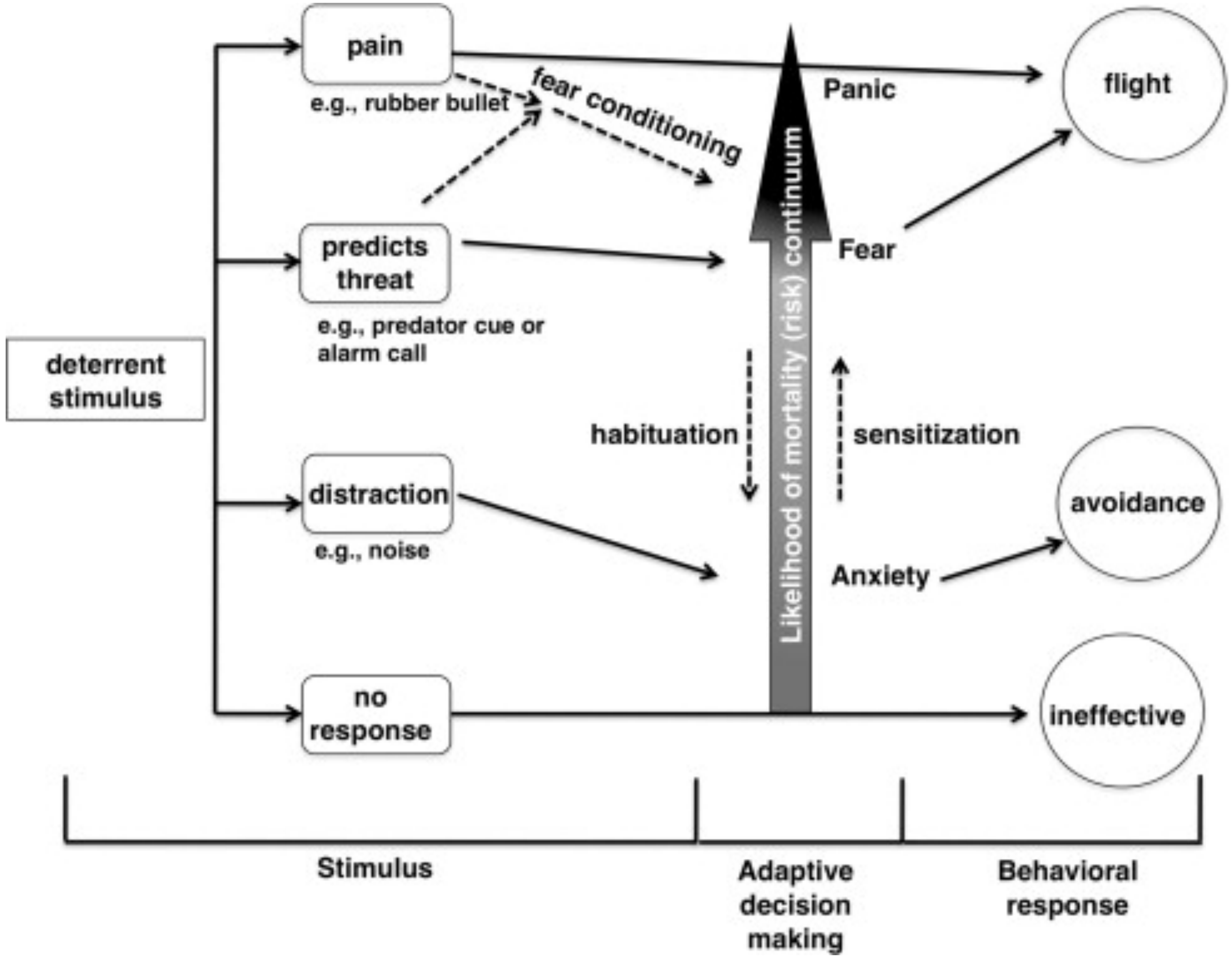
Gotz and Janik 2013 Design of ADDs MEPS 492:285-302

Design Avoidance for Hazard



Benefit of Avoidance Depends on Hazard Distribution

Behavioral Ecology of Deterrence



Schakner and Blumstein (2014) Behavioral Biology of Deterrents. Biol Cons 167:380-389