MODELLING DETECTION PROBABILITIES FOR ODONTOCETE ECHOLOCATION CLICKS

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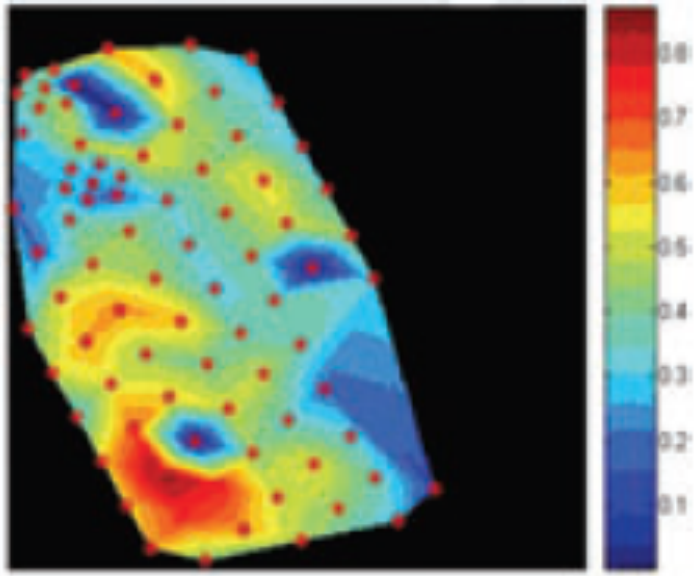
TNO innovation for life

DETECTION PROBABILITIES FOR ECHOLOCATING SPECIES

McCarthy et al. (2011)



Detection probability required for:

- Estimating animal densities

- Monitoring exclusion zone to mitigate effects of loud sound sources

ECHOLOCATION CLICKS

- Many odontocete species use echolocation click for foraging and orientation.
- Stereotyped clicking behavior for some species (e.g. sperm whales, beaked whales)
- High source levels
- Typically broadband (Q > 1)

POPULATION DENSITY ESTIMATION OF ECHOLOCATION CLICKS

Single hydrophone

- Use echolocation clicks as cue → local population density

- For n clicks detected during monitoring time T, population density is:

$$D = \frac{n}{a} \times \frac{(1-c)}{prT}$$

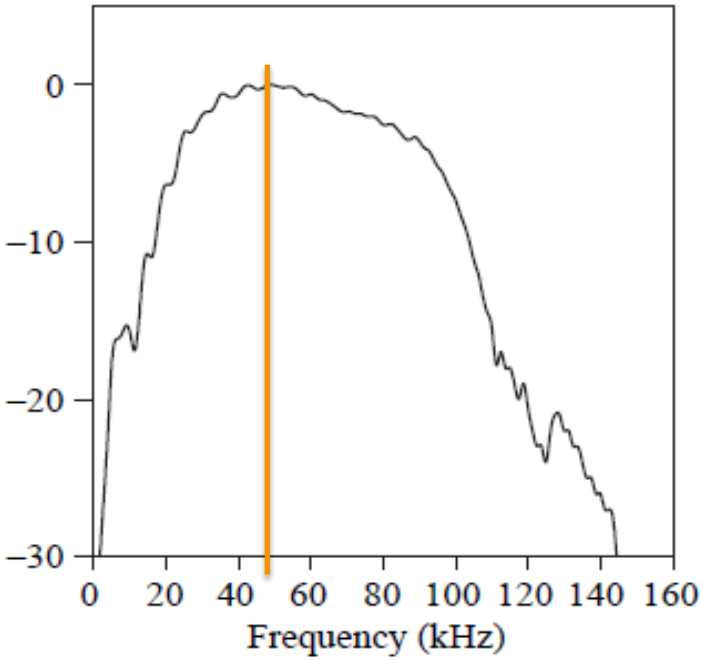
Thomas & Marques (2012), Marques et al. (2013)

- Detection probability p found by *modeling* detection performance using sonar equation and synthetic data, or *empirically* using ground-truth data (e.g. Ward et al. 2008, Marques et al. 2009, von Benda-Beckmann et al. 2010, Küsel et al. 2011, Kyhn et al. 2012, Ainslie, 2013, Matsumoto et al. 2013).

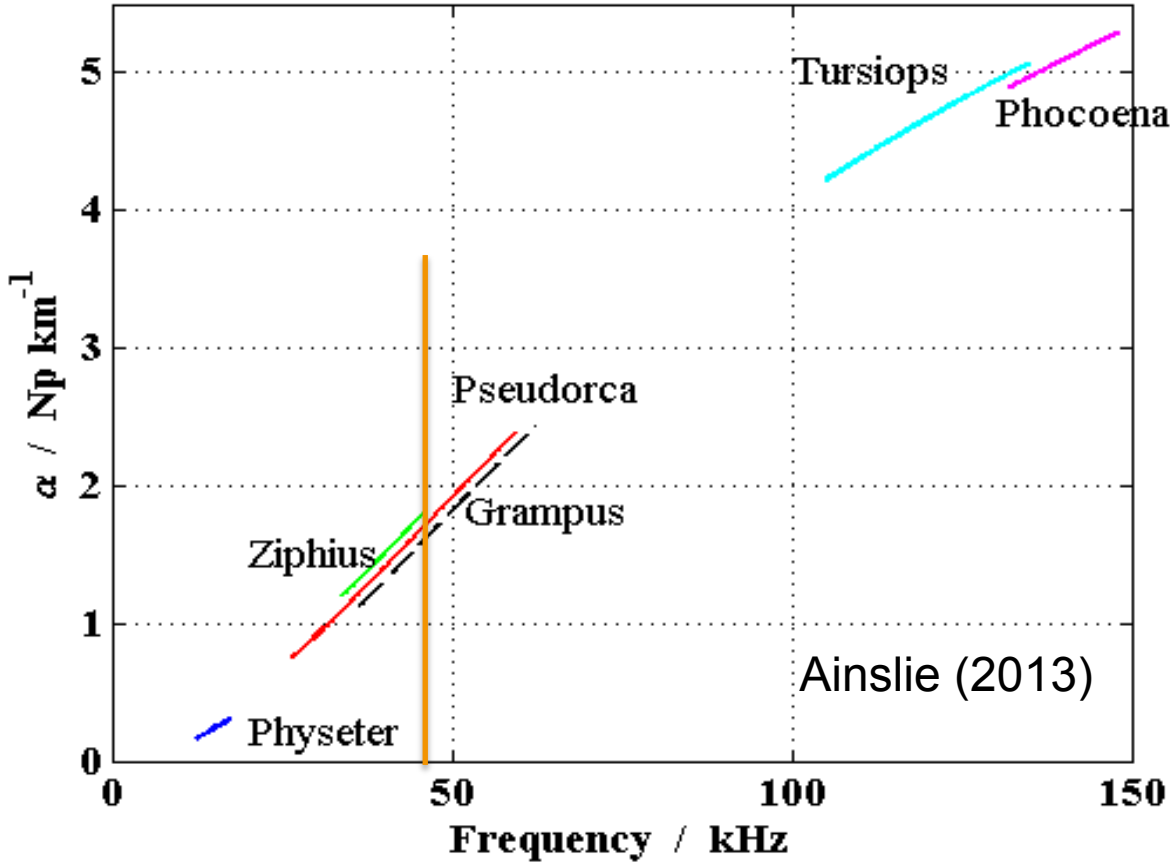
PROPAGATION LOSS FOR BB CLICK (EXAMPLE)

Propagation loss = spreading loss + absorption losses

PL = 20 log (R) + α (f) x (R / 1000 m)



Pseudorca source spectrum (Madsen 2004)



NEGLECTING BROADBAND NATURE OF CLICKS LEADS TO BIASED DENSITY ESTIMATE

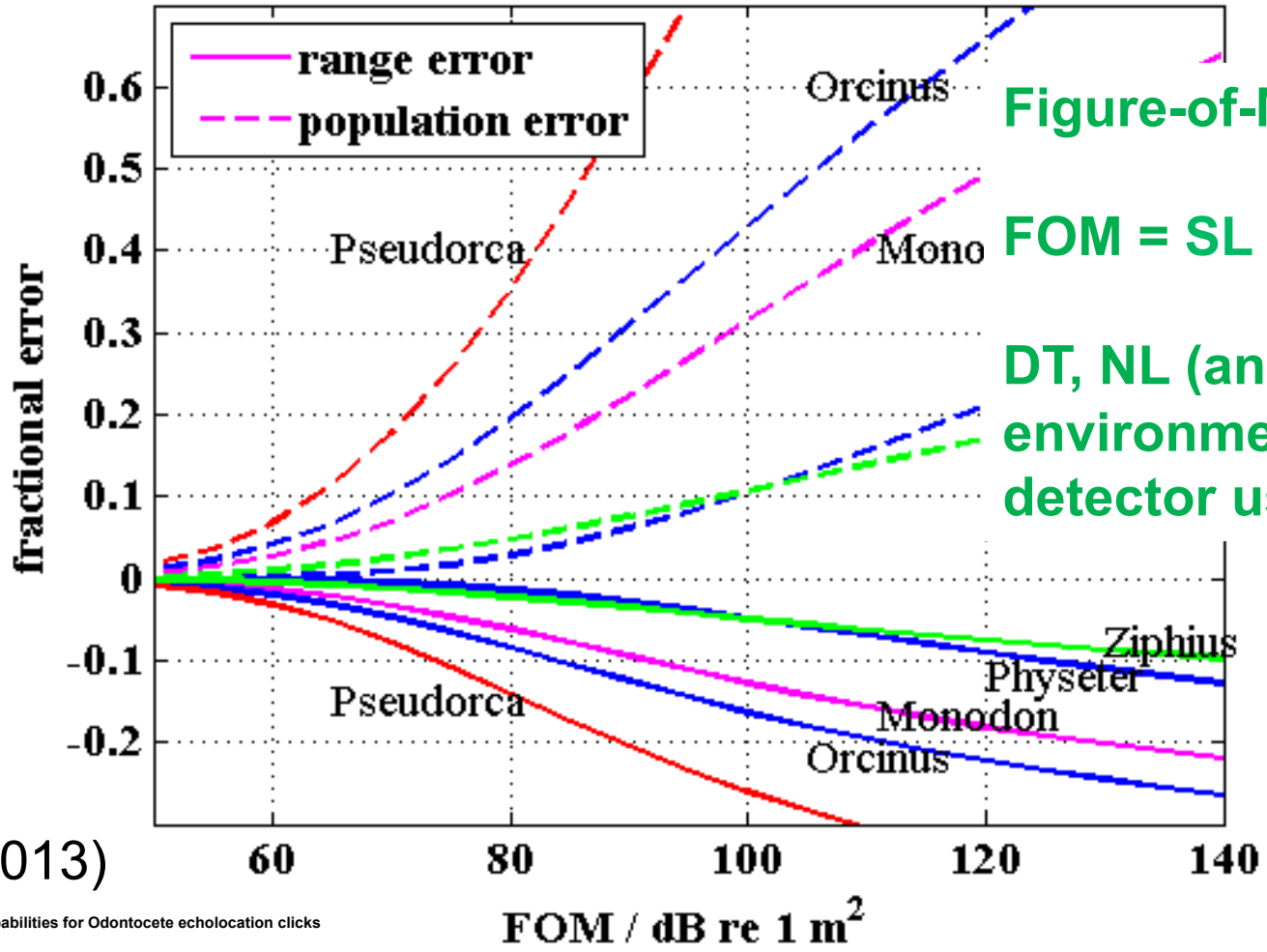


Figure-of-Merit:

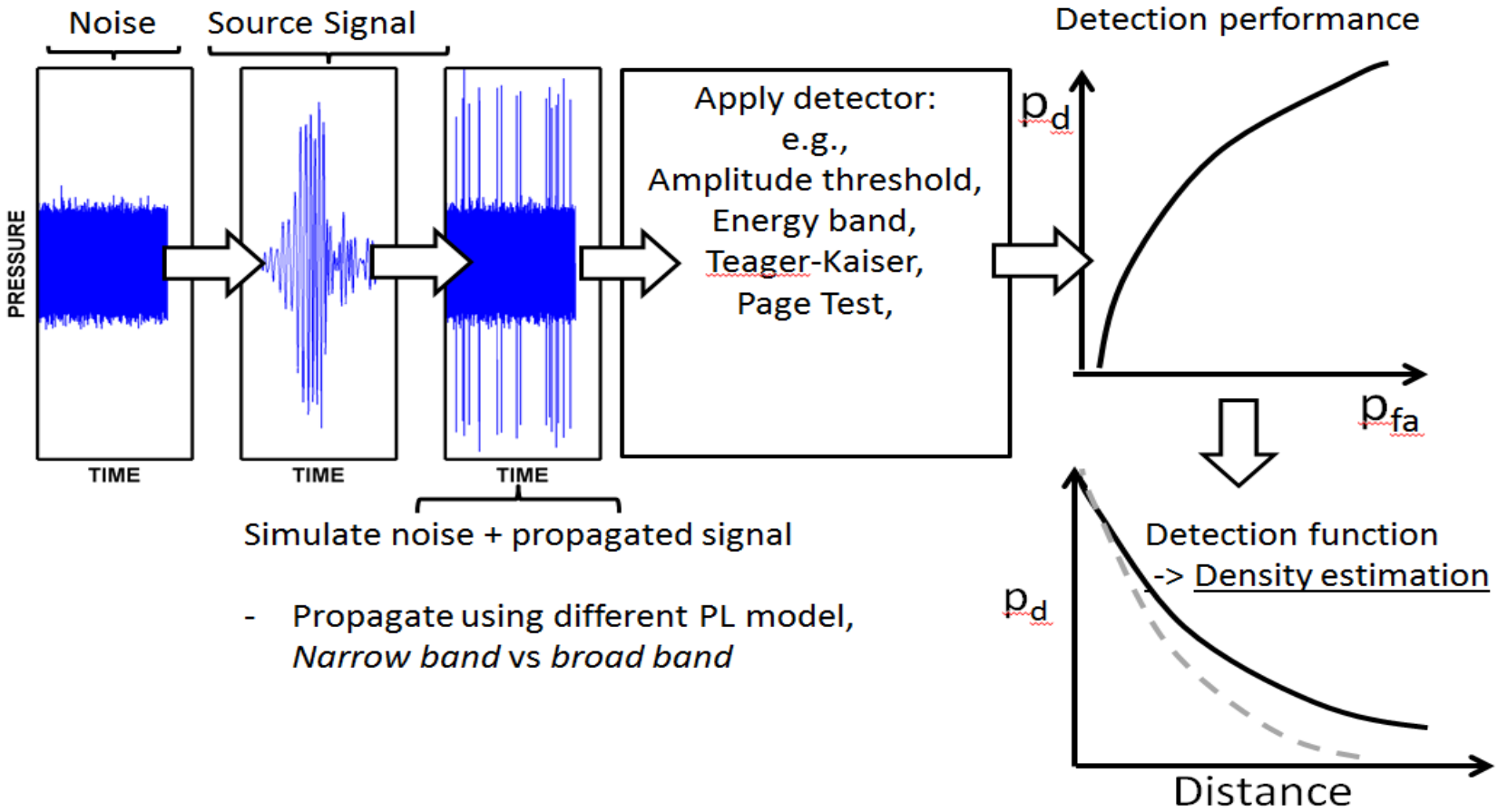
FOM = SL – NL + AG – DT

DT, NL (and AG) depend on environment, system, and detector used.

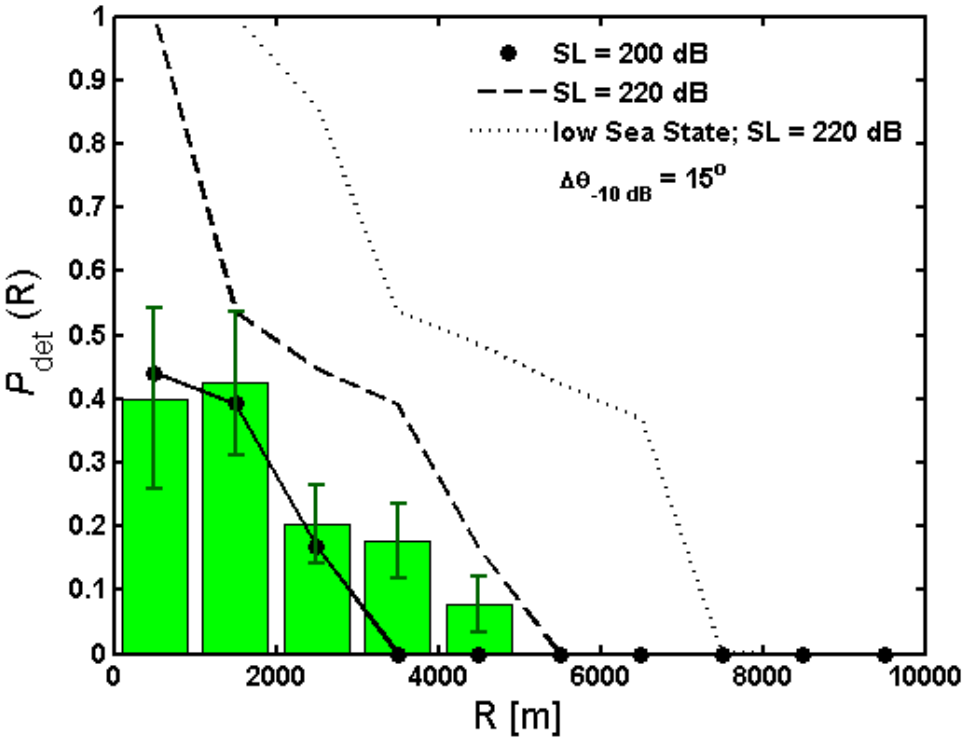
Ainslie (2013)

Modelling detection probabilities for Odontocete echolocation clicks

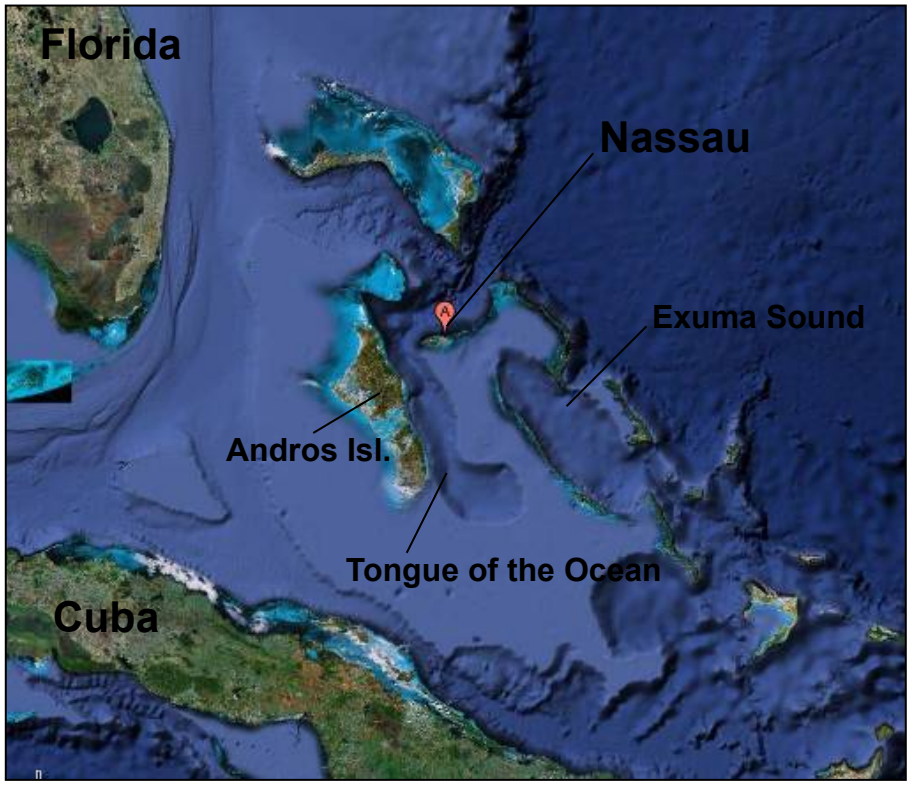
BENCHMARK TOOL FOR DETECTION OF ECHOLOCATION CLICKS



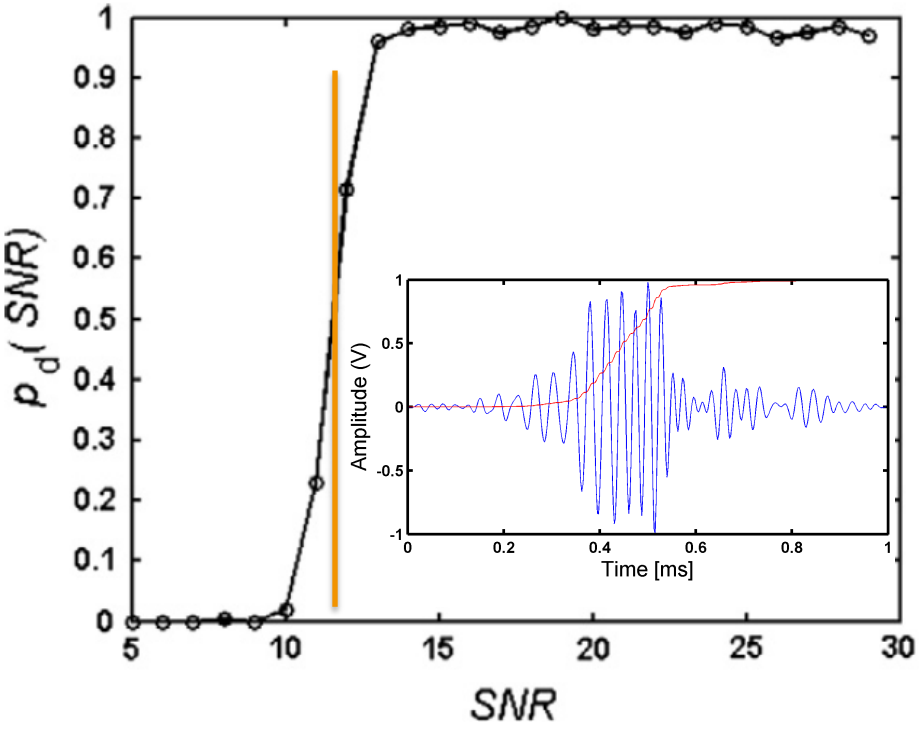
BEAKED WHALE DETECTION FUNCTION – MODEL VS MEASURED

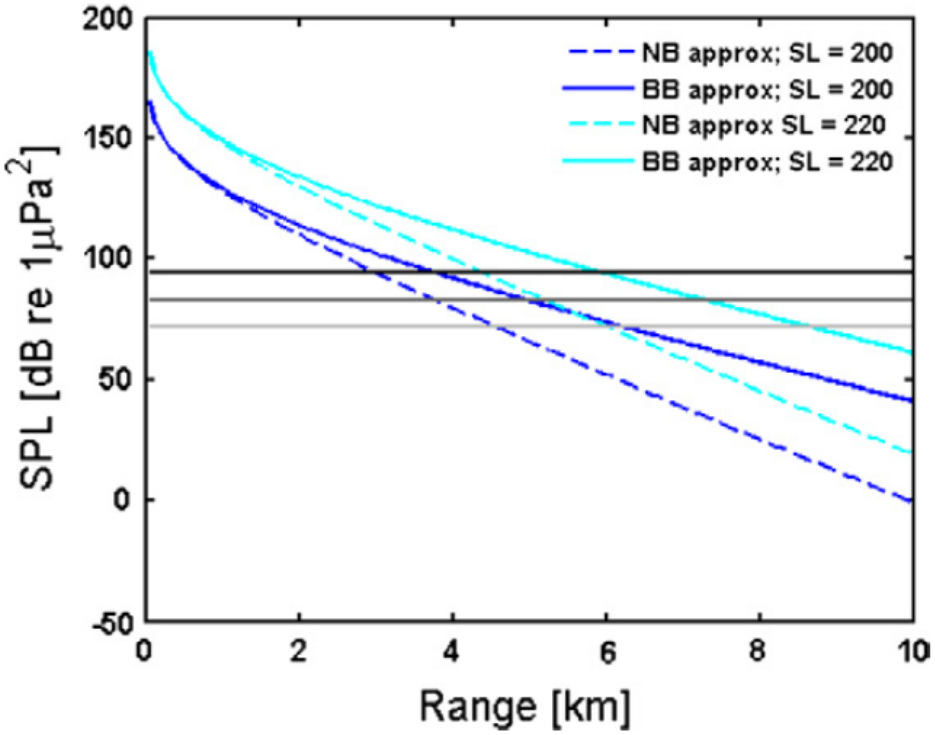


von Benda-Beckmann et al. (2010)



DETECTABILITY OF ECHOLOCATION CLICKS



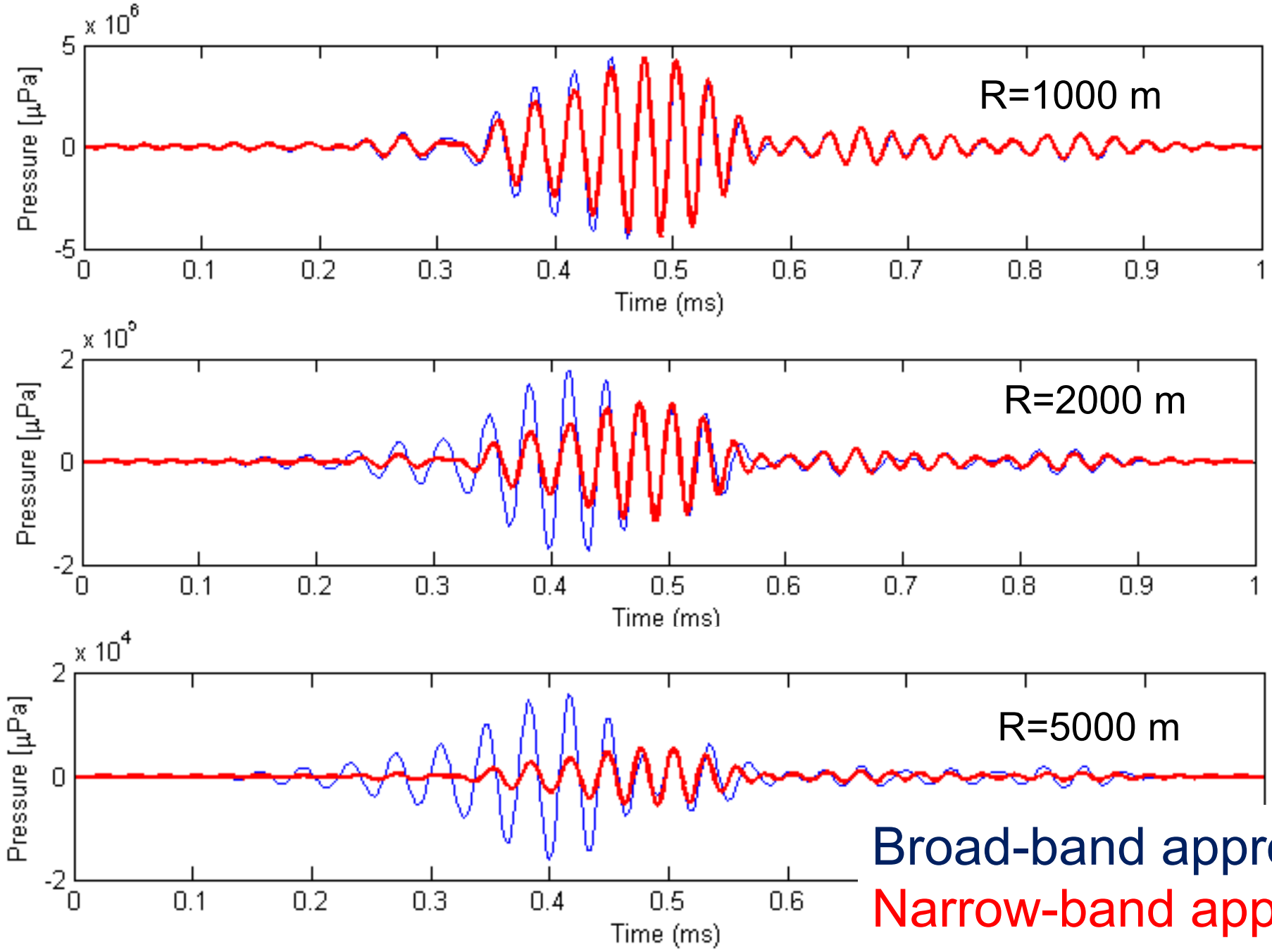


von Benda-Beckmann et al. (2010)

MODELING DETECTION OF BROADBAND ECHOLOCATING CLICKS

- In von Benda-Beckmann et al. (2010)
  - Waveform inserted into measured noise with different SNR
  - Used a Page test detector to detect signals
  - Derived a detection probability of 50% to get DT
  - Then used DT in sonar equation to get detection probability with range R.
  - Neglected false-alarm probability (assumed audited by human operator)

- New approach:
  - Use sonar equation to propagate the source waveform to range R and insert measured noise
  - Use different detectors to get detection probability and false-alarm rate


x 10^6
Pressure [μPa]
Time (ms)
R=1000 m
x 10^5
Pressure [μPa]
Time (ms)
R=2000 m
x 10^4
Pressure [μPa]
Time (ms)
R=5000 m
Broad-band approx.
Narrow-band approx.

CONSIDERATIONS FOR TRANSIENT DETECTOR

- What transient detector used?

Detector	Reference
Pamguard Click detector	Gillespie and Leaper (1995)
FFT energy band detector	Ward et al. (2008)
Power-Law Page test detector	Van IJsselmuide and Beerens (2004)
Matched-filter detector	Ward et al. (2008)
Teager-Kaiser (TK) click detector	Kandia and Stylianou (2005)
Ishmael energy sum click detector	Yack et al. (2010), Mellinger (2001)
Energy Ratio mapping	Klinck and Mellinger, (2011)

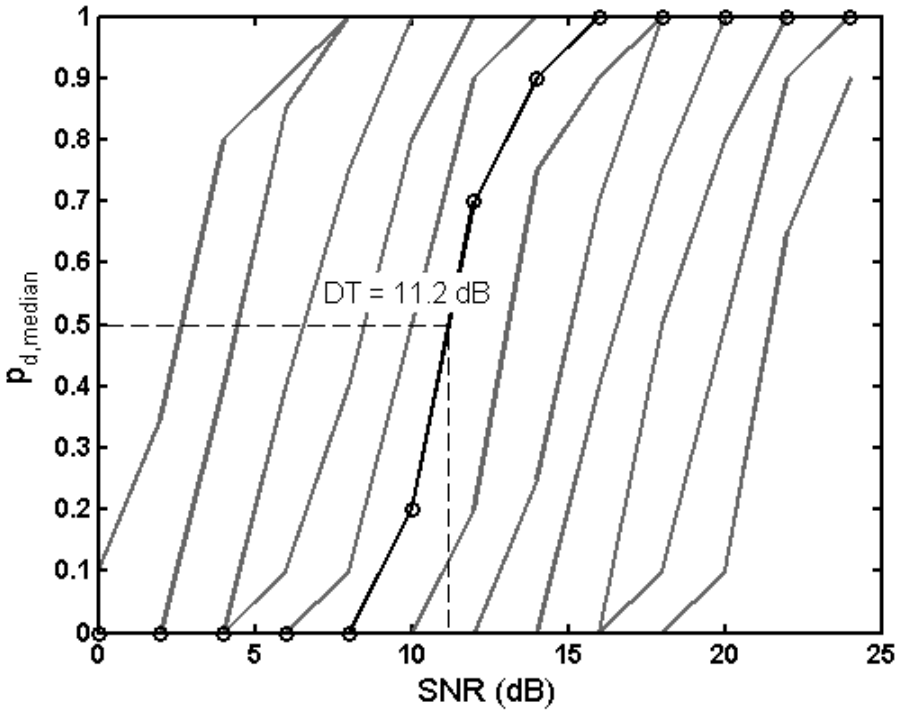
1. Simple subband energy detector (fixed detector threshold)

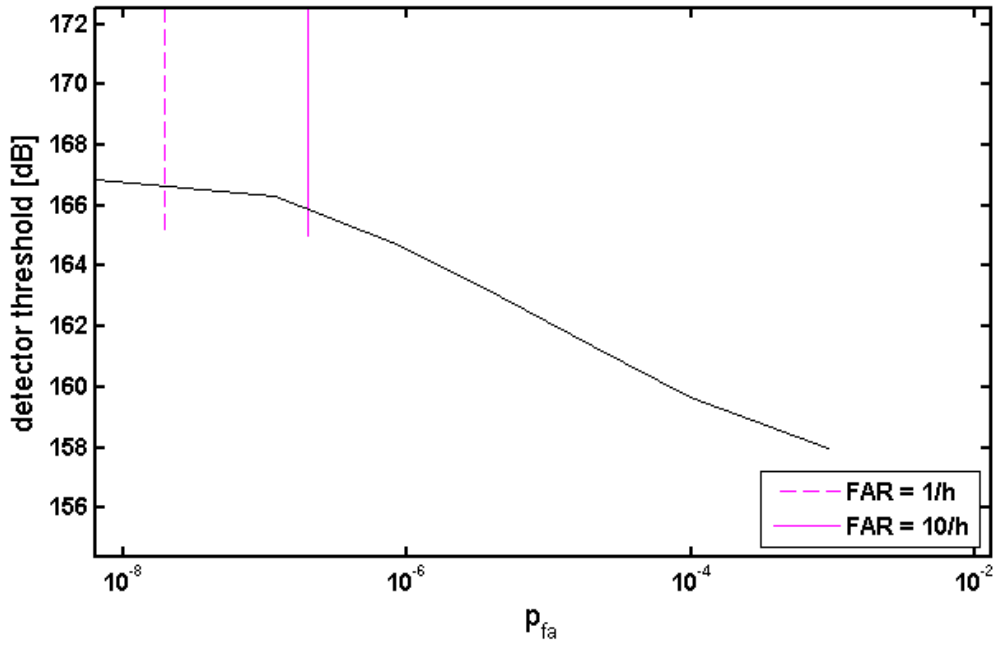
2. Page test detector (adaptive threshold)

CONSIDERATIONS FOR DETECTOR

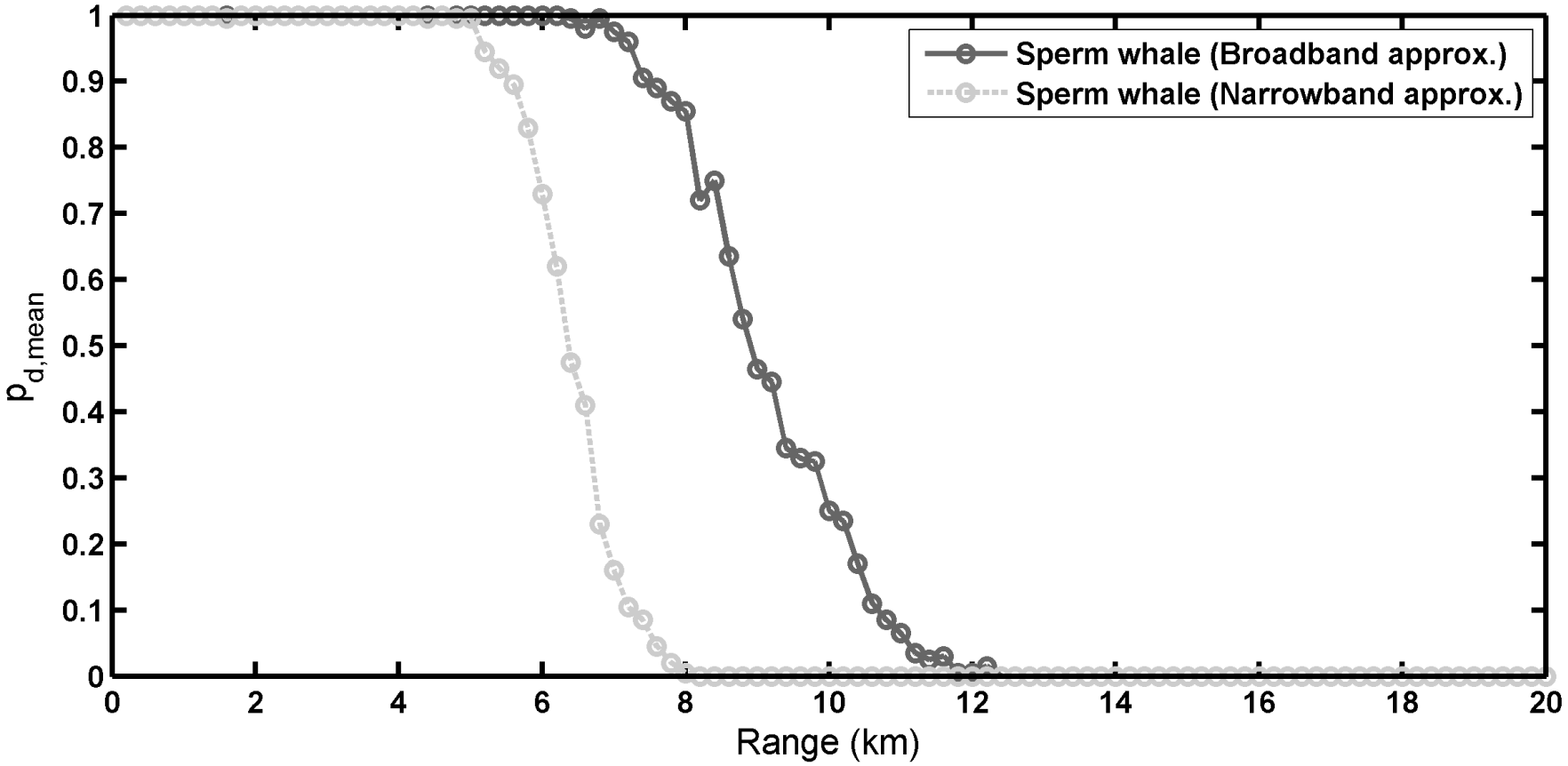
- What transient detector used?
- What detector settings? -> determined by acceptable False-Alarm Rate (FAR)
- With classification/no classification?
- On-edge vs off-axis clicks?

SELECTING DETECTOR THRESHOLD – SUBBAND ENERGY DETECTOR





EXAMPLES DETECTION FUNCTIONS – SUBBAND ENERGY DETECTOR



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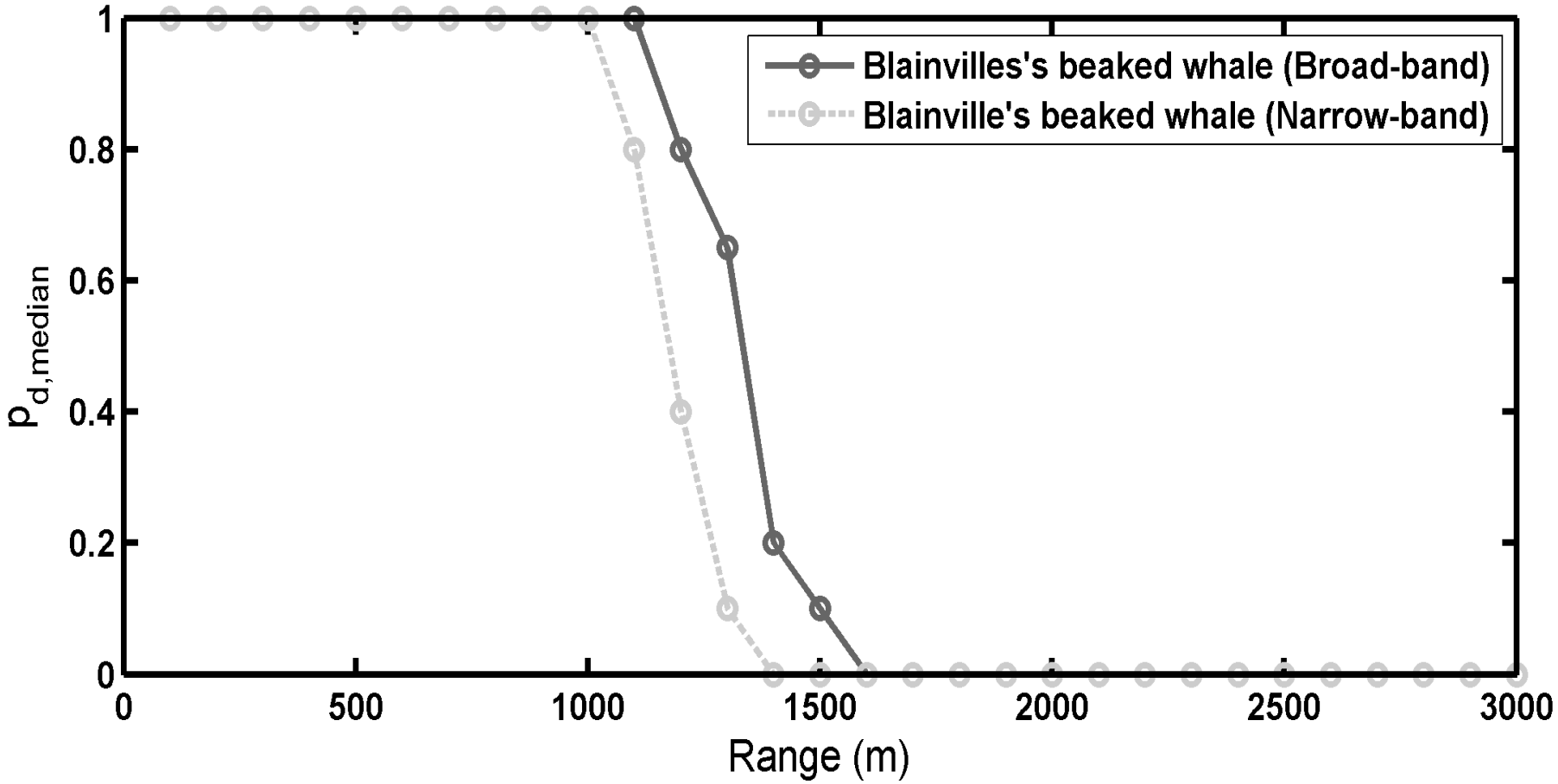

CONCLUSION

- Developed a tool to benchmark detection performance for echolocation clicks
- Oversimplification of propagation loss may lead to bias in modeled detection function of broadband clicks
  - Bias in detection function leads to bias in estimated density!
  - Approximating narrowband leads to underestimation of density
- Bias is species and detector dependent

QUESTIONS?

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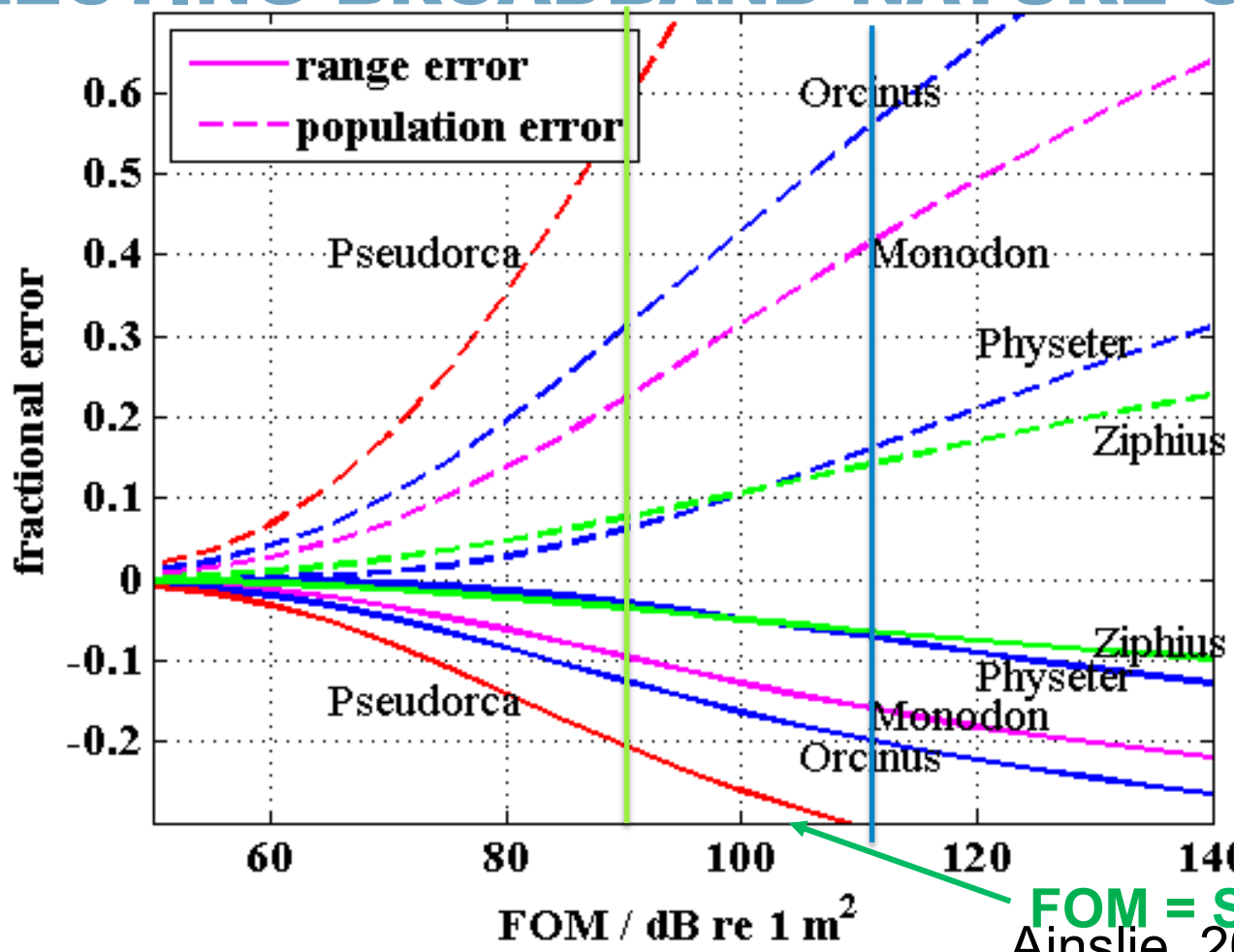
This study was sponsored by ONR (Grant. No. N00014-14-1-0409).

BIAS IN DENSITY ESTIMATE DUE TO NEGLECTING BROADBAND NATURE OF CLICKS



FOM = SL – NL + AG – DT

Ainslie, 2013