   

DE: The State of the Art

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Coauthors

Danielle Harris

Acknowledgements

DECAF
Density Estimation for Cetaceans from passive Acoustic Fixed sensors

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Department for Environment Food and Rural Affairs

[dstl]

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For details, see …

BIOLOGICAL REVIEWS
Cambridge Philosophical Society

Biol. Rev. (2013), **88**, pp. 287–309.
doi: 10.1111/brv.12001

Estimating animal population density using passive acoustics

Tiago A. Marques[1,2,*], Len Thomas[1], Stephen W. Martin[3], David K. Mellinger[4], Jessica A. Ward[5], David J. Moretti[5], Danielle Harris[1] and Peter L. Tyack[6]

For details, see …

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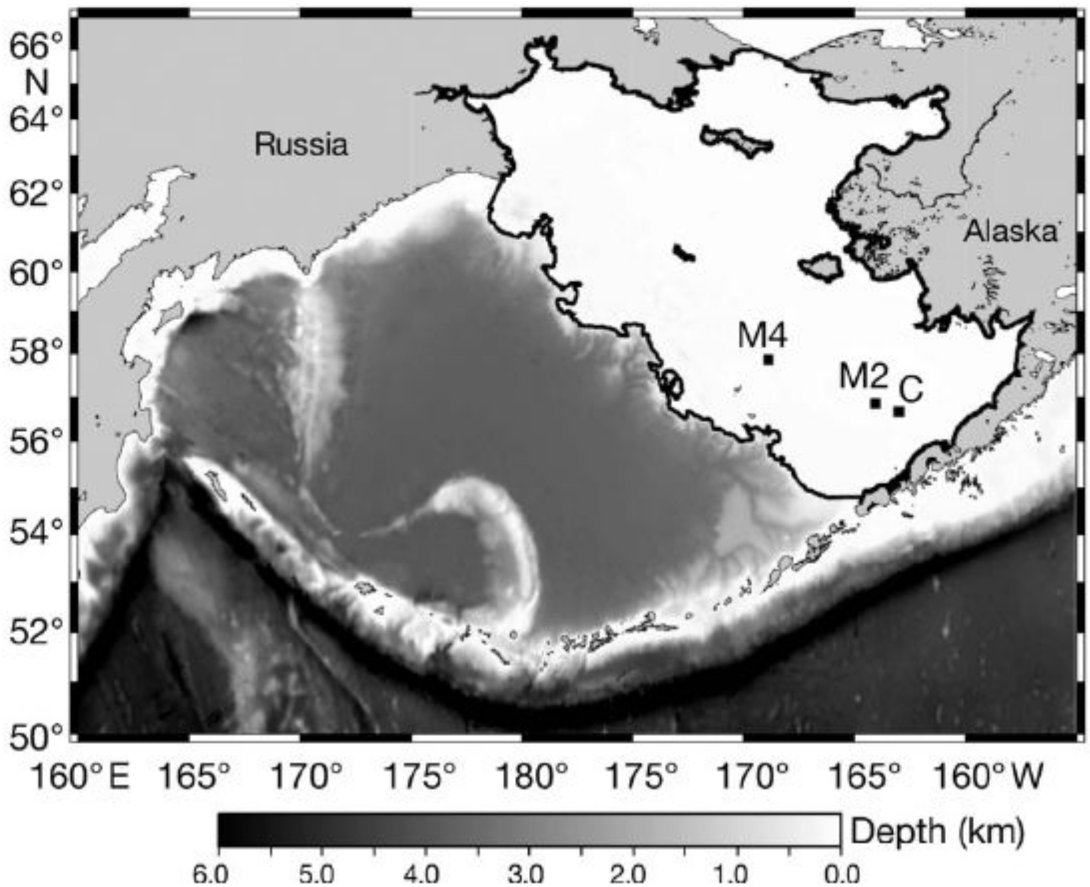
Estimati

passive a

Tiago A. Marque
Jessica A. Ward[5]

Scope of inference



Marques, T. A., Munger, L., Thomas, L., Wiggins, S. & Hildebrand, J. A. (2011) Estimating North Pacific right whale (*Eubalaena japonica*) density using passive acoustic cue counting. Endangered Species Research. 13: 163-172.

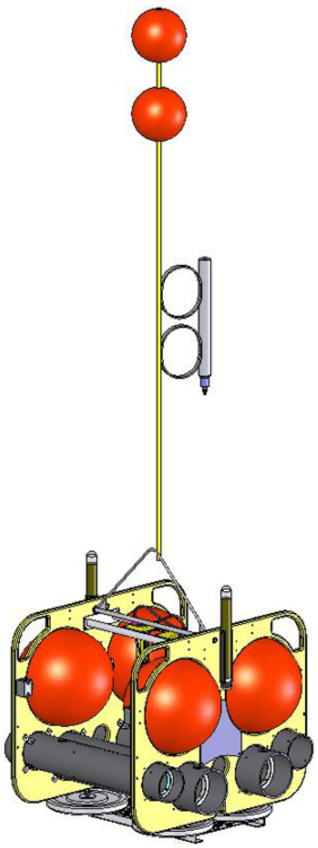
Fundamental requirements

- Randomization
  Random sampling throughout area of inference (in space and time)
- Replication
  Adequate replication of sample units

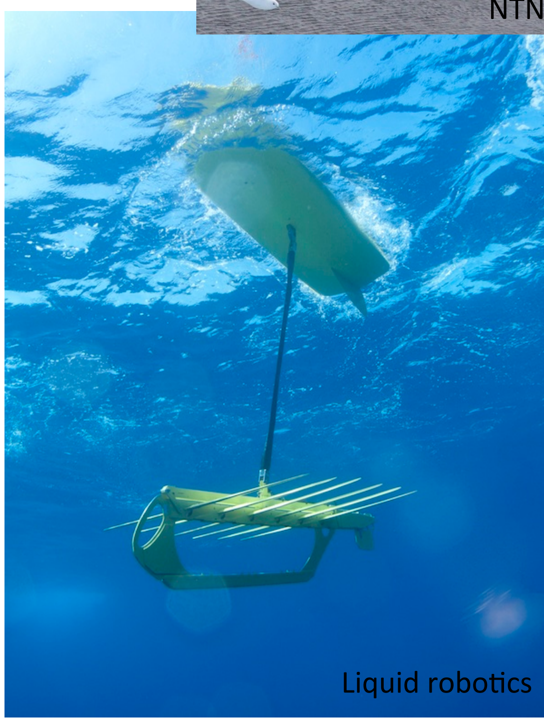
Can be compromised if you use model-based methods

Survey platforms

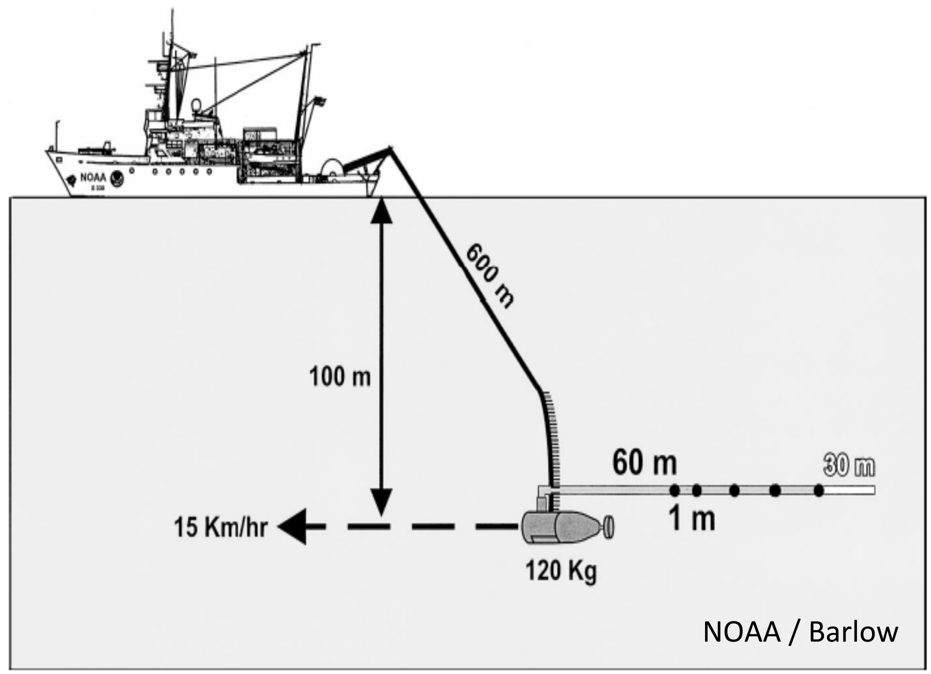
Fixed



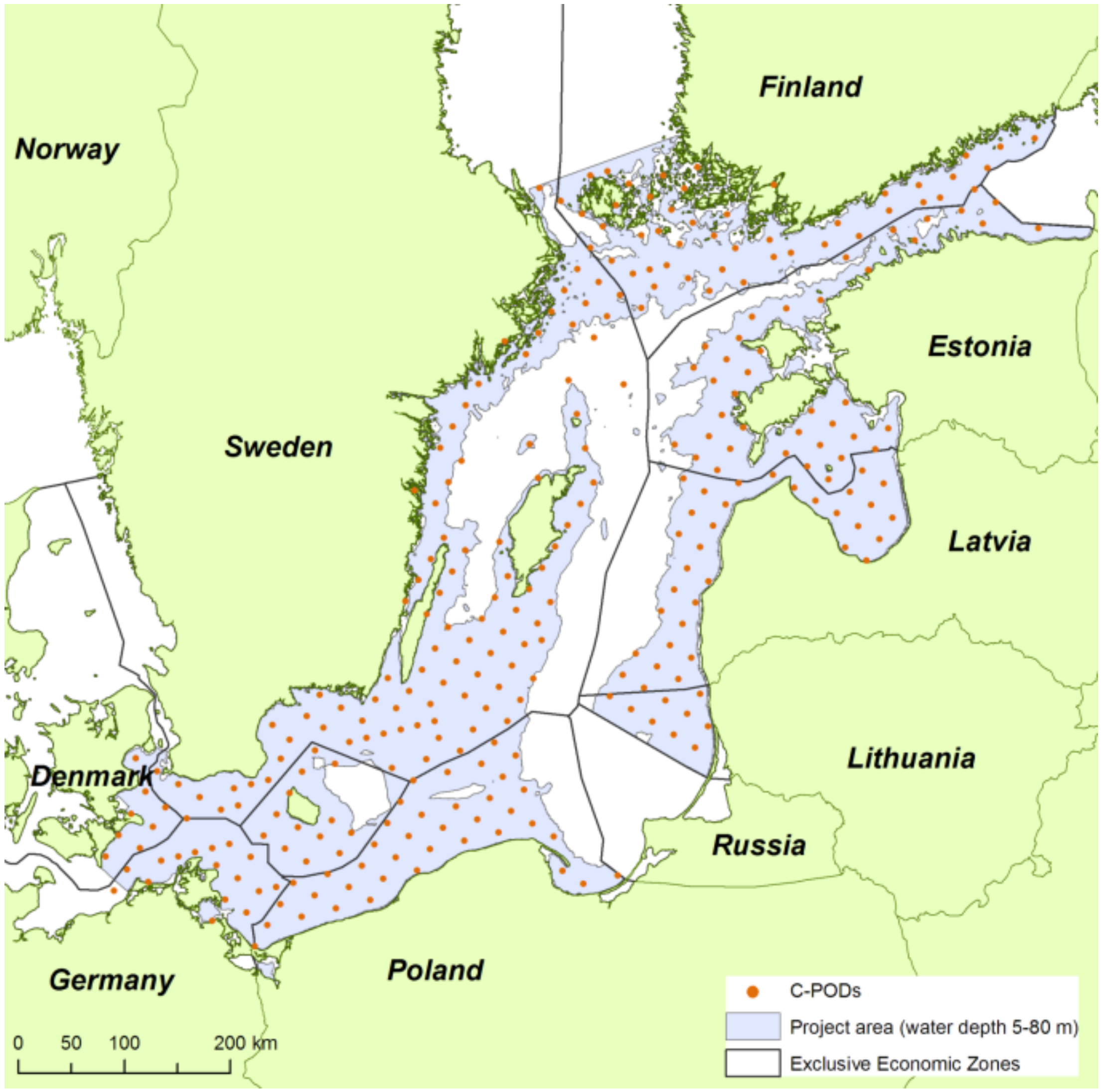
Scripps



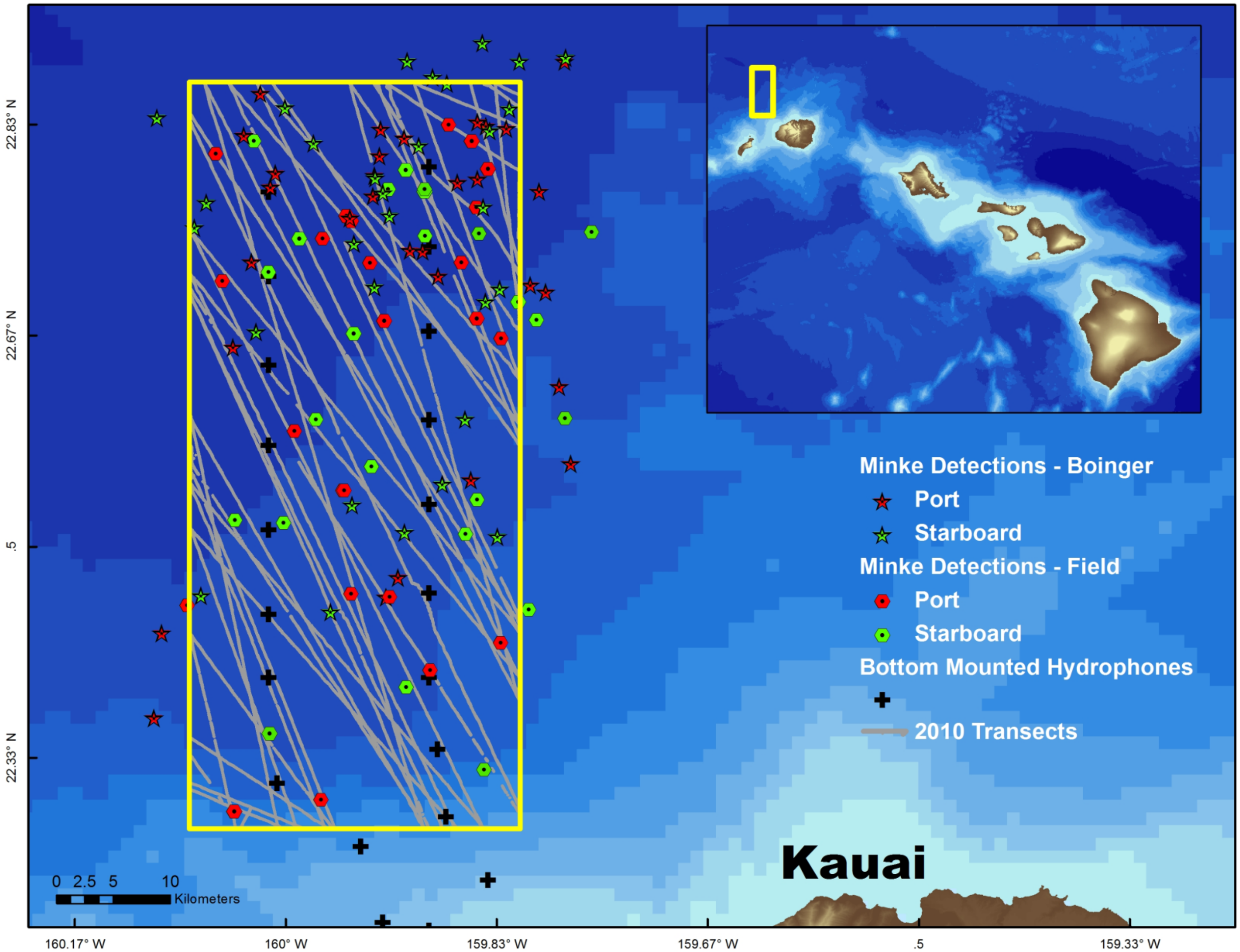
Moving



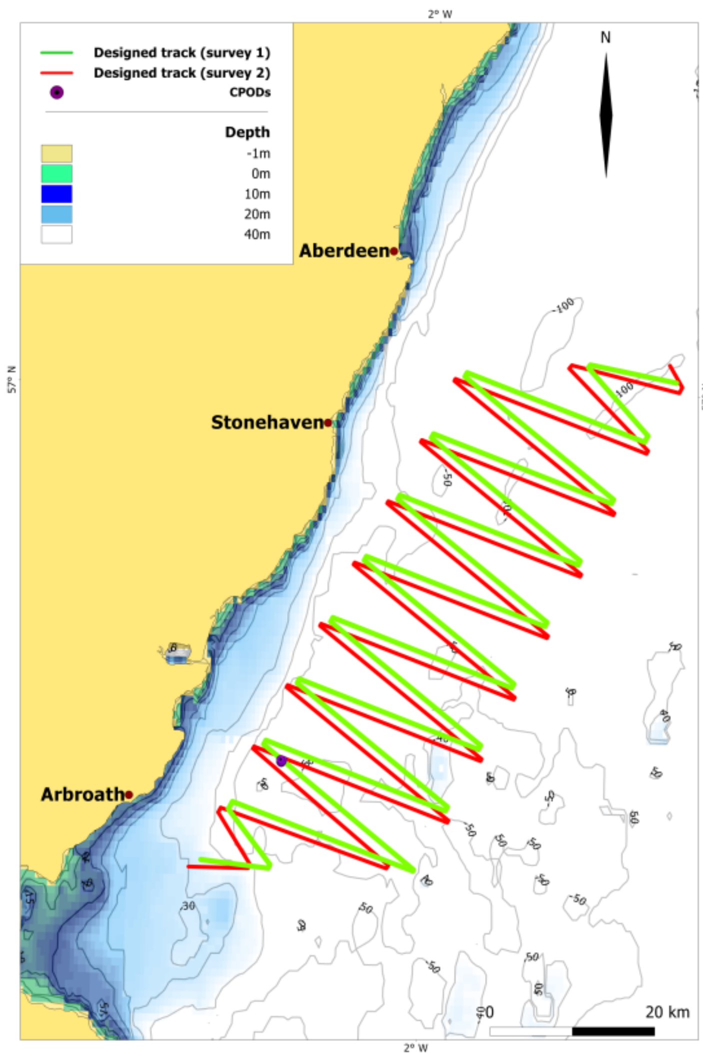
Fixed sensor example: SAMBAH

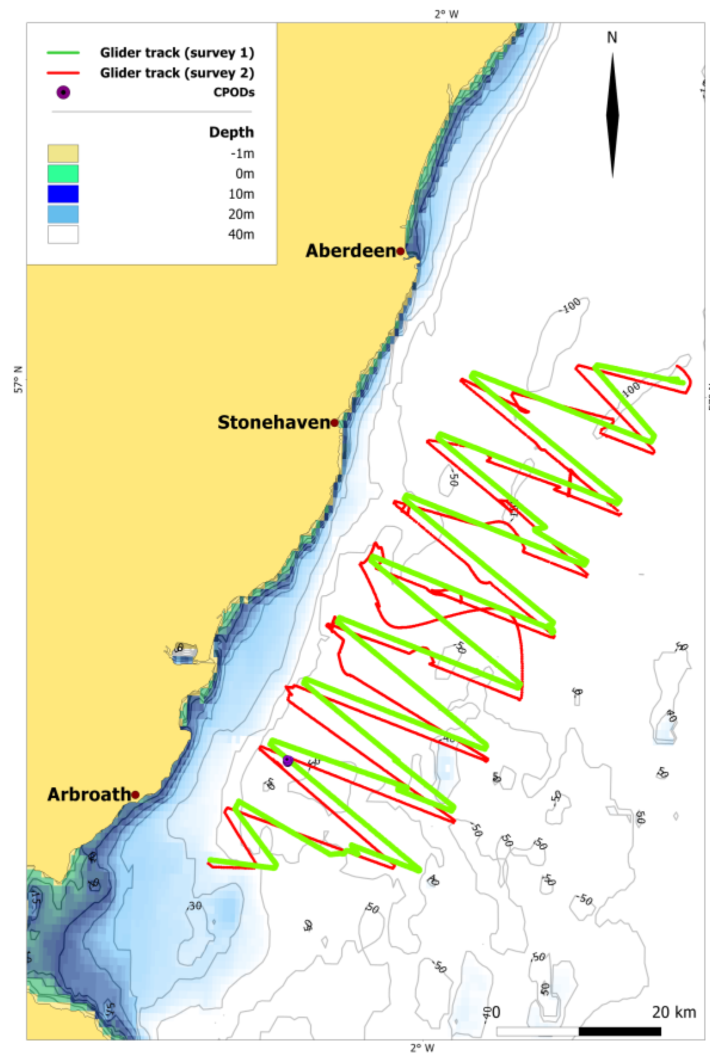


Towed sensor example: BioWaves' Hawaii Minke Survey



Glider example: Tartan waveglider





Canonical formulae

$D = n/a \times z$

$D\downarrow t = n\downarrow t / a \times z\downarrow t$

n→animals
false positives
false negatives

$N = D\,A$

Canonical formulae

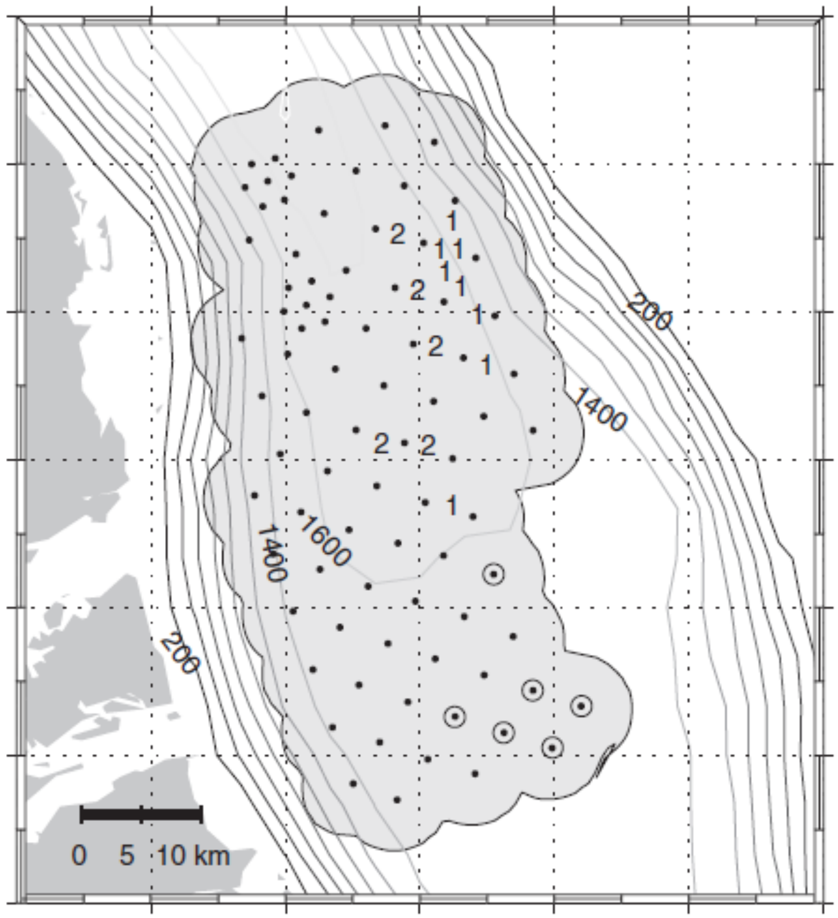
$\text{CV}(D)^2 \approx CV(n)^2 \times CV(z)^2$

n – what to count?

Object	Multiplier required
Vocalizing animal	p(
Vocalizing group	p(
Cue (e.g., vocalization)	cu vo

snapshot vs continuous

Snapshot example: Sperm whales at AUTEC



10 minute "snapshot"

Ward, J.A., L. Thomas, S. Jarvis, N. DiMarzio, D. Moretti, T.A. Marques, C. Dunn, D. Claridge, E. Hartvig and P. Tyack. 2012. Passive acoustic density estimation of sperm whales in the Tongue of the Ocean, Bahamas. Marine Mammal Science 28: E444-E455.

Snapshot example: Sperm whales at AUTEC

number of individuals counted in the 50 samples

proportion of the whole time monitored where sperm whales were possibly present

$$D = n/a \times p_p / t p_v$$

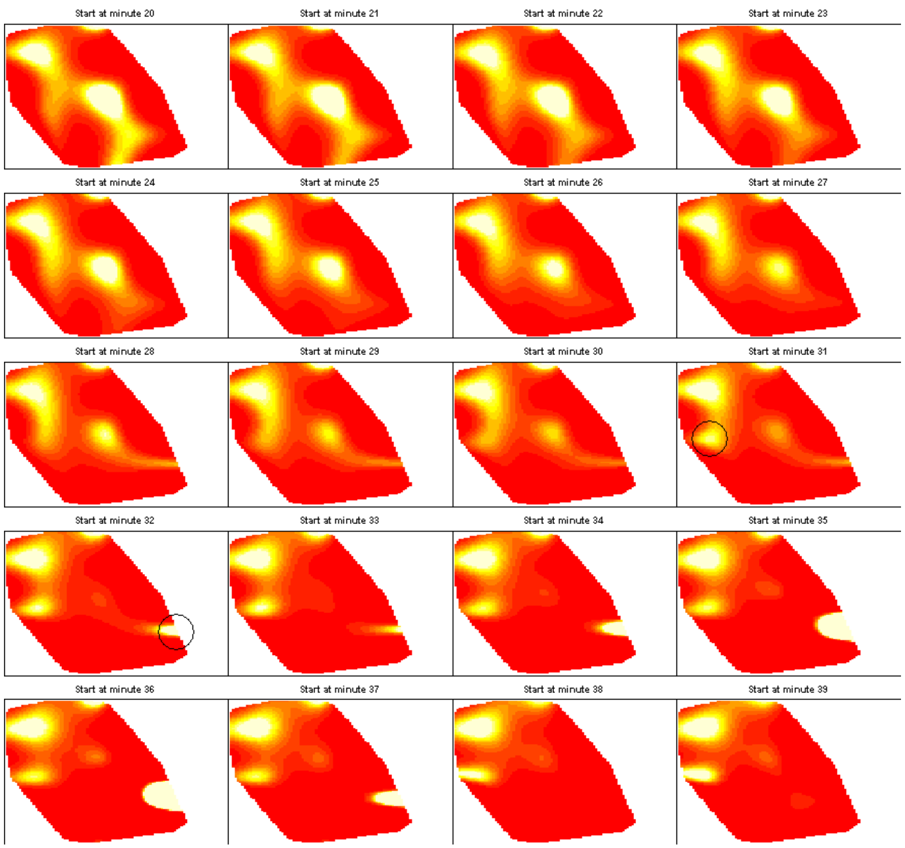
area monitored

number of snapshots (50)

proportion of time whales vocalize in a 10 minute period from 26 tagged whales in GOM and Atlantic

Ward, J.A., L. Thomas, S. Jarvis, N. DiMarzio, D. Moretti, T.A. Marques, C. Dunn, D. Claridge, E. Hartvig and P. Tyack. 2012. Passive acoustic density estimation of sperm whales in the Tongue of the Ocean, Bahamas. Marine Mammal Science 28: E444-E455.

Cue-count example: Blainville's beaked whales at AUTEC – dive starts



cue = start of deep-dive group vocalization

Moretti, D., T.A. Marques, L. Thomas, N. DiMarzio, A. Dilley, R. Morrissey, E. McCarthy, J. Ward and S. Jarvis. 2010. A dive counting density estimation method for Blainville's beaked whale (*Mesoplodon densirostris*) using a bottom-mounted hydrophone field as applied to a Mid-Frequency Active (MFA) sonar operation. Applied Acoustics 71: 1036-1042.

Cue-count example: Blainville's beaked whales at AUTEC – dive starts

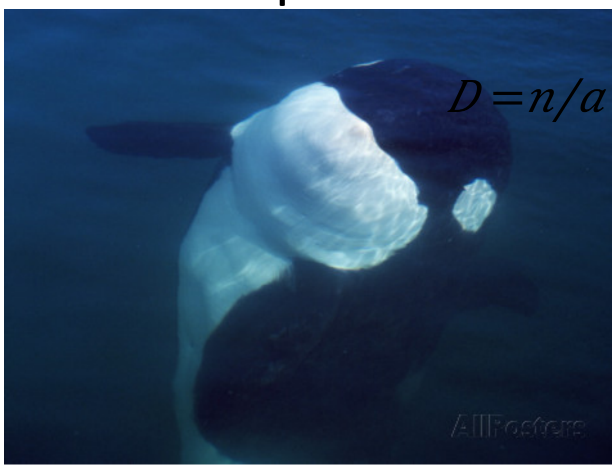
$$D = n/a \times s / Tr$$

- number of dive starts → n
- mean group size from separate visual surveys → s
- area monitored → a
- time spent monitoring → T
- mean dive rate taken from a sample of tagged whales → r

Moretti, D., T.A. Marques, L. Thomas, N. DiMarzio, A. Dilley, R. Morrissey, E. McCarthy, J. Ward and S. Jarvis. 2010. A dive counting density estimation method for Blainville's beaked whale (*Mesoplodon densirostris*) using a bottom-mounted hydrophone field as applied to a Mid-Frequency Active (MFA) sonar operation. Applied Acoustics 71: 1036-1042.

Coping with false positives

True positive



$$D = n/a \times (1 - c)$$

False positive

- "Ground truth" a subsample – *at the level you want estimates (e.g., by month)*
- Are human classifiers a gold standard?
- Multi-species approach

Caillat, M., L. Thomas and D. Gillespie. 2013. The effects of acoustic misclassificaiton on species abundance estimation. Journal of the Acoustical Society of America 134: 2469-2476.

Coping with false negatives

$D = n/a \times 1/p$

Example: Blainville's beaked whales at AUTEC – click counts

number of detected clicks

false positive proportion

$$D = n/a \times (1-c)/p\,T\,r$$

mean click rate taken from a sample of tagged whales

area monitored = $K\pi w \uparrow 2$

sensors

max range

mean detection prob within area monitored from tagged whales

time spent monitoring

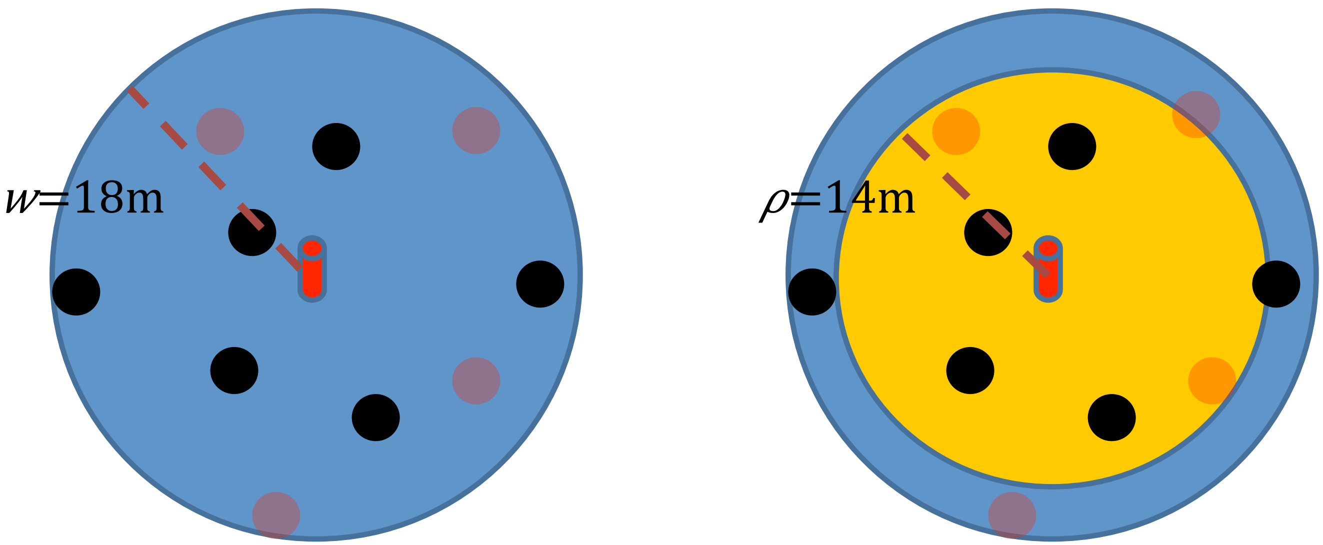
Marques, T.A., L. Thomas, J. Ward, N. DiMarzio, P. L. Tyack. 2009. Estimating cetacean population density using fixed passive acoustic sensors: an example with beaked whales. Journal of the Acoustical Society of America 125: 1982-1994.

Effective detection area

$$\hat{D} = \frac{n(1-\hat{c})}{\pi w^2 \hat{p}} = \frac{n(1-\hat{c})}{\pi \rho^2} = \frac{n(1-\hat{c})}{\hat{v}}$$

Effective detection radius

Effective detection area



$\pi w^2 = 1000 m^2$ $p = 0.6$

$v = 600 m^2$

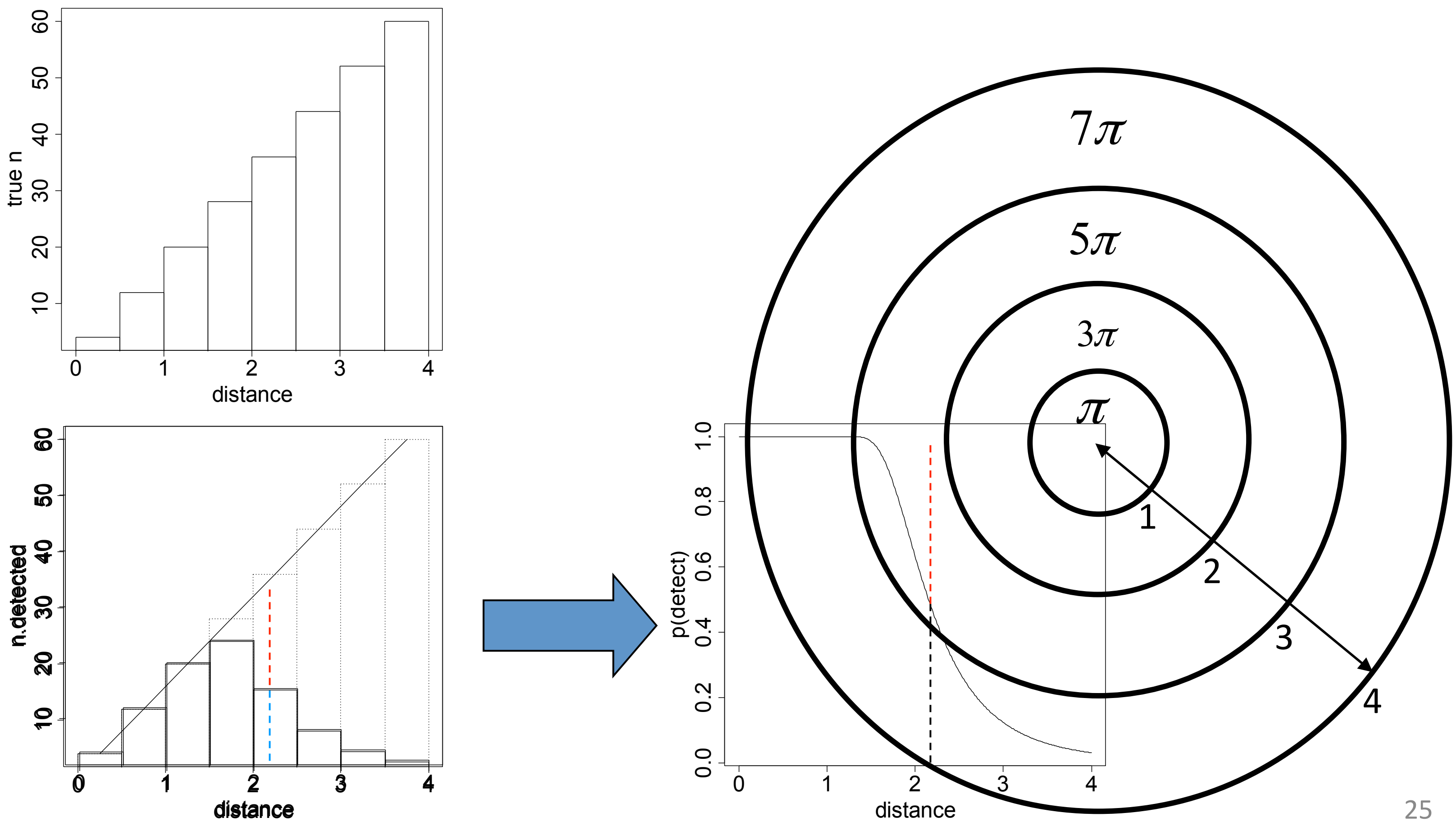
Estimating *p*

- Collect additional information o e of) detections
  - range → distance sam
  - association (dete multiple phones) → SECR
- Auxiliar
  - imals at known locations
  - stic modelling

Other Methods Exist

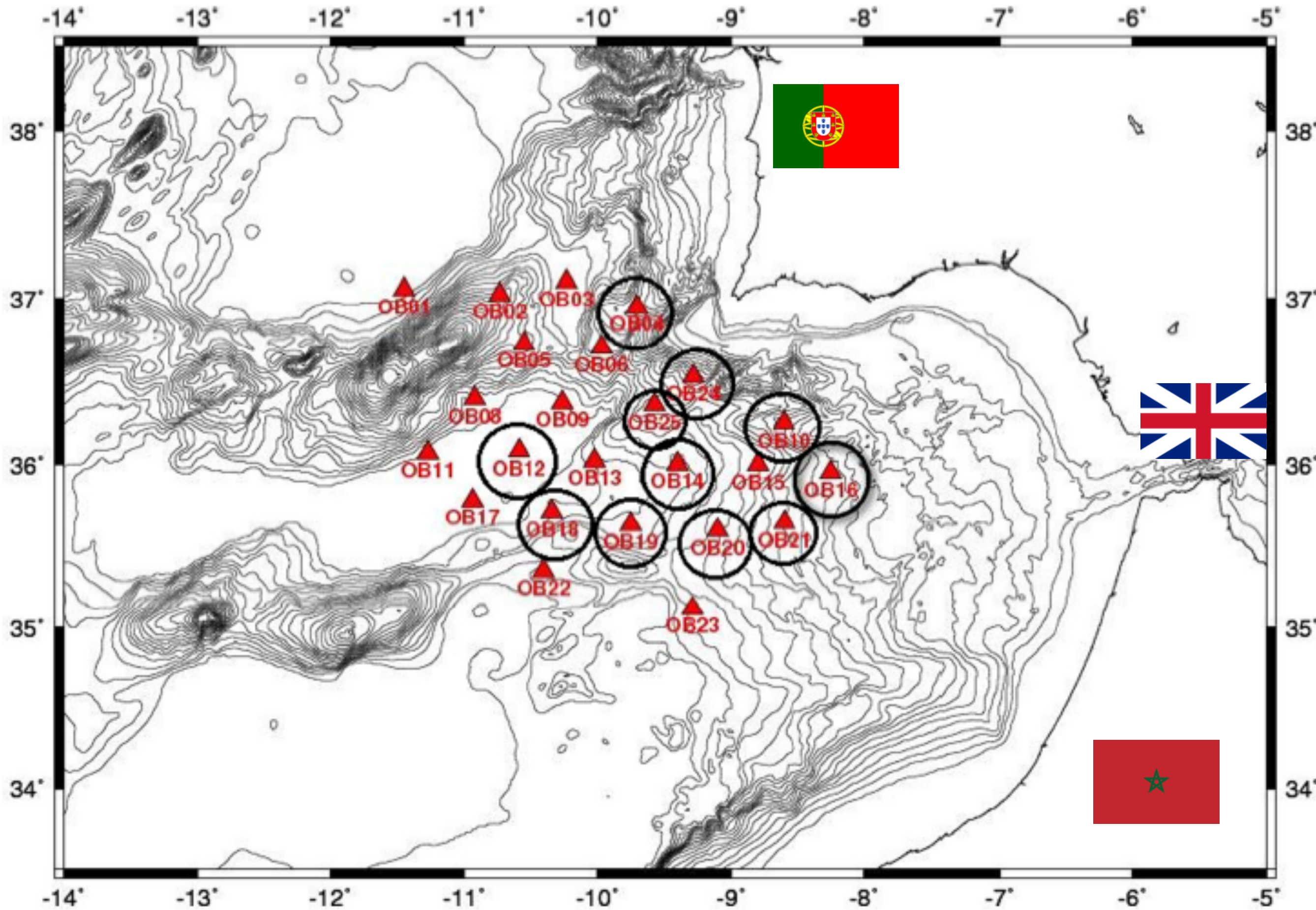
Distance sampling

- Need (a) accurate distances to detected objects; (b) "randomly" placed hydrophones; (c) stationary objects; (d) perfect detection at 0 distance



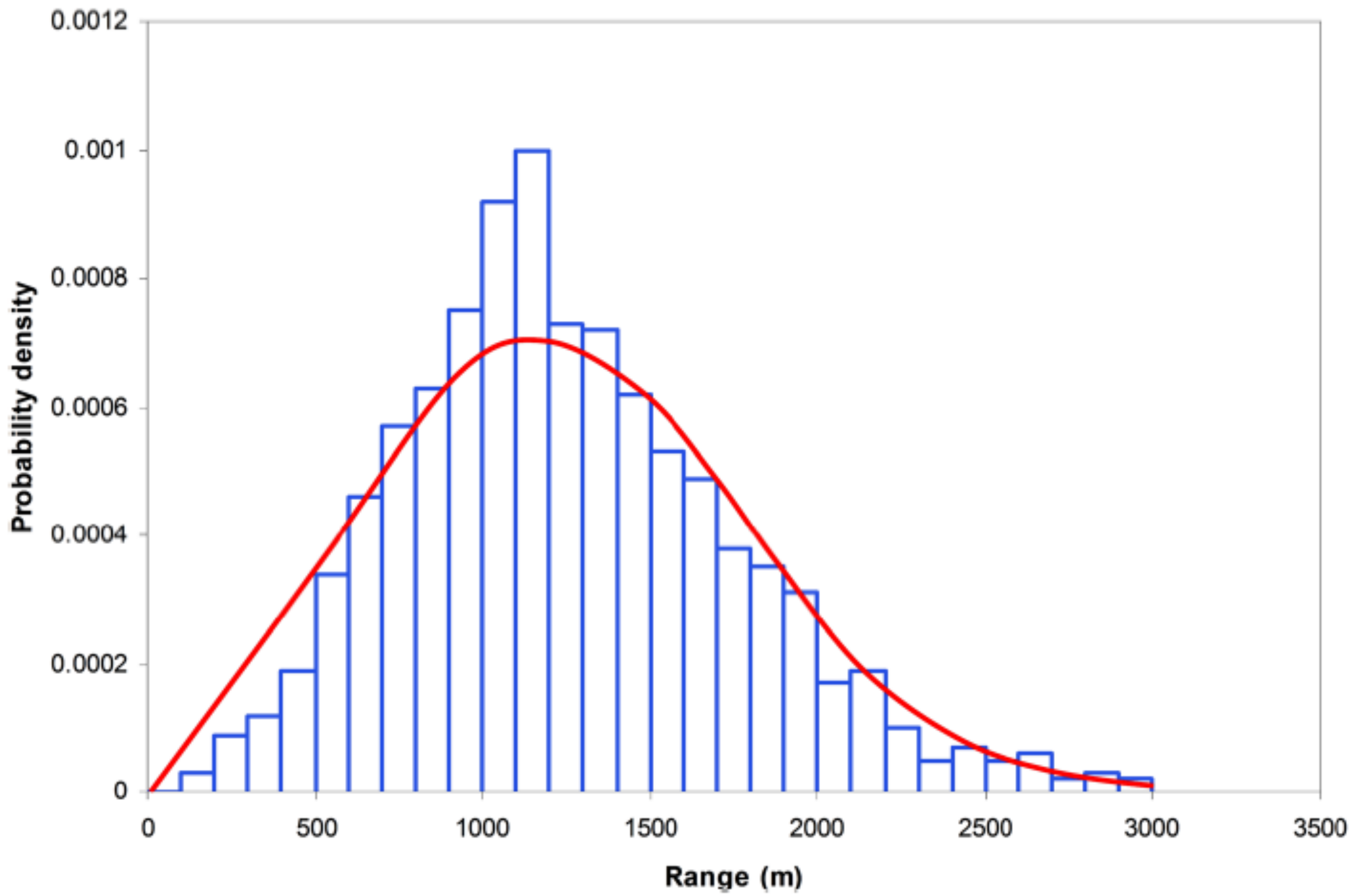
Example: Fin whale calls in Atlantic

OBS
Sensors



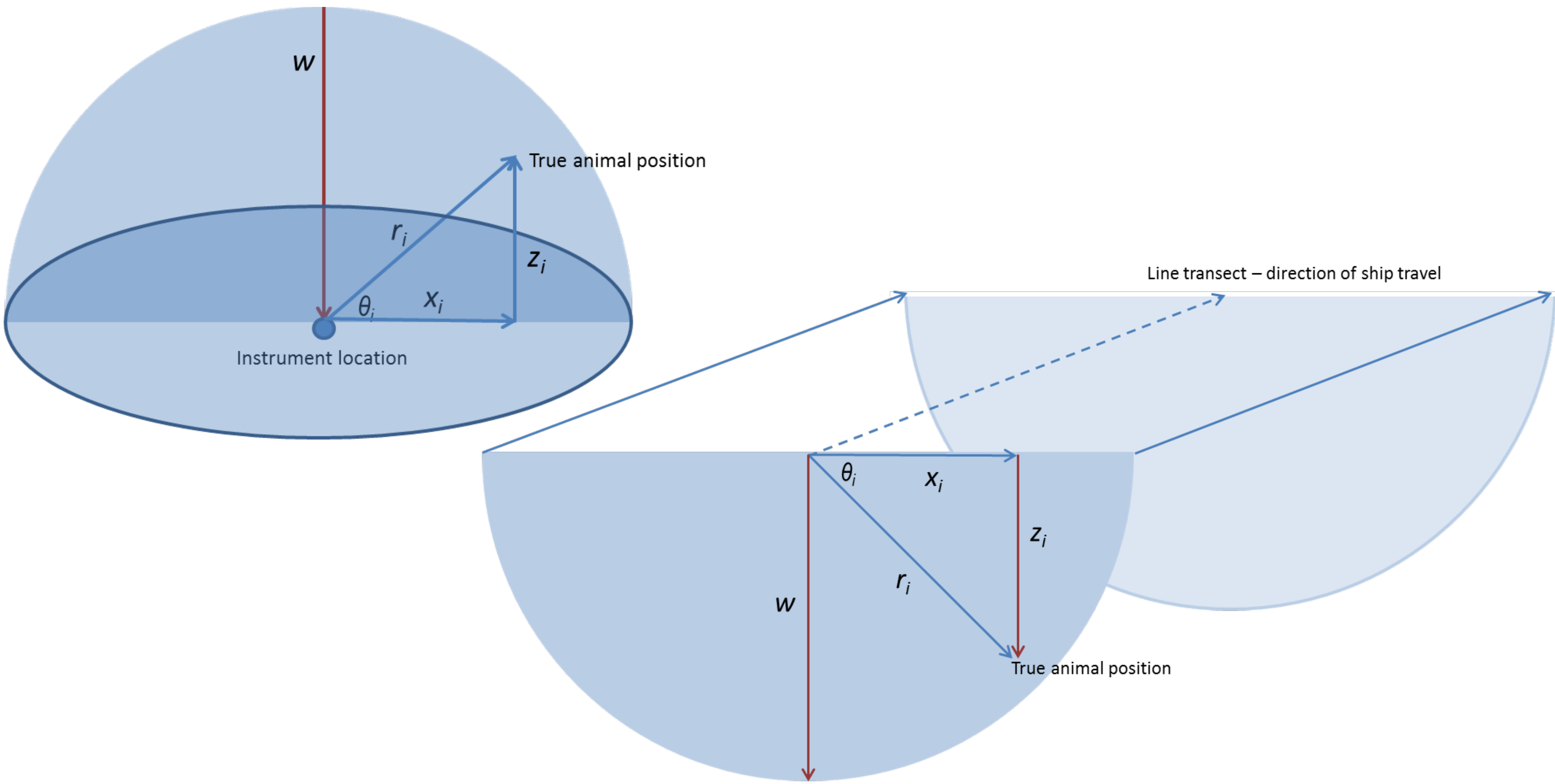
Harris, D.,L. Matias, L. Thomas, J. Harwood and W.F. Geissler. 2013. Applying distance sampling to fin whale calls recorded by single seismic instruments in the northeast Atlantic. Journal of the Acoustical Society of America 134: 3522-3535.

Example: Fin whale calls in Atlantic



Harris, D.,L. Matias, L. Thomas, J. Harwood and W.F. Geissler. 2013. Applying distance sampling to fin whale calls recorded by single seismic instruments in the northeast Atlantic. Journal of the Acoustical Society of America 134: 3522-3535.

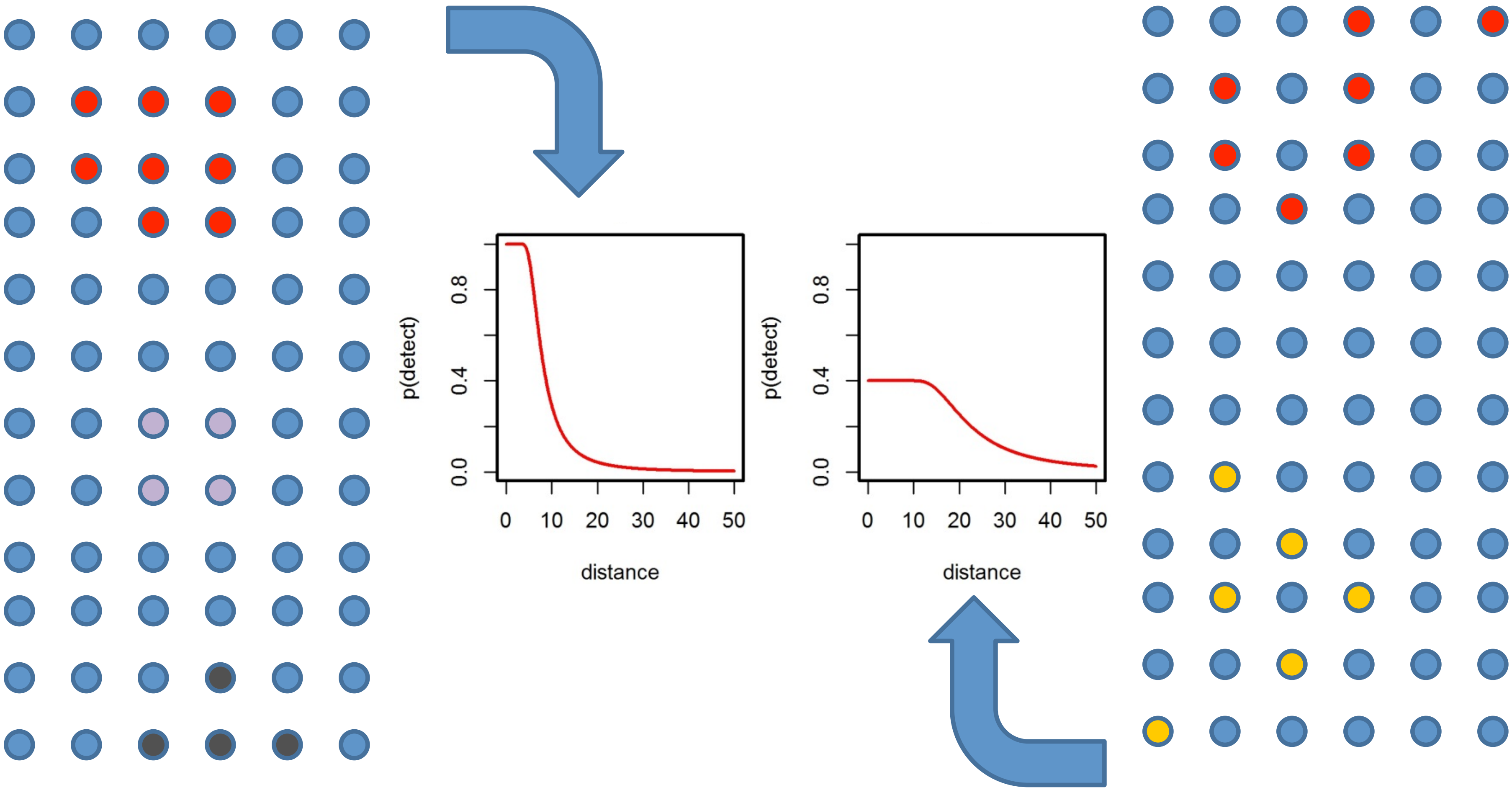
Dealing with depth



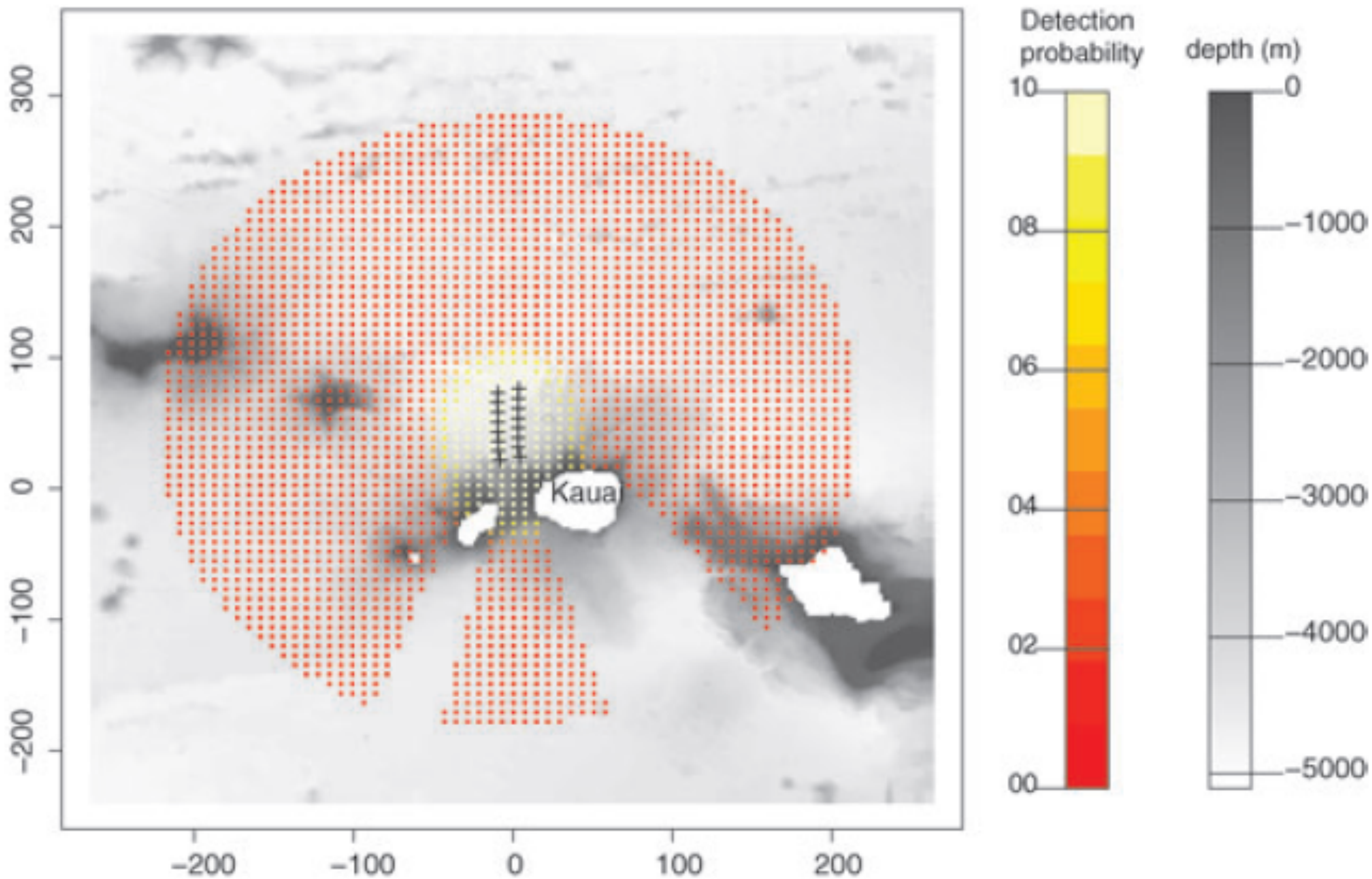
Harris, D., L. Thomas, L. Matias and T. Yack. In prep. Dealing with depth: adapting distance sampling methods to estimate densities of diving marine mammals using passive acoustic recordings.

Spatially Explicit Capture Recapture

- Need: (a) calls detected and associated on multiple hydrophones (not necessarily this many!);
  (b) smooth density surface (not necessarily uniform)

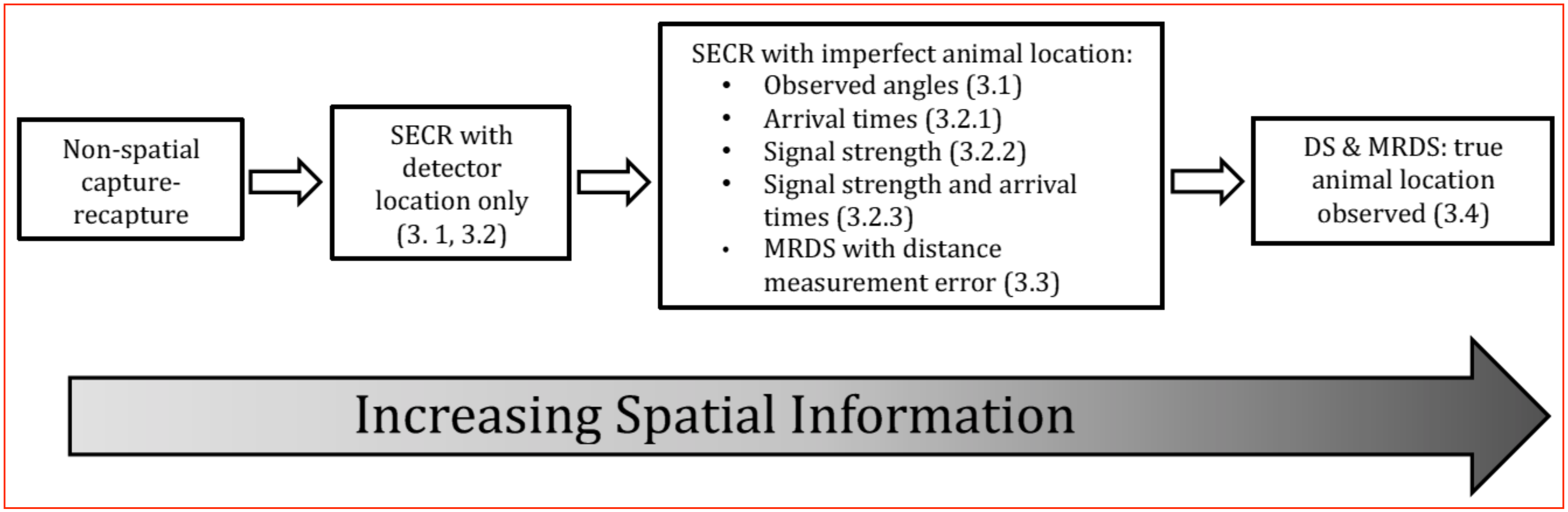


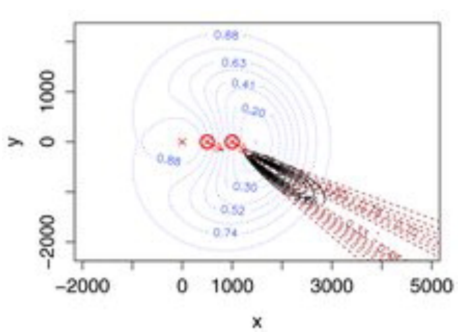
Example: Minke whale boings in Hawaii

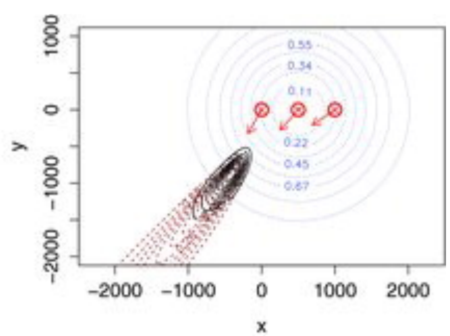


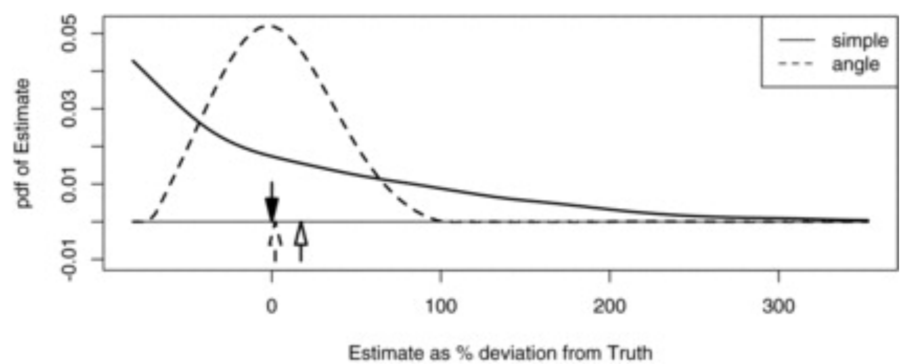
Martin, S.W., T.A. Marques, L. Thomas, R.P. Morrissey, S. Jarvis, N. DiMarzio, D. Moretti and D. Mellinger. 2013. Estimating minke whale (*Balenoptera acutorostrata*) boing sound density using passive acoustic sensors. Marine Mammal Science 29: 142-158.

Beyond SECR







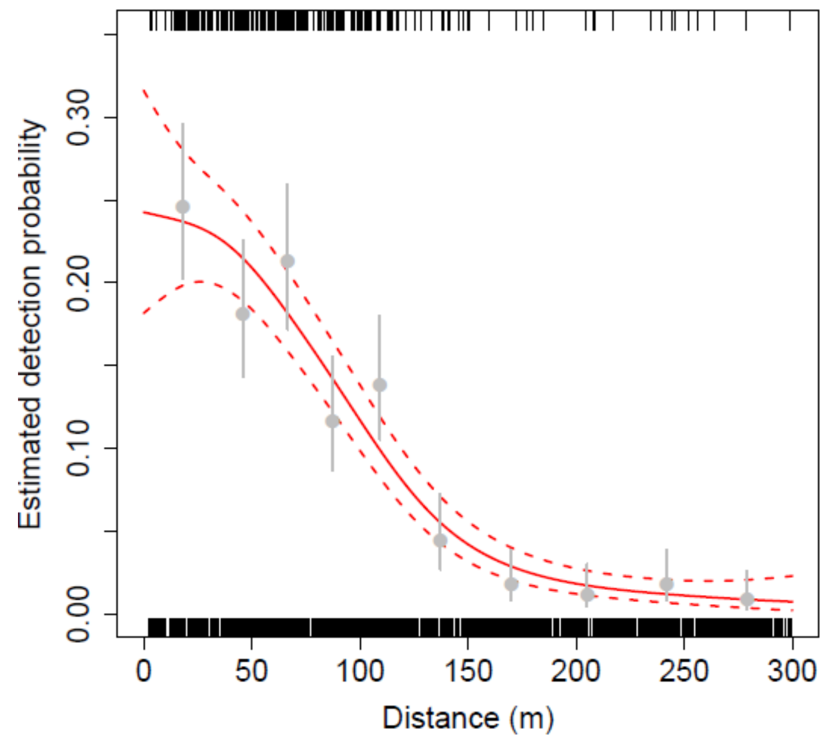


Borchers, D.L., B.C. Stevenson, D. Kidney, L. Thomas, T.A. Marques. 2015. A unifying model for capture-recapture and distance sampling surveys of wildlife populations. Journal of the American Statistical Association 110: 195-204.

Trials

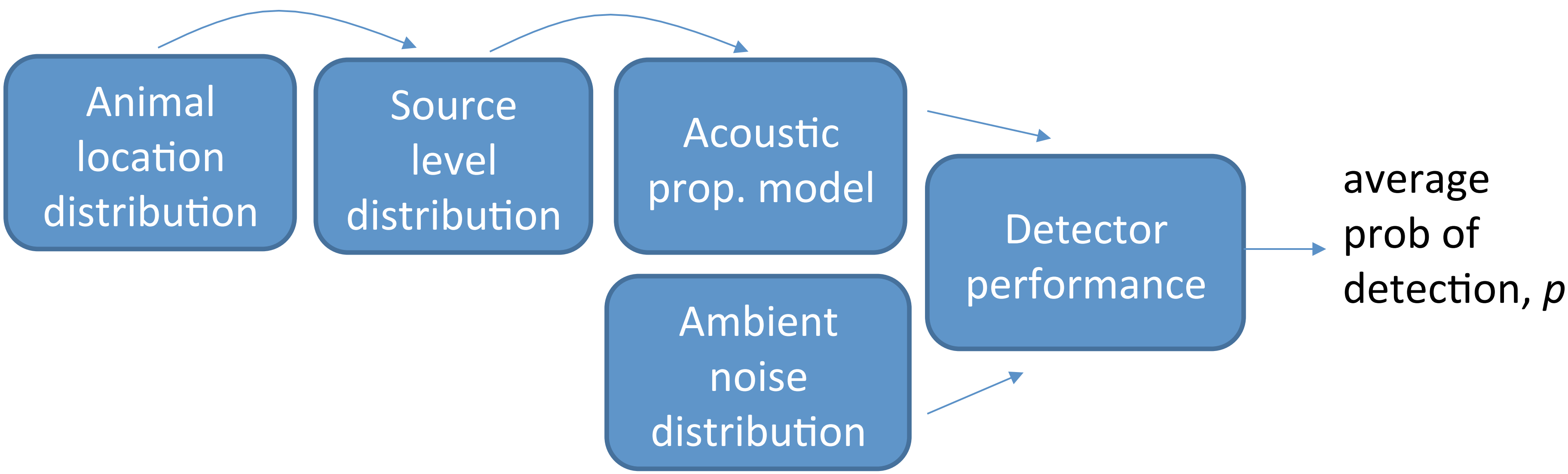
- Need: (a) trials on animals at known distances; (b) known local density surface

- Example: Danish harbour porpoise snapshots



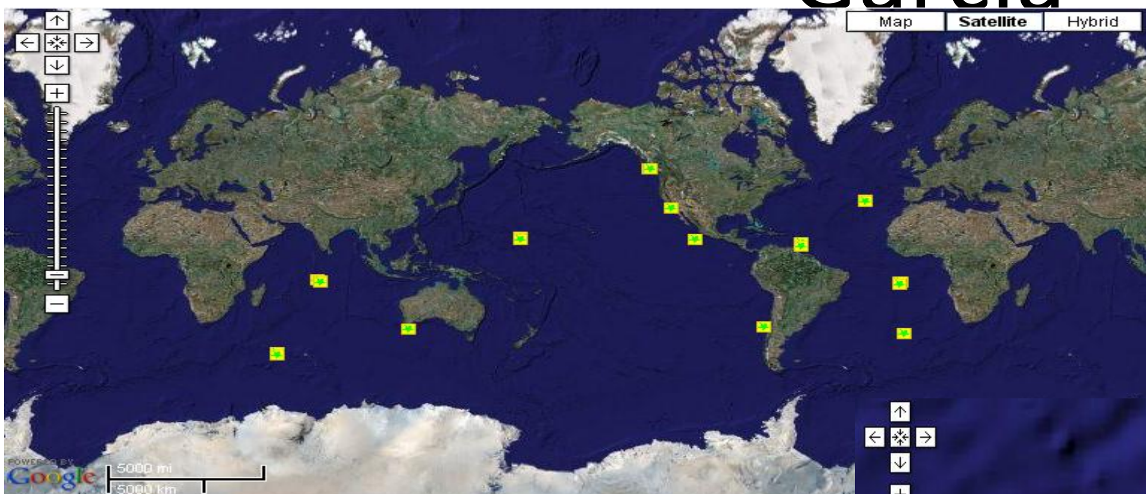
Kyhn L.A., J. Tougaard, L. Thomas, L.R. Duve, J. Steinback, M. Amundin, G. Desportes and J. Teilmann. 2012. From echolocation clicks to animal density - Acoustic sampling of harbour porpoises with static dataloggers. Journal of the Acoustical Society of America 131: 550-560.

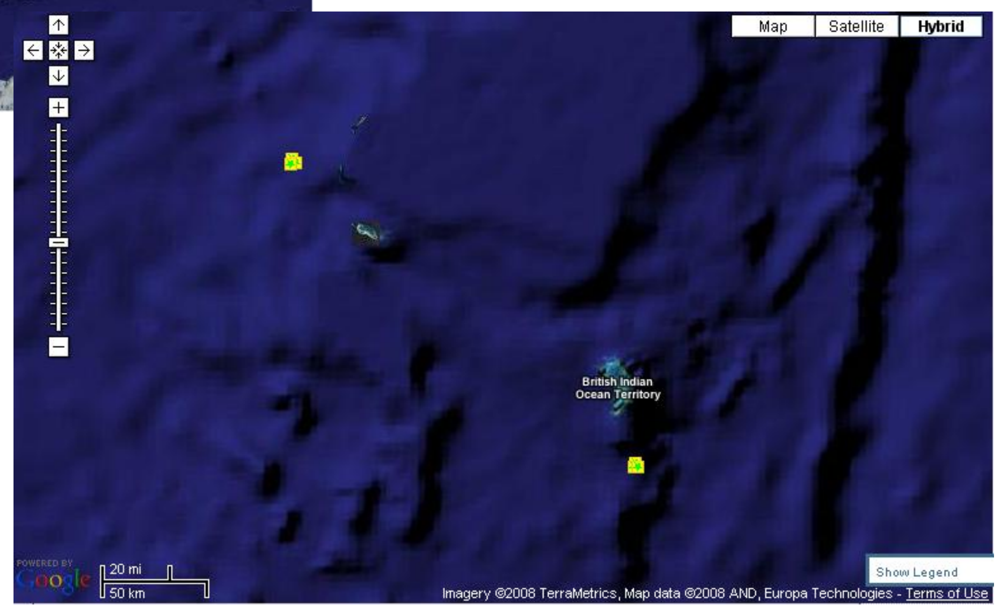
Acoustic modelling



Küsel, E.T., D.K. Mellinger, L. Thomas, T.A. Marques, D.J. Moretti, and J. Ward. 2011. Cetacean population density from single fixed sensors using passive acoustics. Journal of the Acoustical Society of America 129: 3610-3622.

Example: Blue whale calls at Diego Garcia





Comprehensive nuclear Test Ban Treaty Organization (CTBTO) sensors

2 years of data

D. Harris, L. Thomas, T. Clarke, J. Hildebrand, D. Mellinger, D. Miles, S. Wiggins, J. Harwood. In prep. Estimating the detection probability of long-ranging baleen whale calls using a single sensor: towards density estimation.

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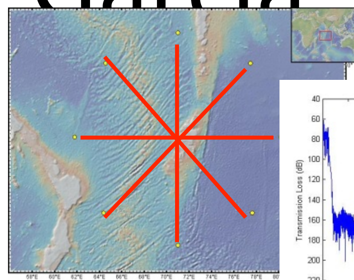
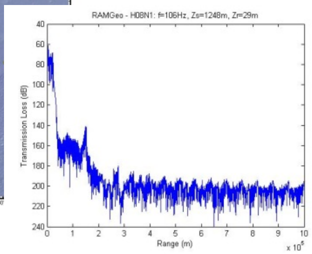
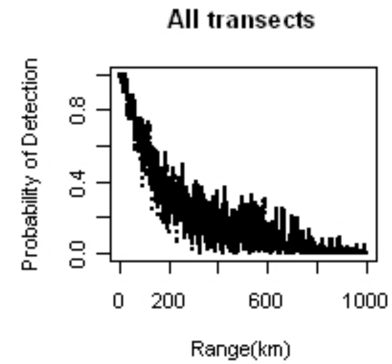


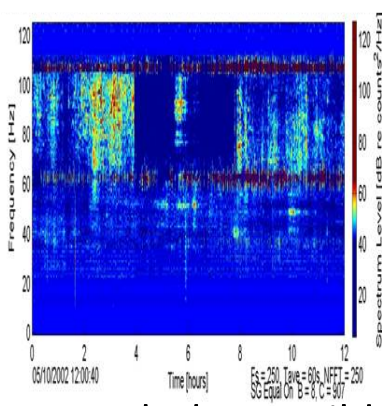


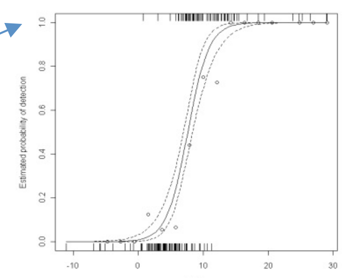


Animal location distribution → Source level distribution → Acoustic prop. model → Detector performance

Ambient noise distribution → Detector performance

Detector performance → average prob of detection, *p*





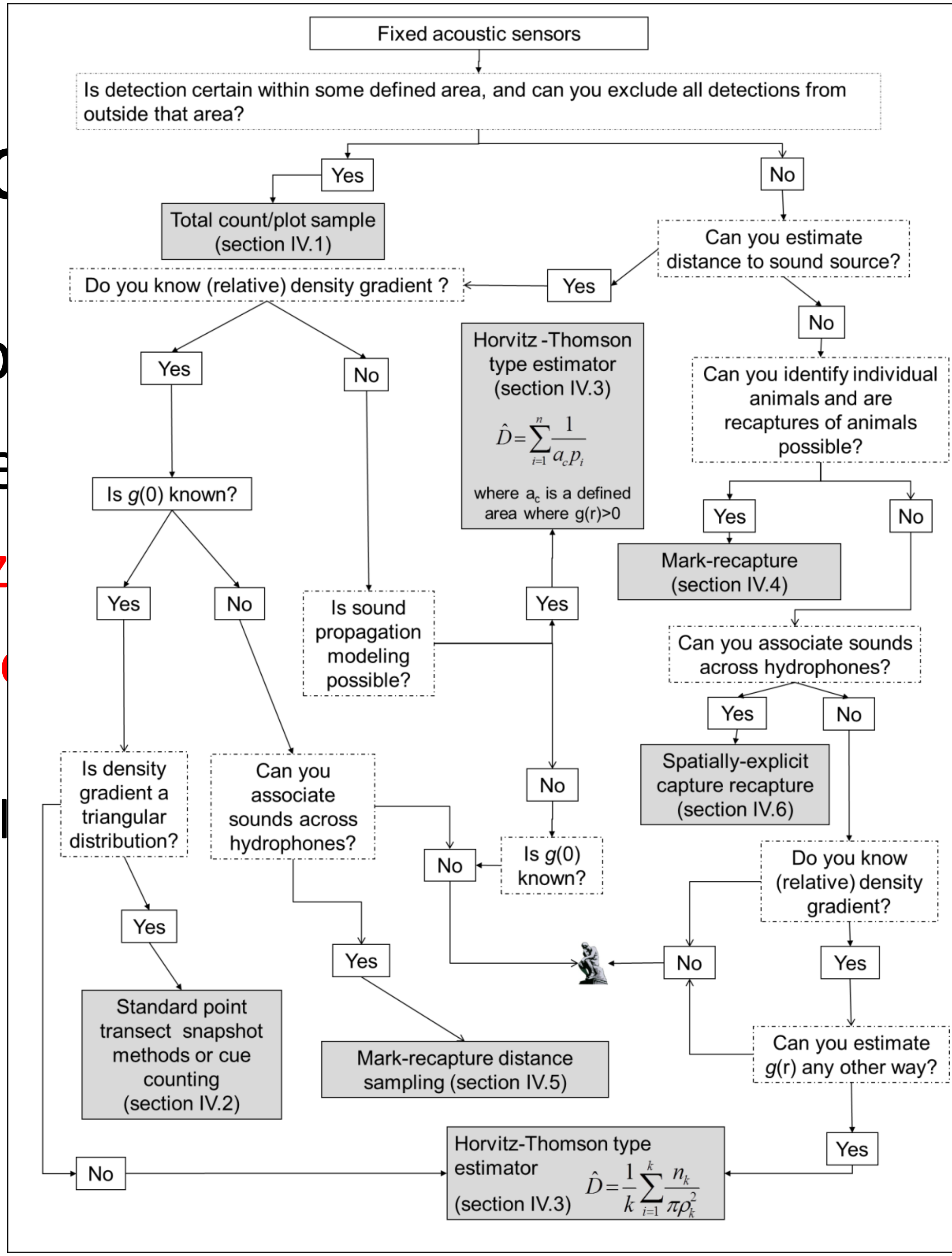
D. Harris, L. Thomas, T. Clarke, J. Hildebrand, D. Mellinger, D. Miles, S. Wiggins, J. Harwood. In prep. Estimating the detection probability of long-ranging baleen whale calls using a single sensor: towards density estimation.

Acoustic modelling current work

- Effect of broadband propagation – see von Benda-Beckman talk, Monday
- Delphinid example – see Frasier talk, Tuesday
- Adding bearing and SNR data – see Harris talk, Wednesday
- Total energy method – see Mellinger talk, Weds

Cond ... od?

- Roadmap
- Survey de
  - Minimiz
  - Measur ... rvey
    - If not ... ame time and pl
    - If not ... u can

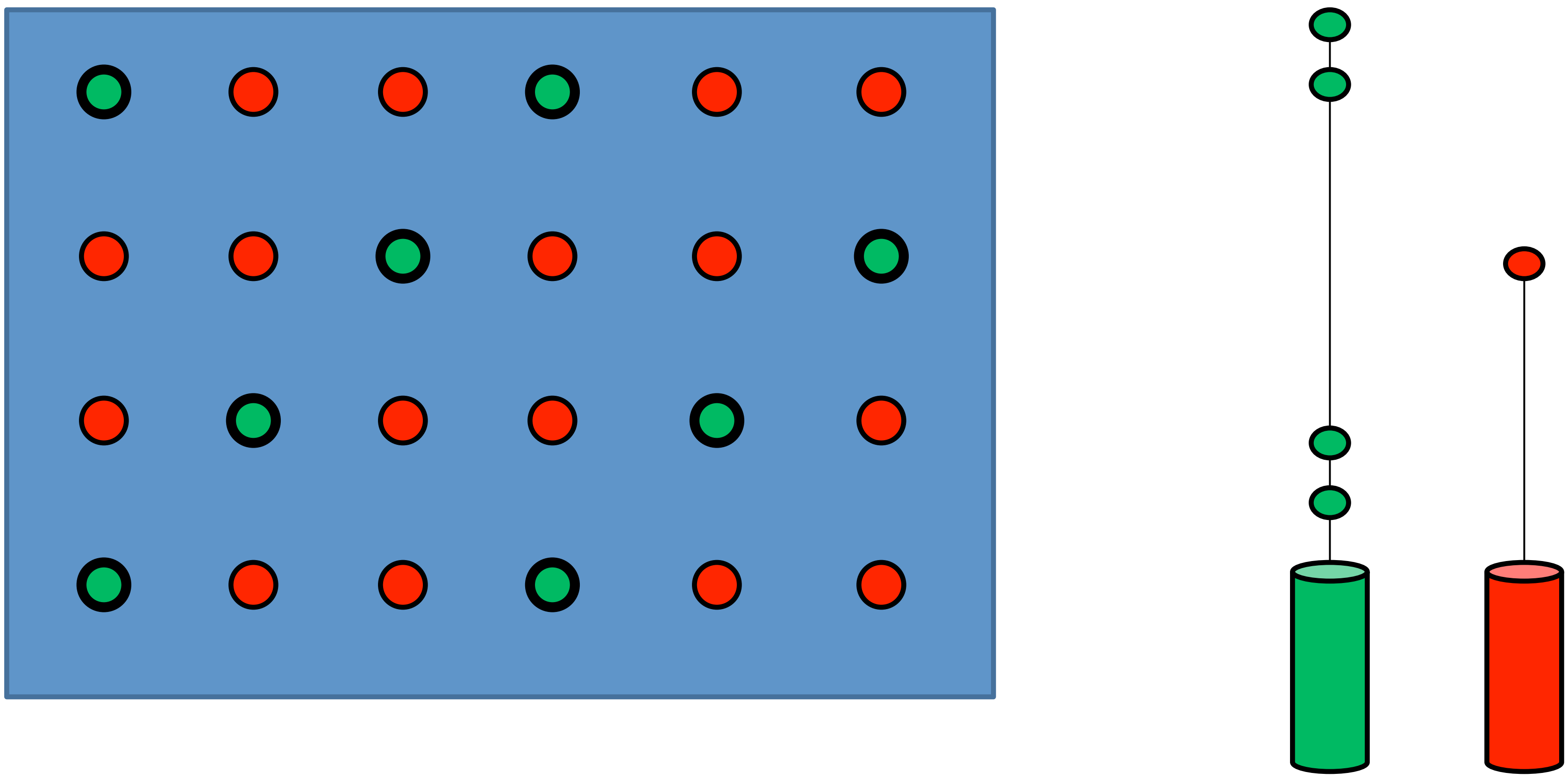


Conclusions – which method?

- Total count of individuals is best (but expensive)
- Distance sampling or SECR (or beyond SECR) on individuals is 2nd best.
- But often neither are practical – usually we work on cues; often we need auxiliary info approaches to get *p*
- Nevertheless, use a good sampling design to obtain any multipliers you can, e.g.:
  - detector performance (false positive rate, detection prob given SNR)
  - ambient noise

DECAF-TEA

Density Estimation for Cetaceans from Acoustic Fixed sensors in Testing and Evaluation Areas



Future directions

- Statistical developments:
  - Methods explicitly designed for animal movement
  - Expand scope – more ways to estimate p
- Acoustical processing developments:
  - Improved DC, for more species
  - Single sensor ranging
- Hardware developments:
  - Inexpensive sensors with ranging/association
  - Floating sensors; Gliders
  - Long-term tags and attachments
- More demonstration projects:
  - Gulf of Mexico?
  - Lessons from terrestrial studies?

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