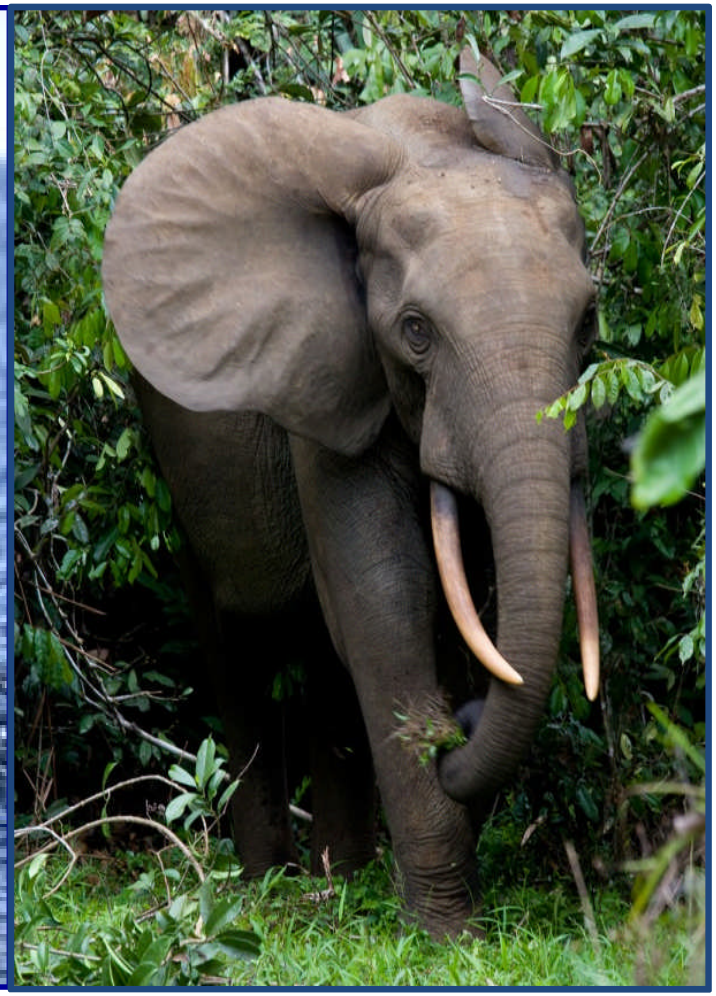
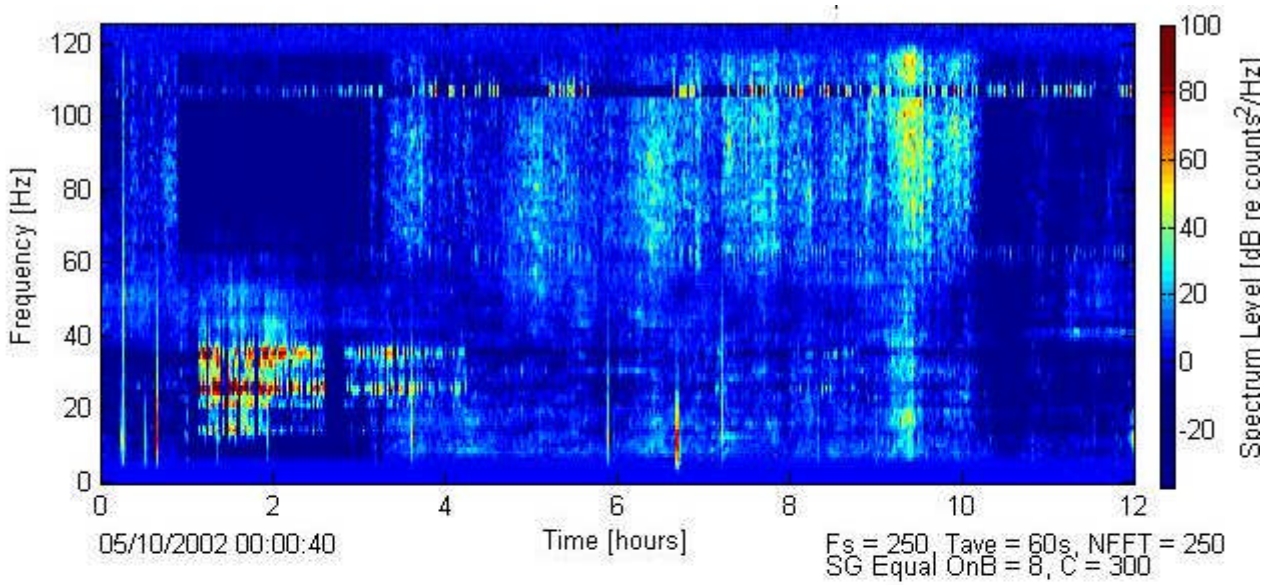
From calls to counts: Estimating animal density using passive acoustic monitoring (PAM)



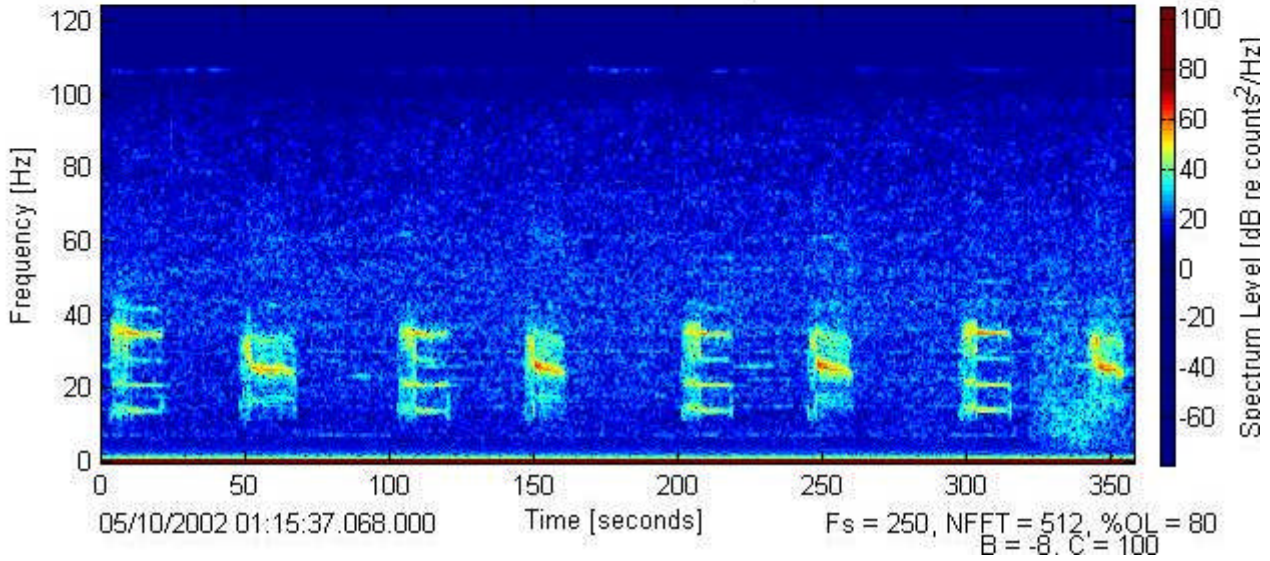
Images courtesy of J. Hildebrand (L) and http://www.birds.cornell.edu/brp/elephant (R)

Why acoustics?

A wealth of recorded information

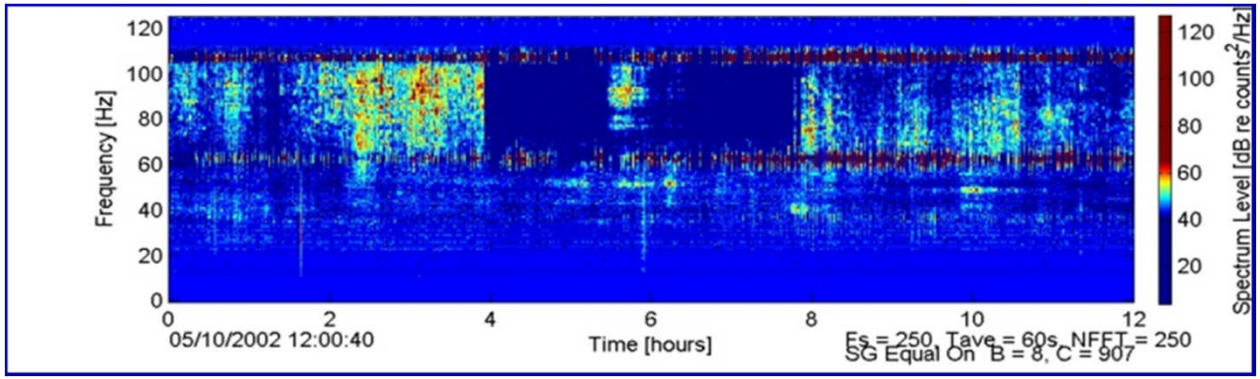


dified Triton 1.64 test data set\Data - xwav and ltsas\H08N1 2002-picks-151008\Unbundled data\H08N1_1_16i

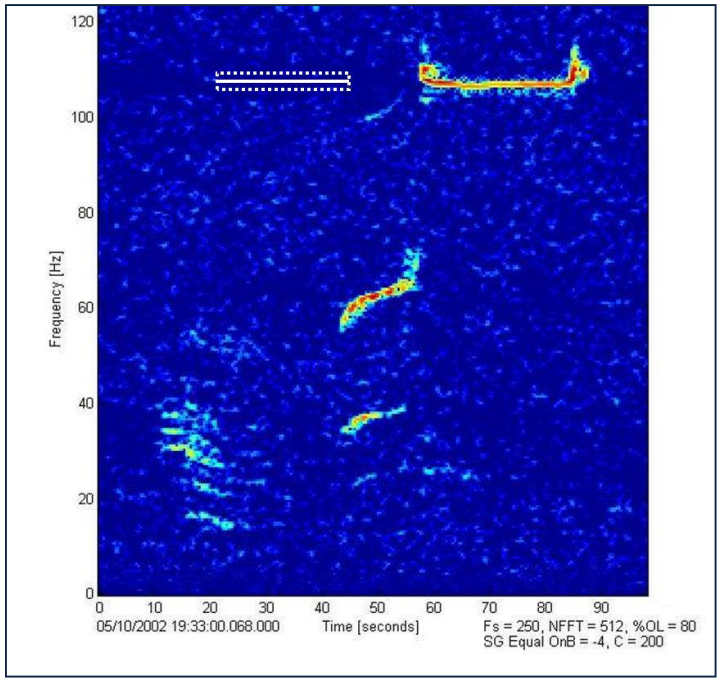


Acoustic density/abundance estimation

From recordings of calls…

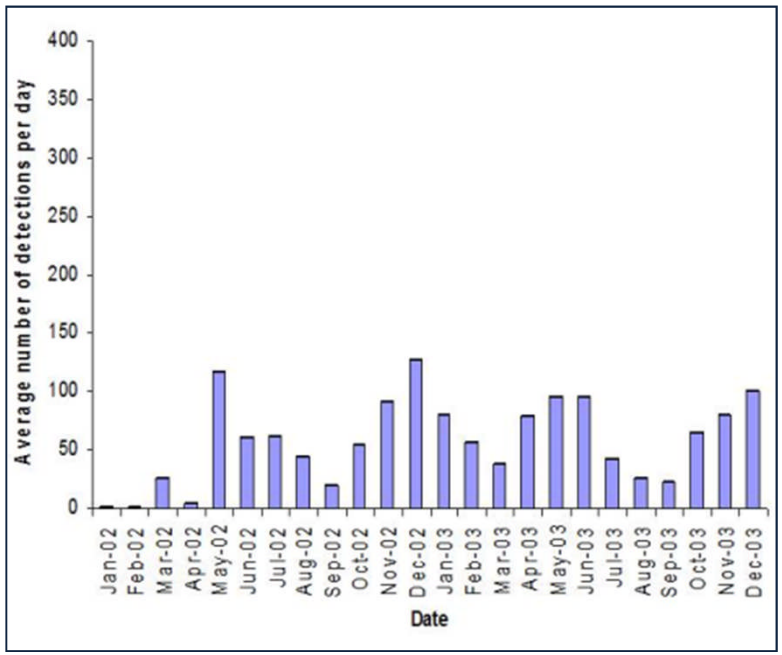


…to detecting target signal…



Acoustic density/abundance estimation

…to numbers of detections…



…to density or abundance number of animals in a given area

- **Consider missed detections**
- **Estimate the surveyed area**
- **Consider false detections**
- **Consider vocal behaviour**

Fixed acoustic monitoring points

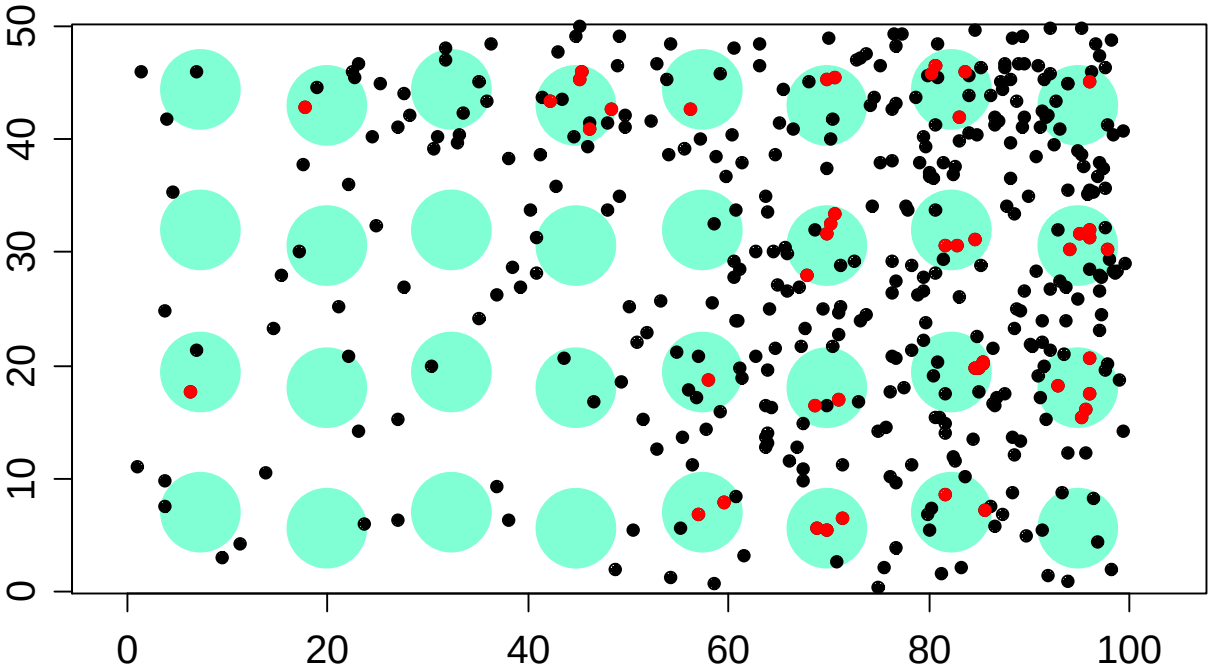


Image courtesy of FreeDigitalPhotos.net

Counting animals

$$\hat{D} = \frac{n}{\pi w^2 k \hat{P}}$$

$\hat{D}$ = estimated density

n = number of detections

w = radius of points

k = number of points

$\hat{P}$ = proportion of animals detected

Fixed acoustic monitoring points

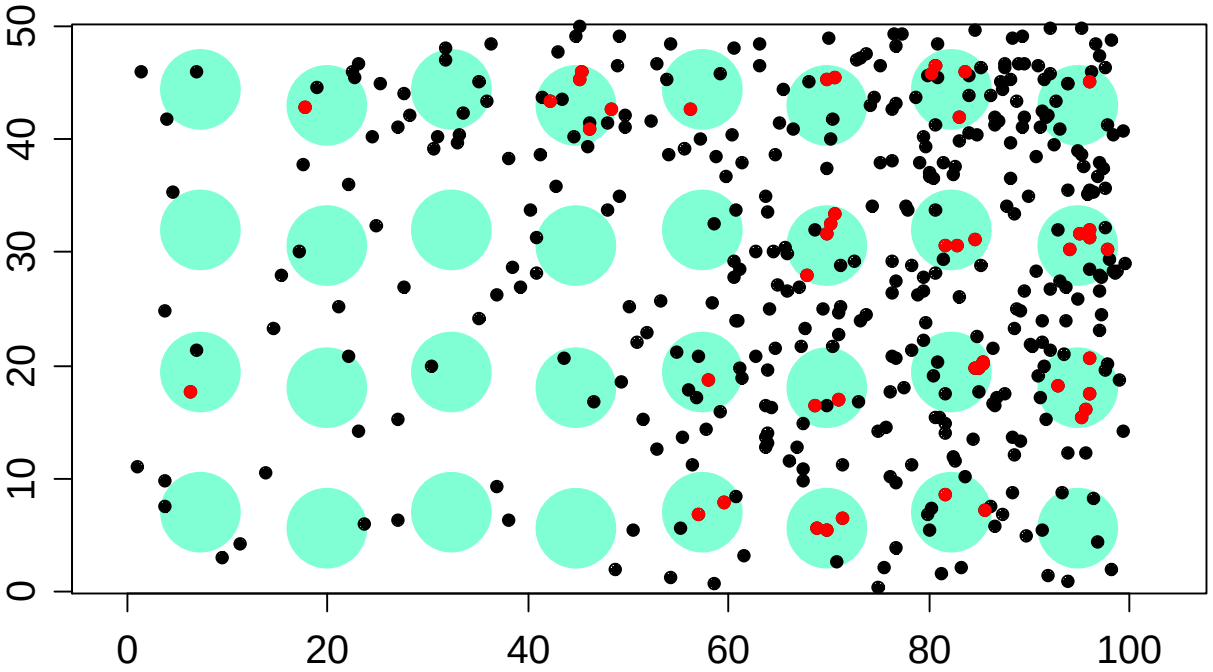


Image courtesy of FreeDigitalPhotos.net

Counting animals

$$\hat{D} = \frac{n}{\pi w^2 k \hat{P}}$$

Counting calls, not animals

$$\hat{D} = \frac{n}{\pi w^2 k \hat{P} T \hat{r}}$$

T = monitoring time $\hat{r}$ = cue rate

Detecting sounds, not individual animals

A simplified example:

125 detections in a 1 hour survey (t = 1).

$\hat{c}$ = 0.2.

$\hat{P}$ (probability of detecting a whale call) = 0.4.

$\hat{r}$ = 5 calls per hour.

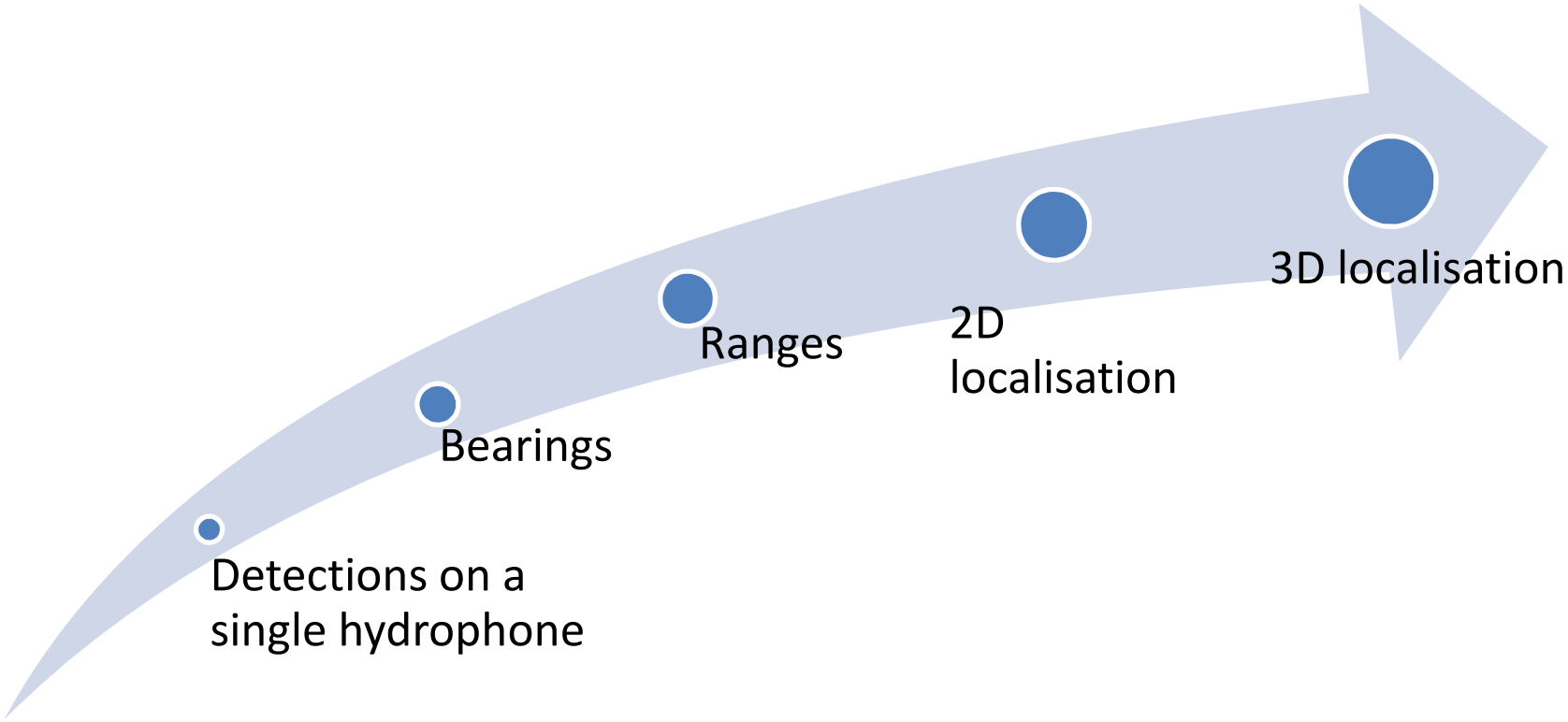
$$\widehat{N}_{calls} = \frac{n(1-\hat{c})}{\hat{P}} = \frac{125 \times 0.8}{0.4} = \frac{100}{0.4} = 250 \text{ calls in 1 hour}$$

$$\widehat{N}_{animals} = \frac{\widehat{N}_{calls}}{\hat{r}.t} = \frac{250}{5 \times 1} = 50 \text{ whales}$$

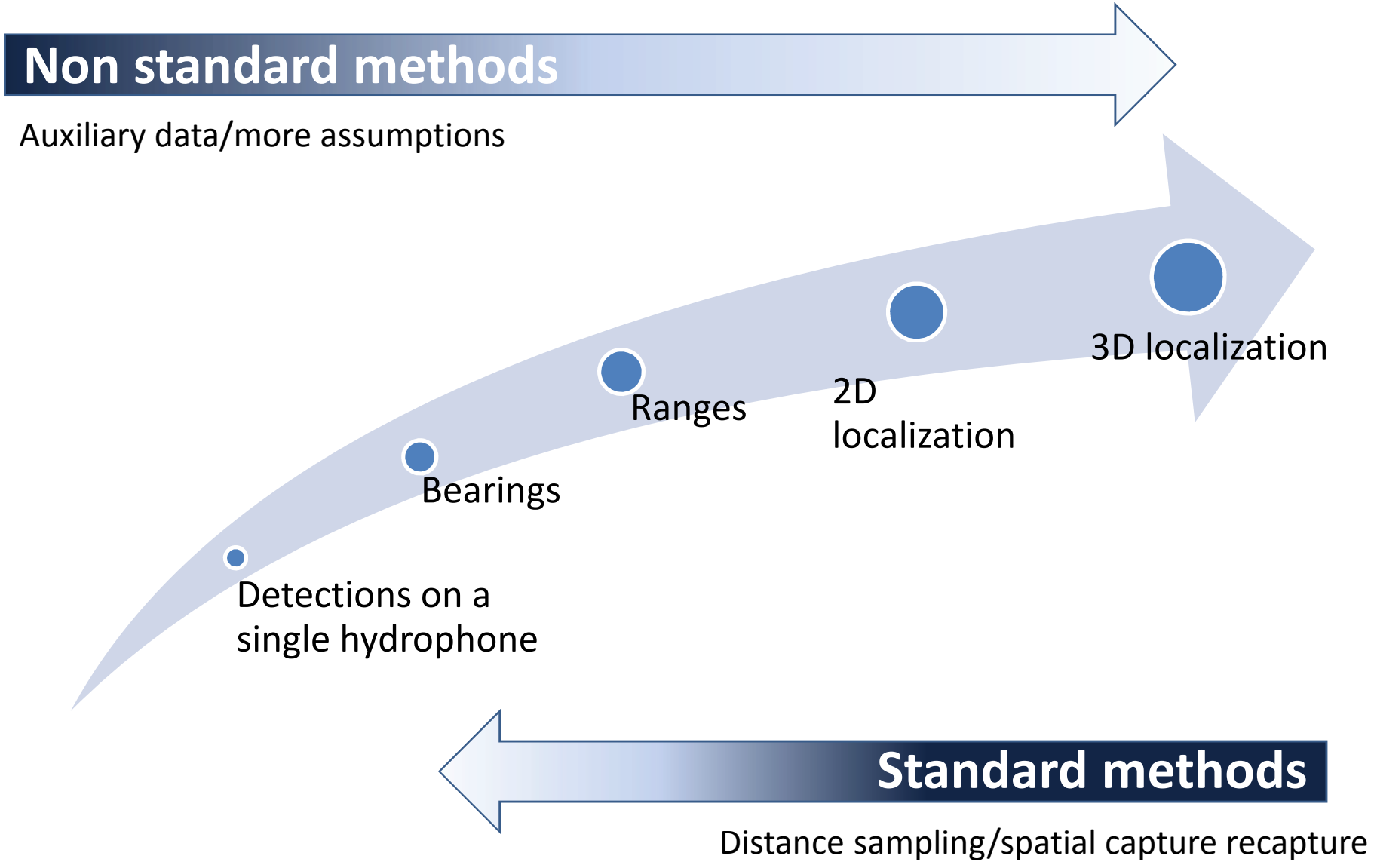
- Need vocalisation production rate **e.g., estimated call production rate**, $\hat{r}$.
- If using an automatic detector - need an **estimate of false positive proportion**, $\hat{c}$.
- False negatives (in general) are taken care of by $\hat{P}$
- Can incorporate uncertainty/variance of any parameter into the estimator

Density estimation methods

- Suite of methods available to estimate detection probability
- Require different spatial information (NB: survey design)
- Pros and cons to each method
- Not just relevant for density/abundance e.g., how far out was my hydrophone/microphone monitoring?



Density estimation methods



Can apply to many species…

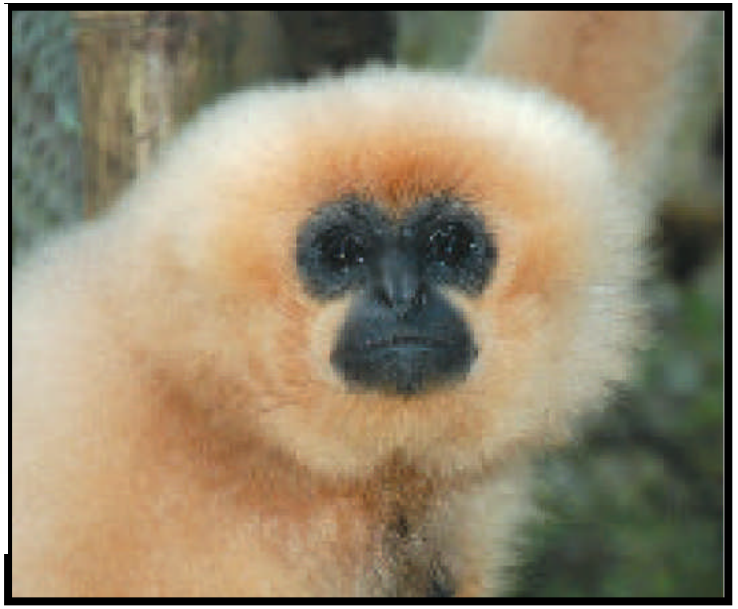


Image taken from: Van Ngoc Thinh *et al* (2010)

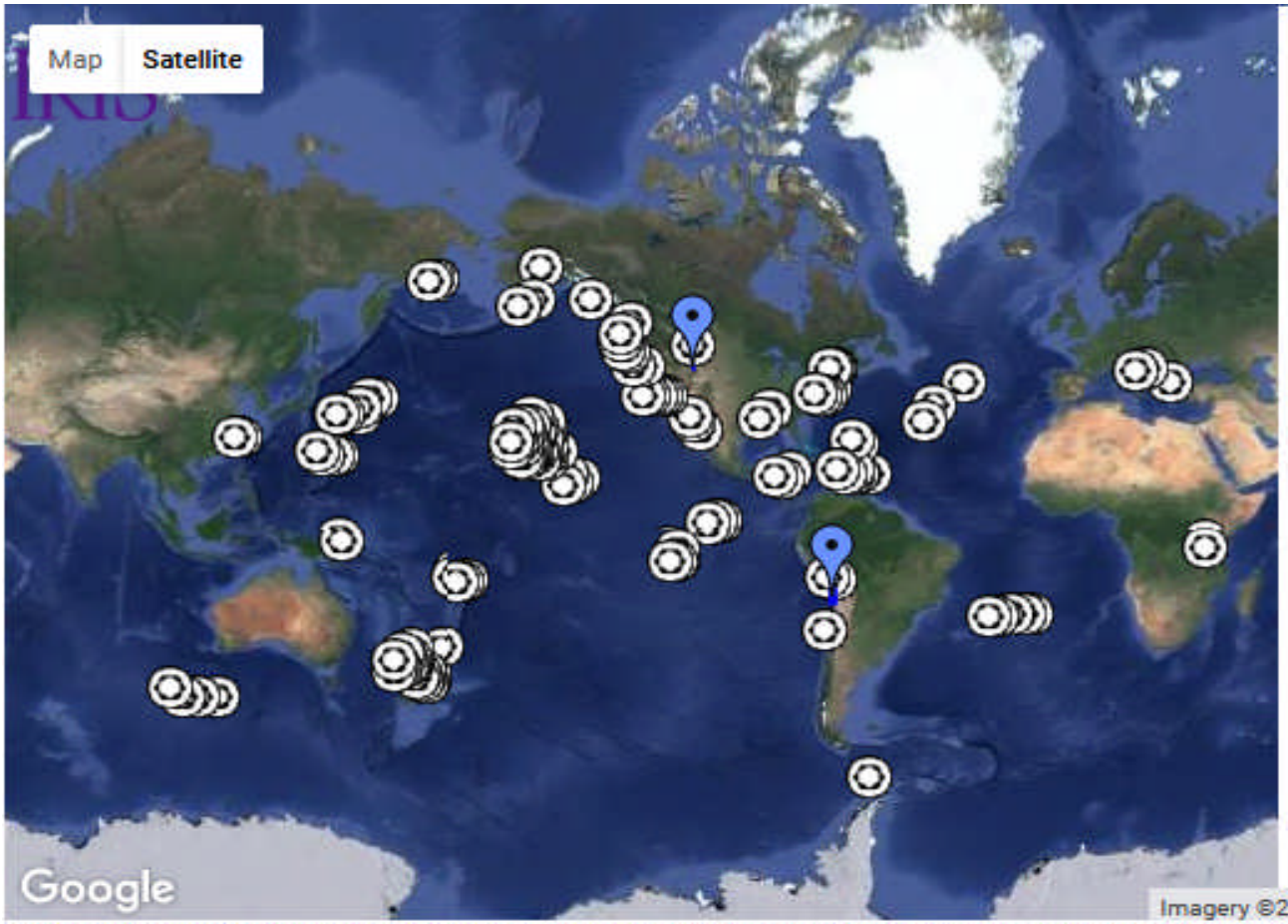
Image taken from: Measey *et al* (2016)

Image courtesy of Phil_Bird at FreeDigitalPhotos.net

So many instruments…

http://nearest.bo.ismar.cnr.it/

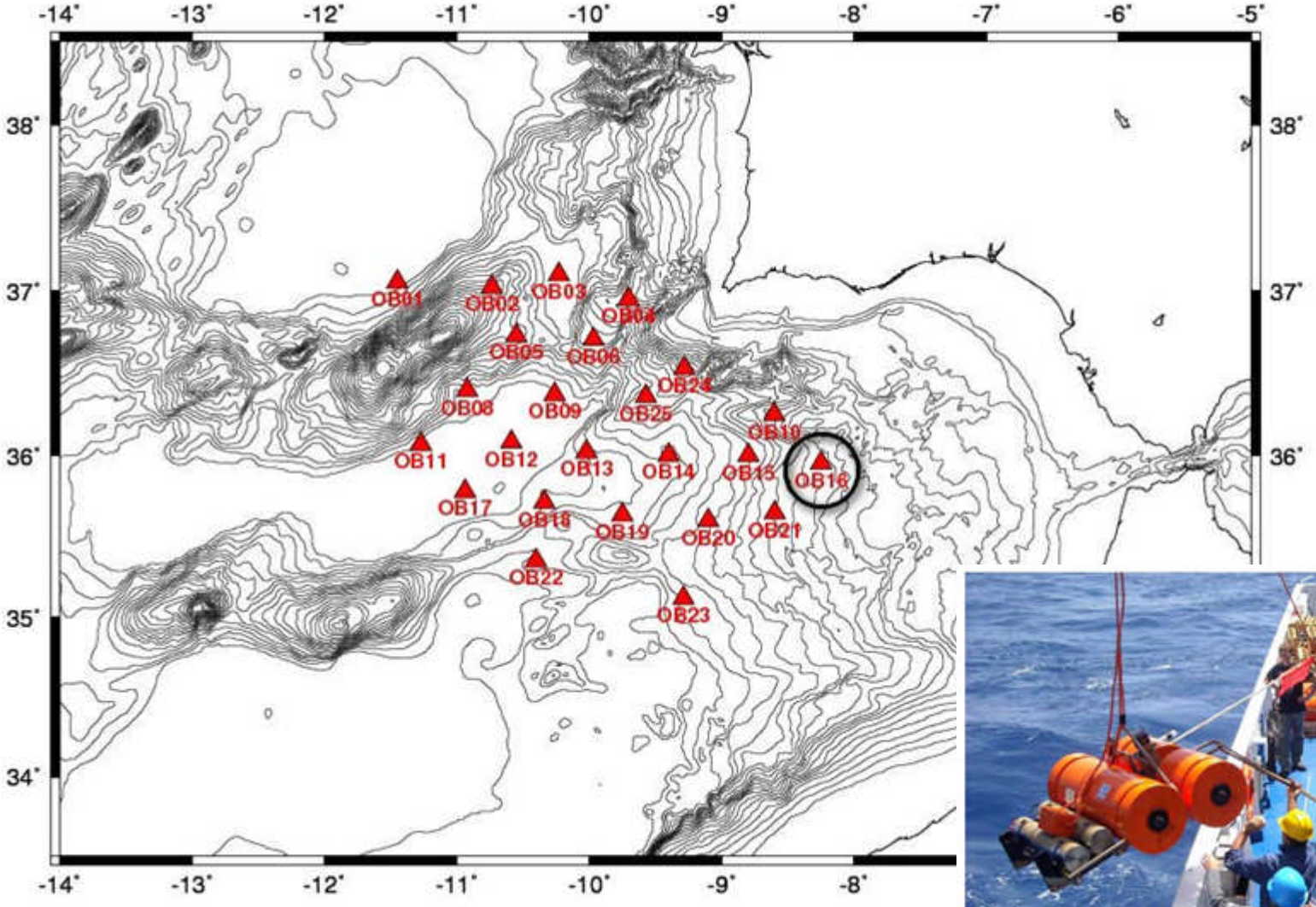
So many instruments…



Courtesy of http://www.afsc.noaa.gov

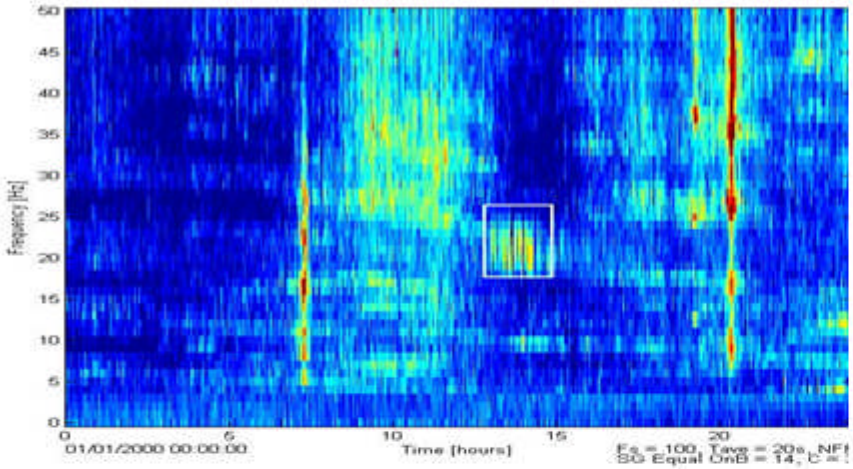
Note: The black and white symbols show past OBSIP deployments with data currently available at the IRIS DMC. Clicking on a station will show a link to additional information about the experiment and station through the IRIS DMC MetaData Aggregator. Red markers show future deployments of OBSIP instruments and blue show current deployments.

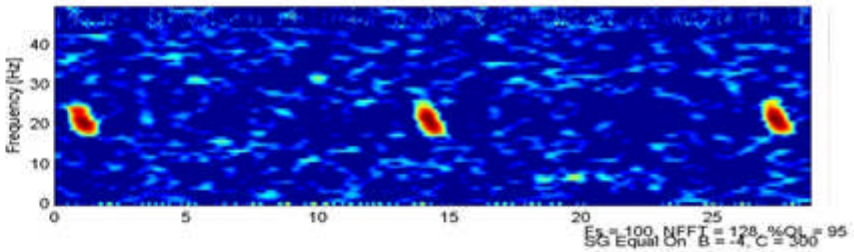
Points instead of transect lines…

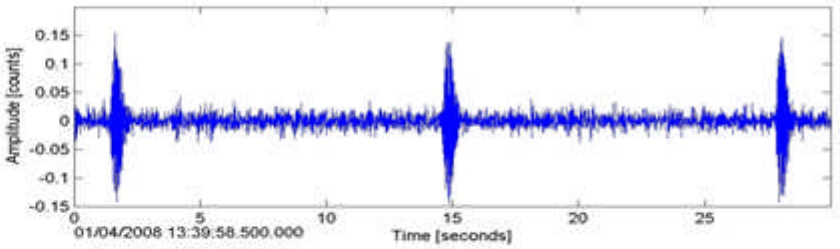


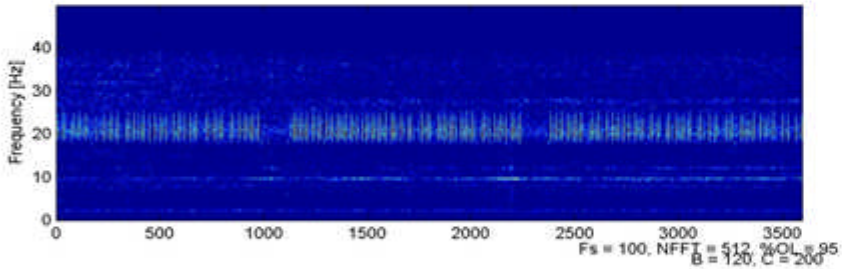
From: http://nearest.bo.ismar.cnr.it/

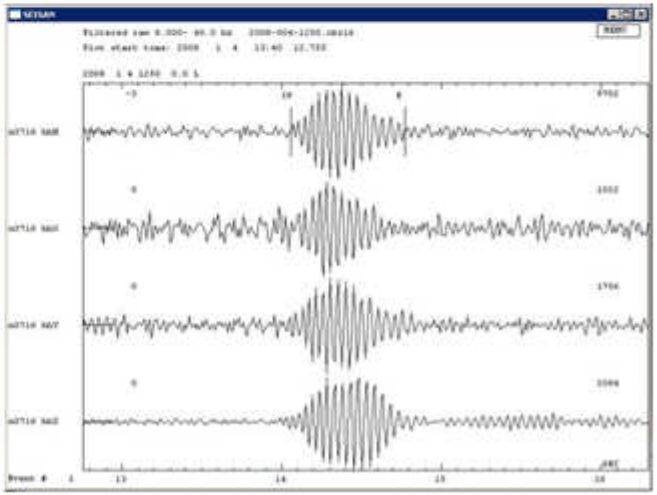
Points instead of transect lines...

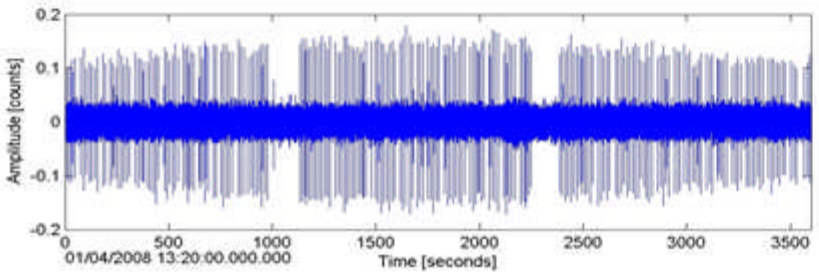




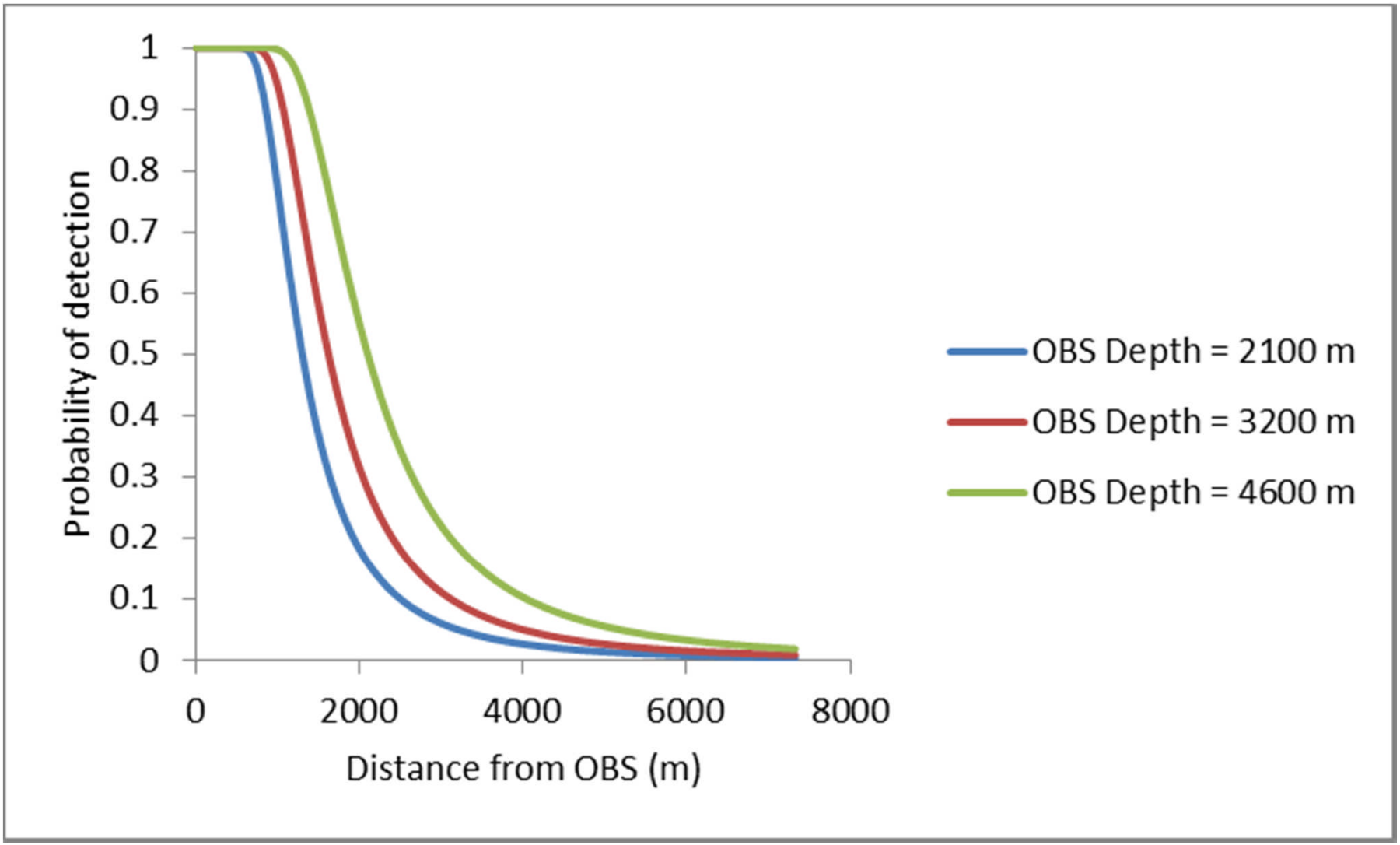






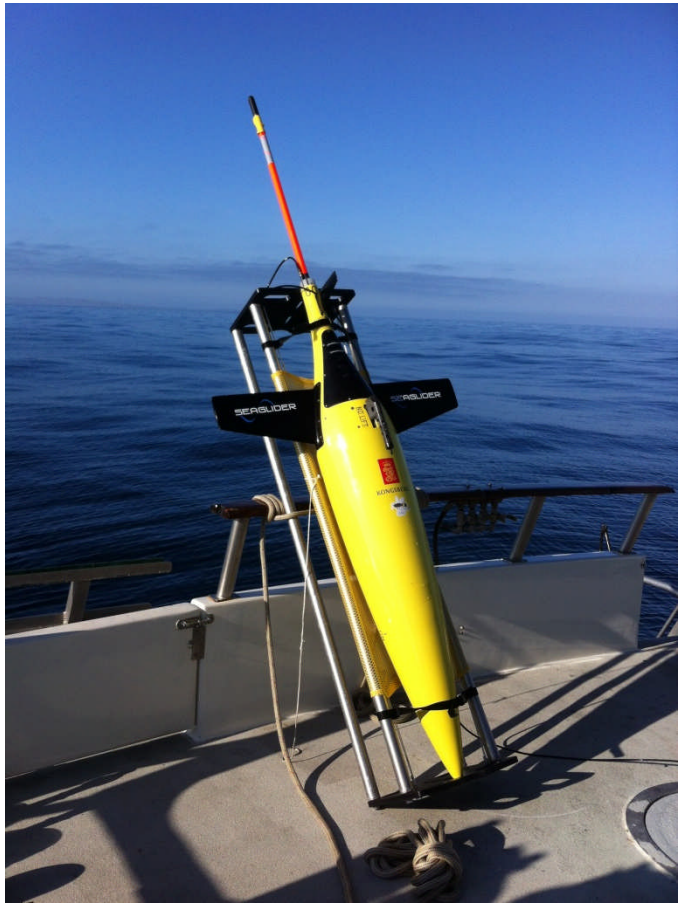


Points instead of transect lines…



NB: Preliminary results

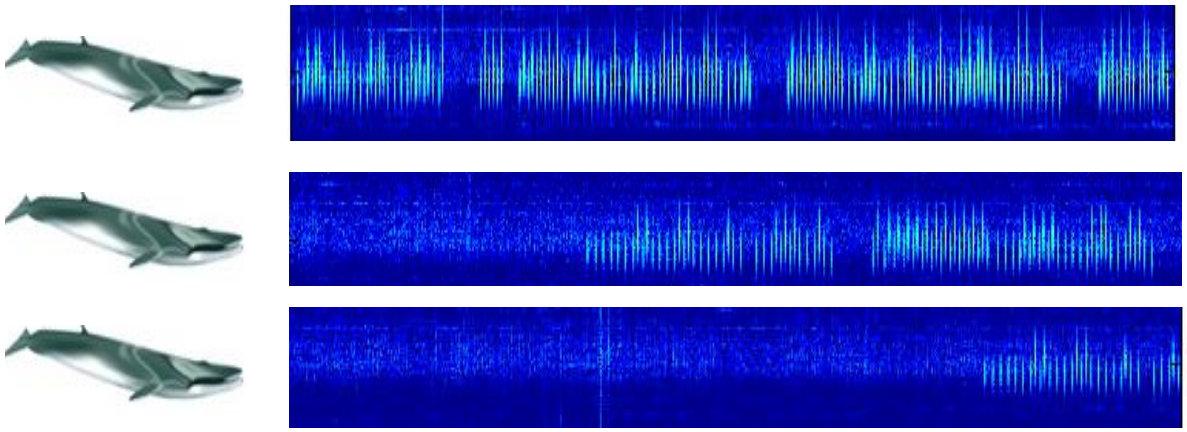
Exploring new technologies



- Improved spatio-temporal coverage.
- Better spatial coverages than fixed sensors.
- Better temporal coverage than towed acoustic arrays.
- But slow moving – how do these instruments fit with our existing methods?

Considering behaviour

- It is VITAL to understand the vocal behaviour of the study species.
  - **Which vocalisation is best to monitor?**
  - **What proportion of the population make that sound?**
  - **What is the production rate of the vocalisation?**
  - **Does the rate show spatial and temporal variation?**



In conclusion…

- Increasing amount of acoustic data available worldwide.
- Both from dedicated surveys and opportunistic datasets.
- Density/abundance estimation using acoustics is possible.
- A suite of statistical methods are available.
- For planned surveys – ideally use standard methods.
- For data already collected, a non-standard analysis may be possible.
- Large limitation is current lack of information about acoustic behaviour of many species. Call rate is a prime example.

Key references

- Marques, T.A., L. Thomas, S. Martin, D. Mellinger, J. Ward, D. Moretti, D. Harris and P. Tyack. (2013). Estimating animal population density using passive acoustics. Biological Reviews 88: 287-309

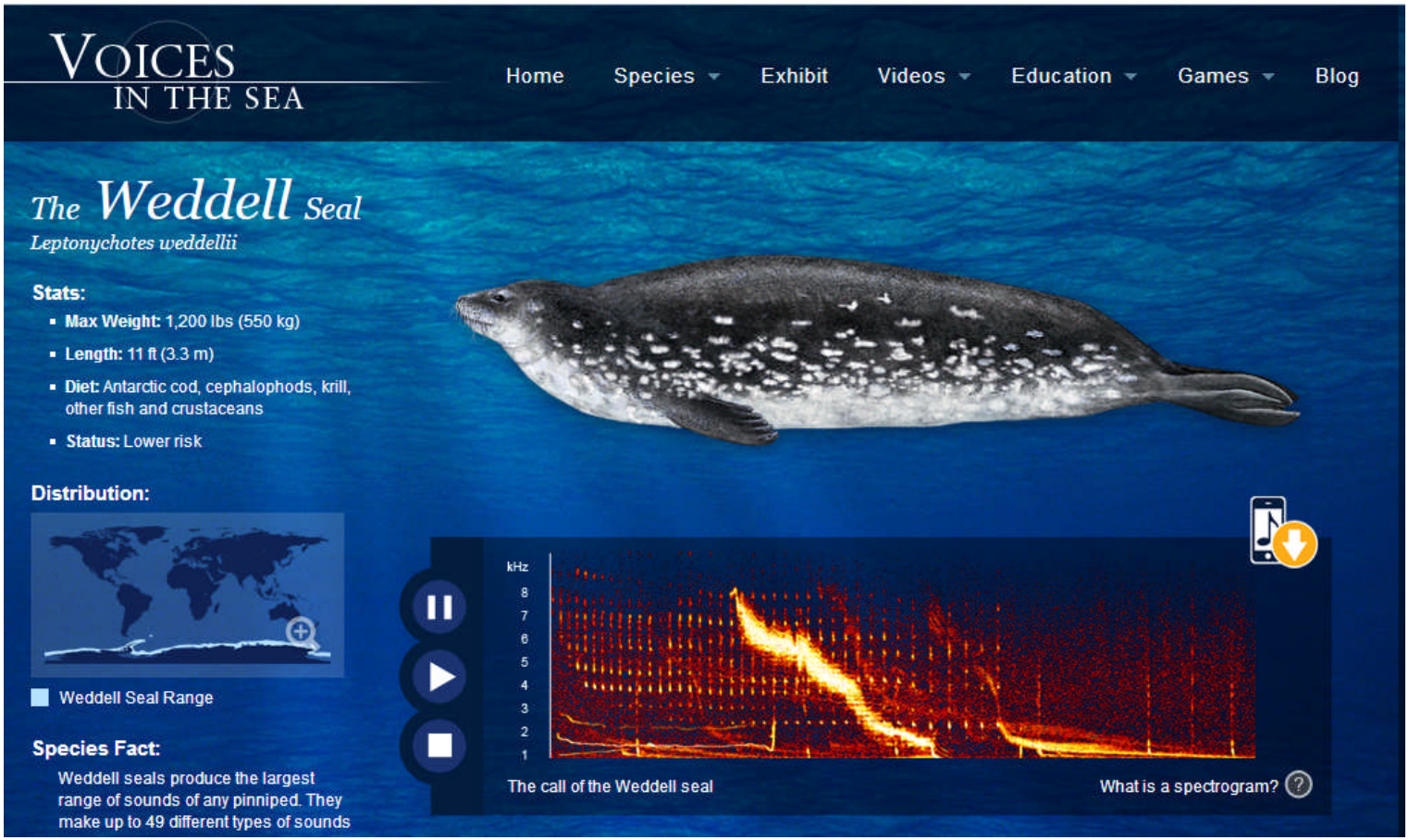
- Stevenson, B.C., Borchers, D.L., Altwegg, R., Swift, R.J., Gillespie, D.M., and Measey, G.J. (2015) A general framework for animal density estimation from acoustic detections across a fixed microphone array. *Methods in Ecology and Evolution*, 6 38-48.

- Requested seismometer reference:

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

Considering behaviour

- It is VITAL to understand the vocal behaviour of the study species.



http://cetus.ucsd.edu/voicesinthesea_org/species/pinnipeds/weddellSeal.html