University of St Andrews

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Sampling elusive wildlife species: Accounting for detection probability

Breeding stock 'D' humpback whale population estimates from NWC, WA

Using line transect sampling to monitor the recovery of large cetaceans from the air

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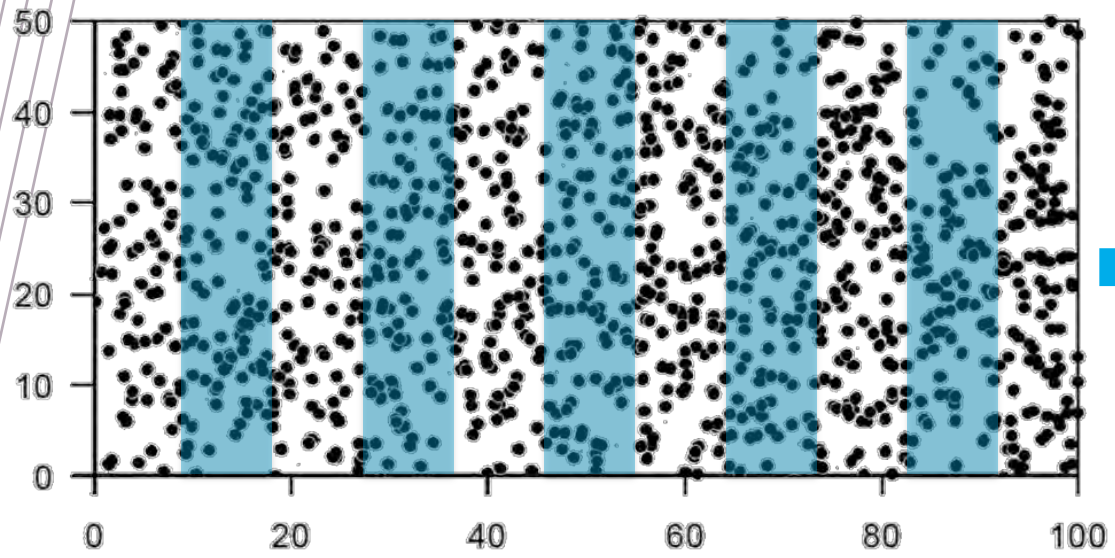
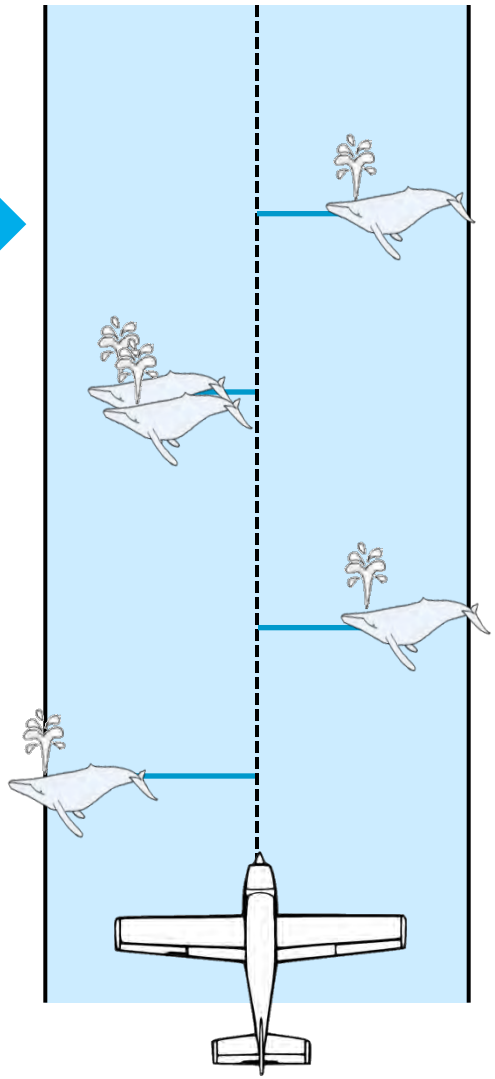
woodside

Line transect sampling 101

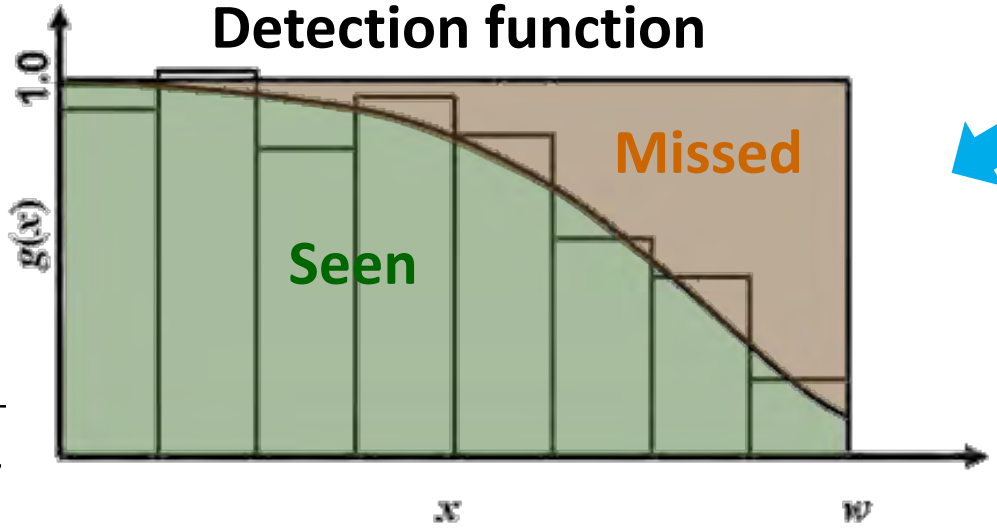
Quick refresher on the basics



Perp. distances



Detection function

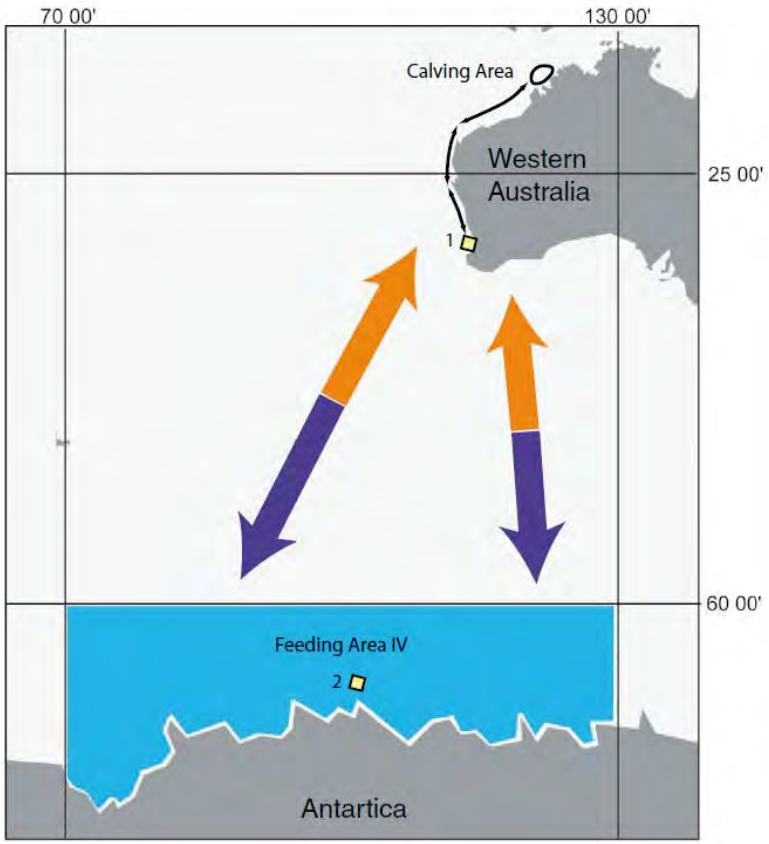


$$\hat{N} = \frac{nA}{2\hat{\mu}L}$$

Background

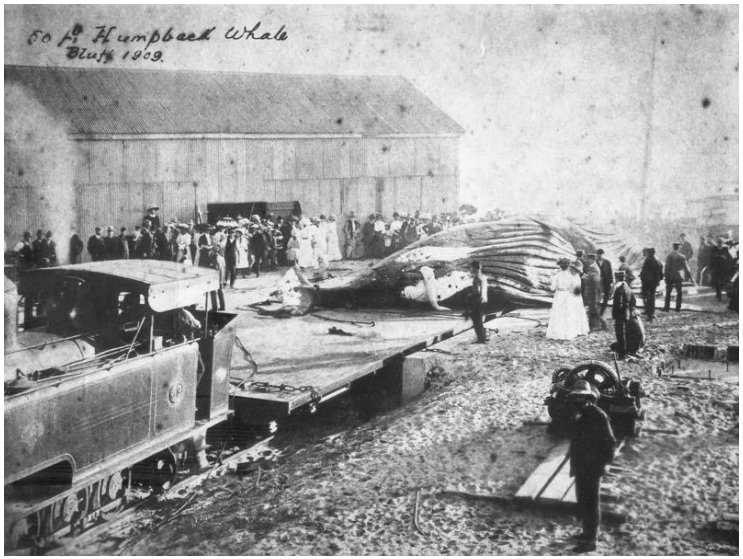
Humpback whales *(M. novaeangliae)* in Western Australia

- **Migrate** between Australia and Antarctica
- WA = breeding **stock "D"** (formerly "group IV")



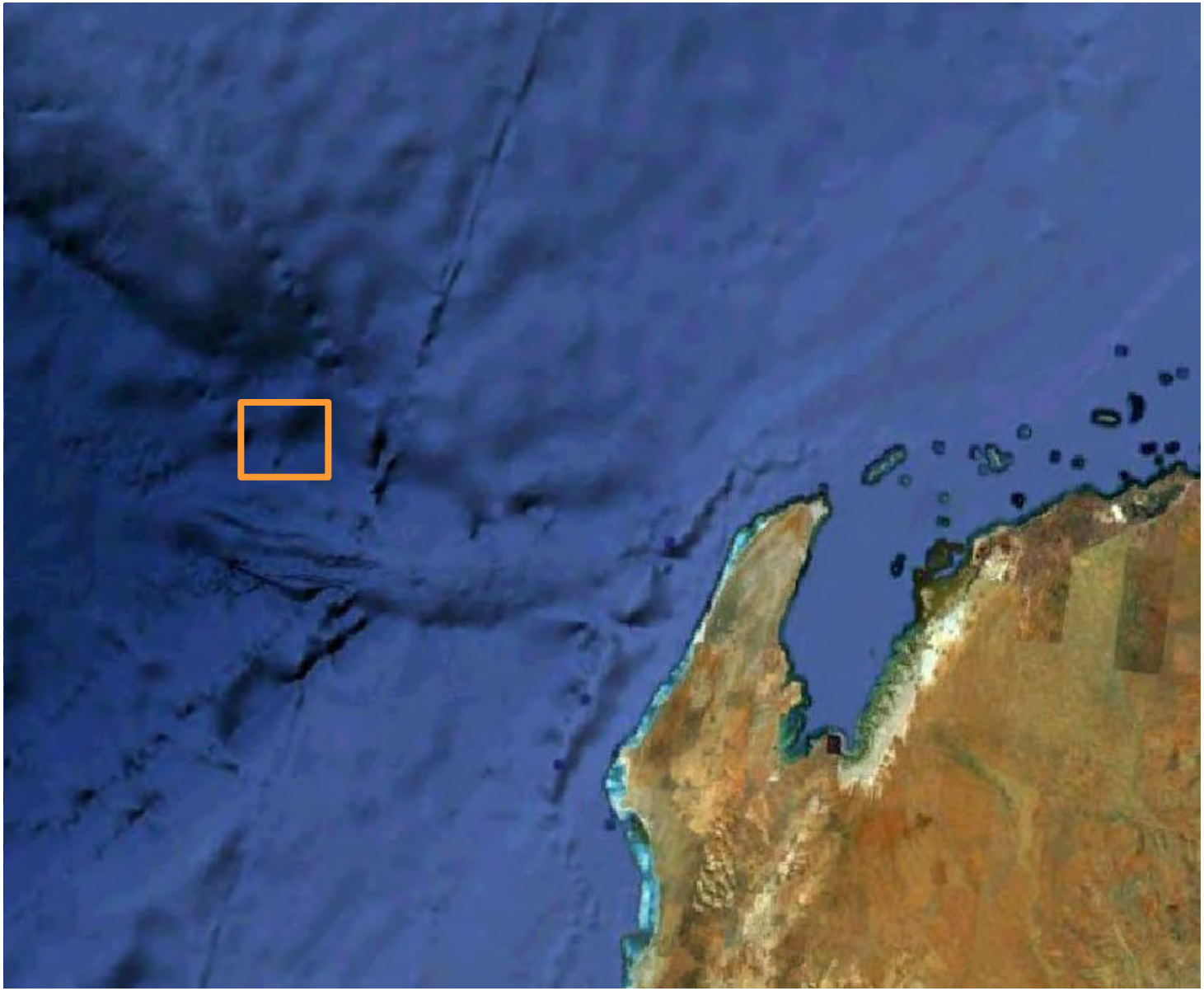
From Jenner *et al.* 2001

- **Decimated** during whaling times



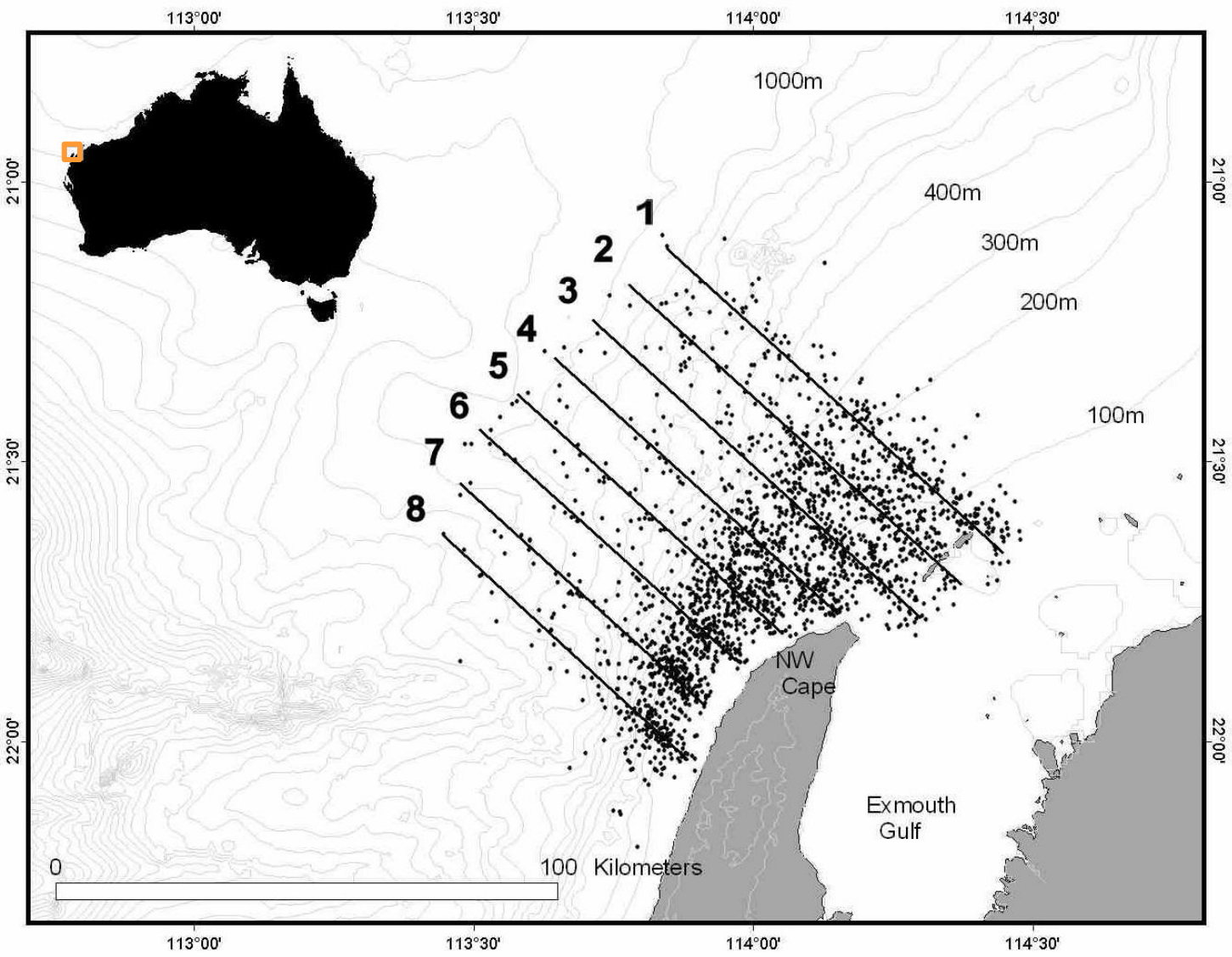
Study area

North West Cape, Western Australia



Methods

Design of an aerial line transect survey



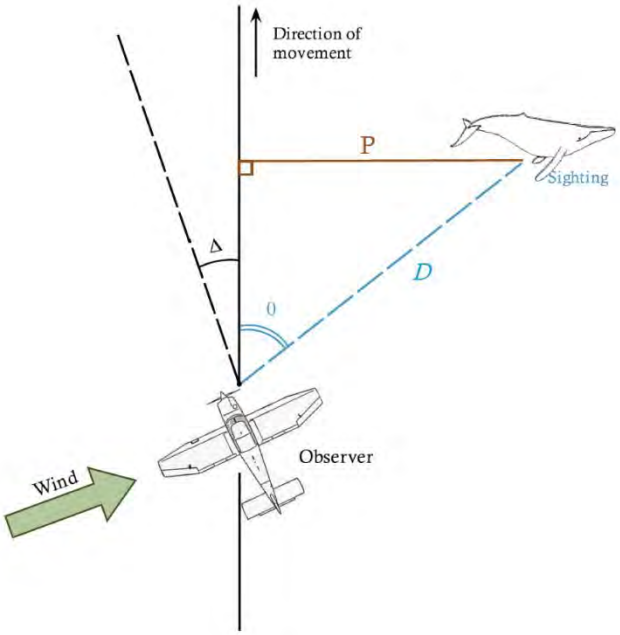
Methods

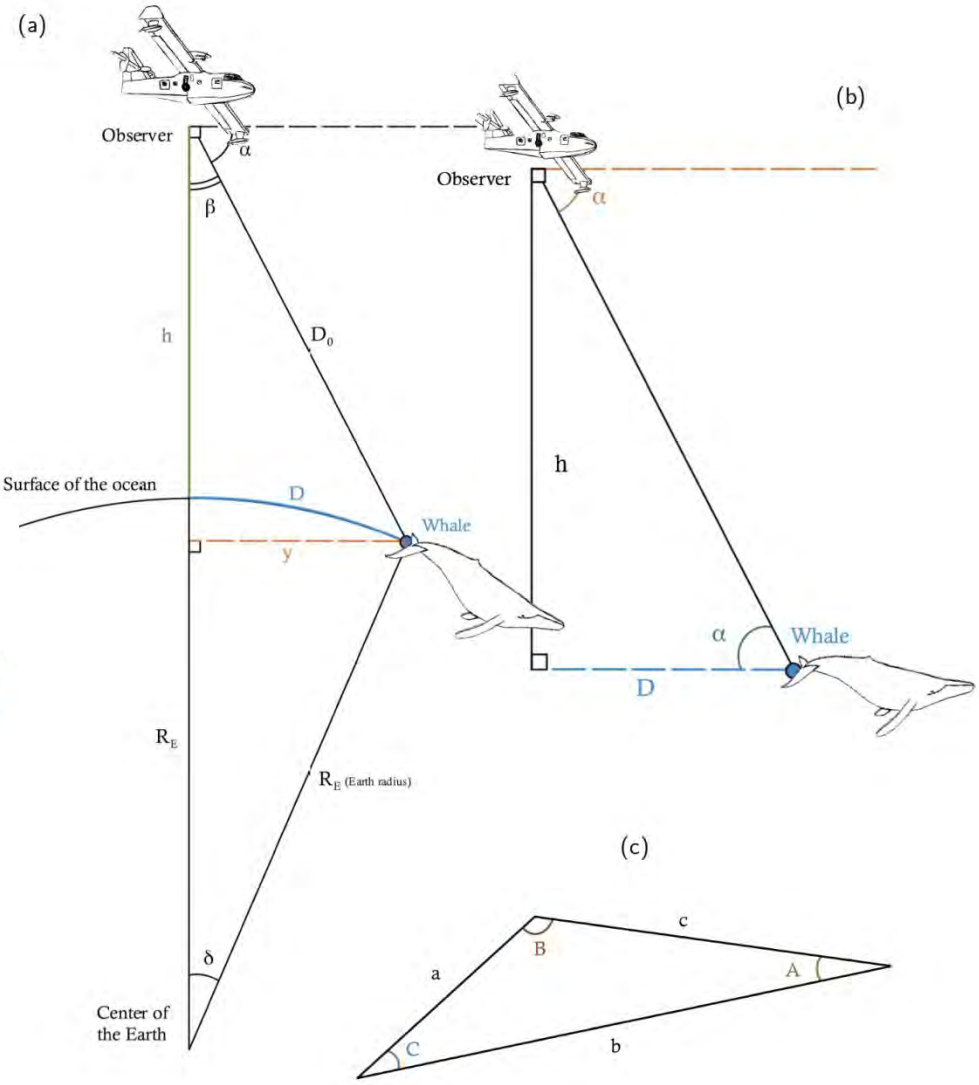
Data processing and analysis

- Perpendicular distances

Methods

Data processing and analysis





Methods

Data processing and analysis

- Perpendicular distances
- Swimming directions

Methods

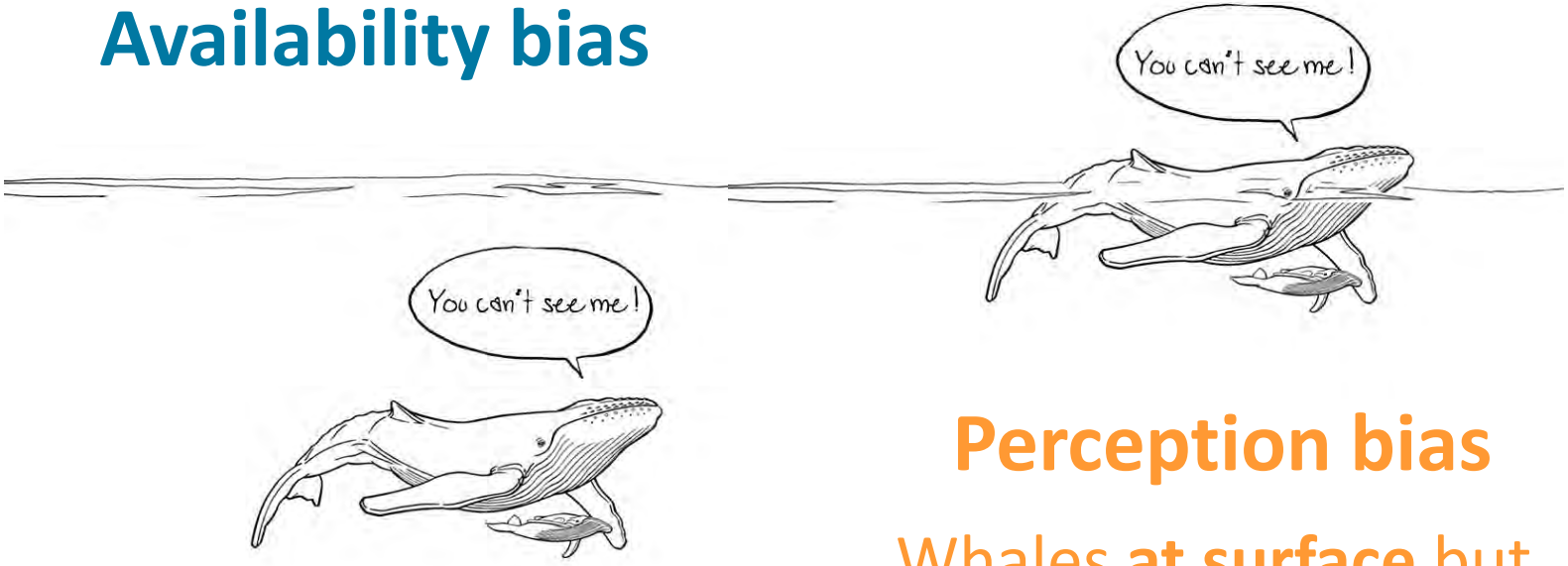
When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability

Methods

When things start getting more complicated

Availability bias



Whales **at depth** so cannot be detected

Perception bias

Whales **at surface** but limited detectability

Methods

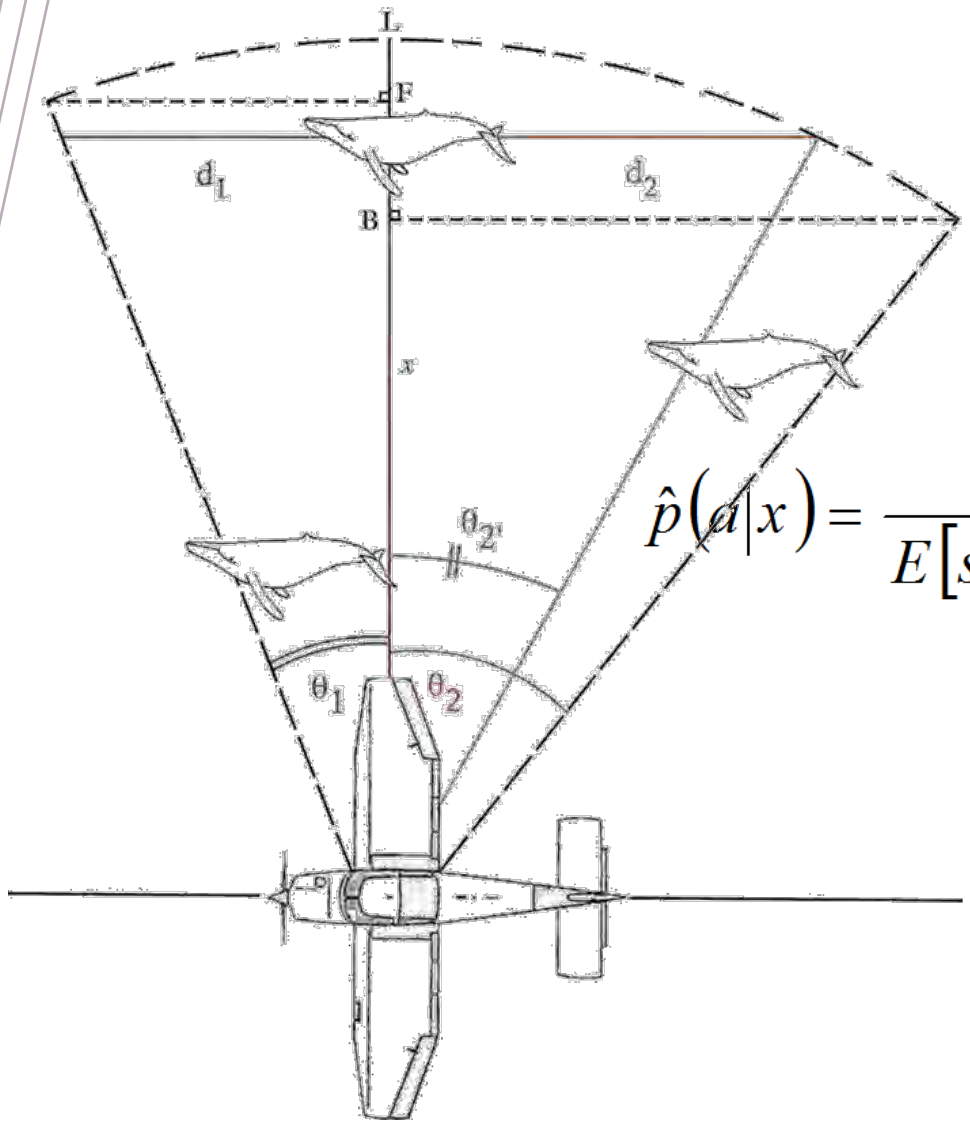
When things start getting more complicated

Whale #1

Whale #2

Methods

When things start getting more complicated



Time windows:

$$t = \frac{d_1 + d_2}{v}$$

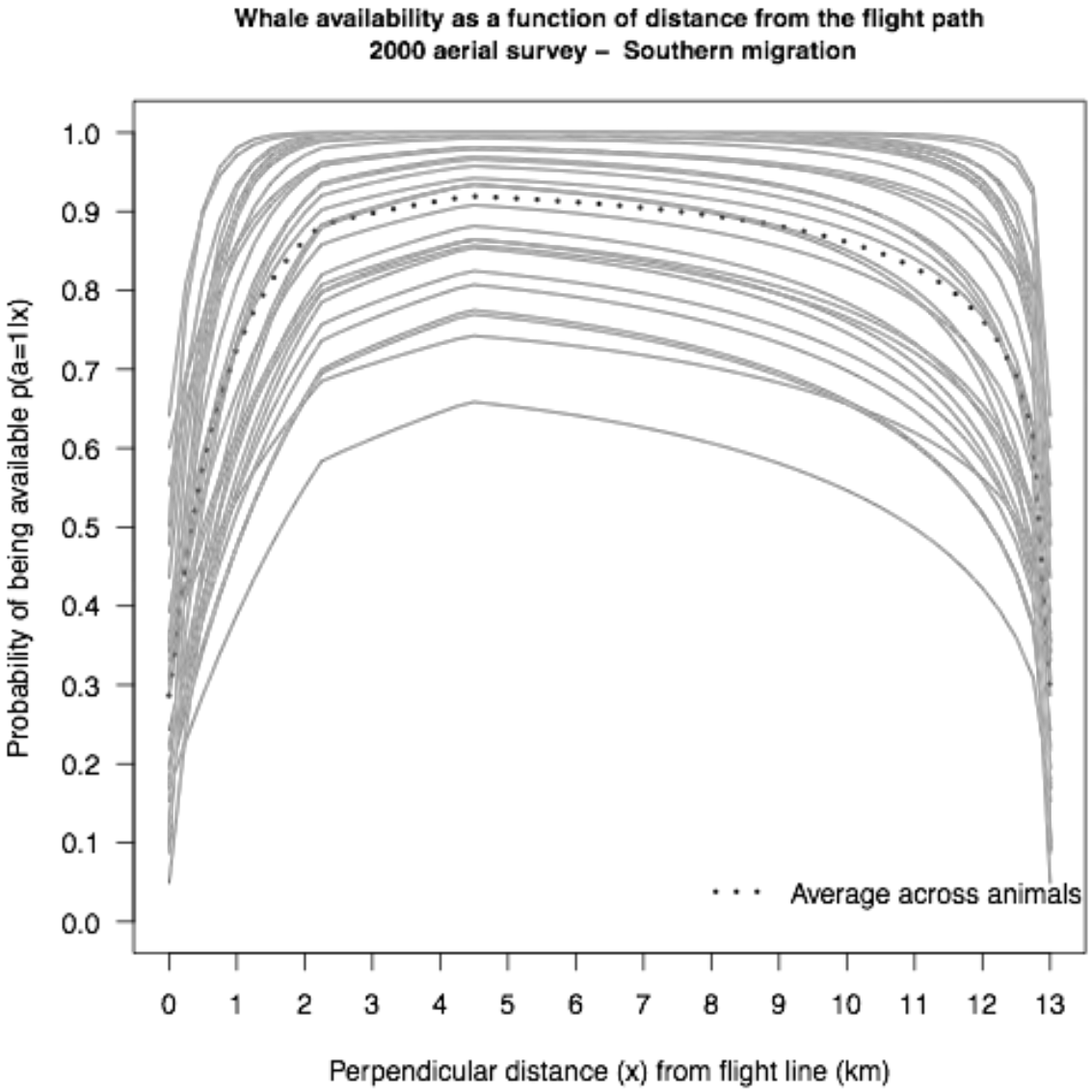
Laake's equation:

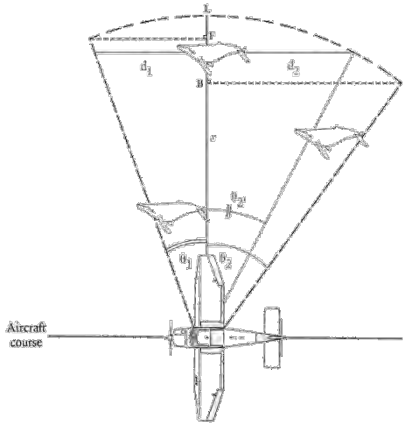
$$\hat{p}(d|x) = \frac{E[s]}{E[s] + E[d]} + \frac{E[d](1 - e^{\frac{-t}{E[d]}})}{E[s] + E[d]}$$

Laake, J.L., J. Calambokidis, S.D. Osmek, and D.J. Rugh. 1997. Probability of detecting harbour porpoise from aerial surveys: estimating g(0). *Journal of Wildlife Management,* 61:63-75.

Methods

When things start getting more complicated





Methods

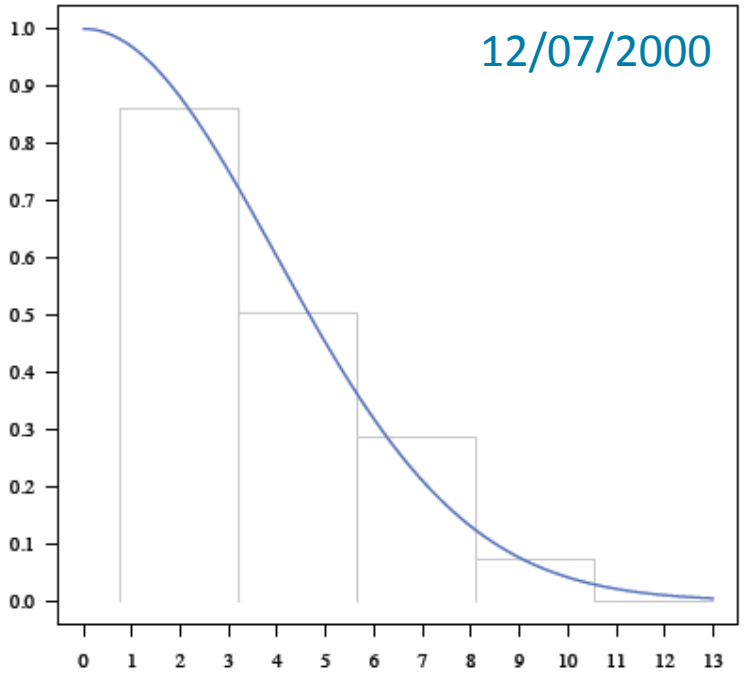
When things get a little complicated

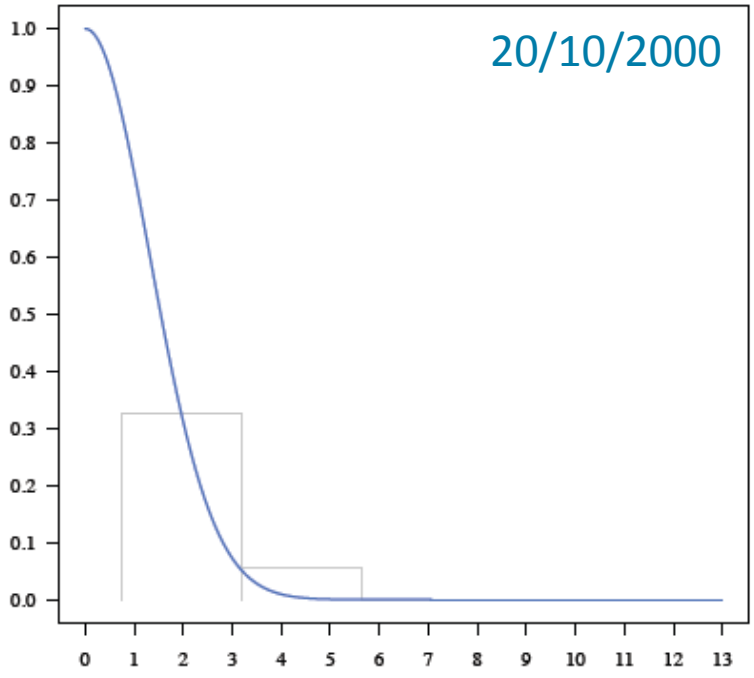
- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available

Methods

When things get a little complicated

- Right-truncation (7 nm = 13 km)
- Left-truncation (0.4 nm)
- Constrained HN model
- No covariates





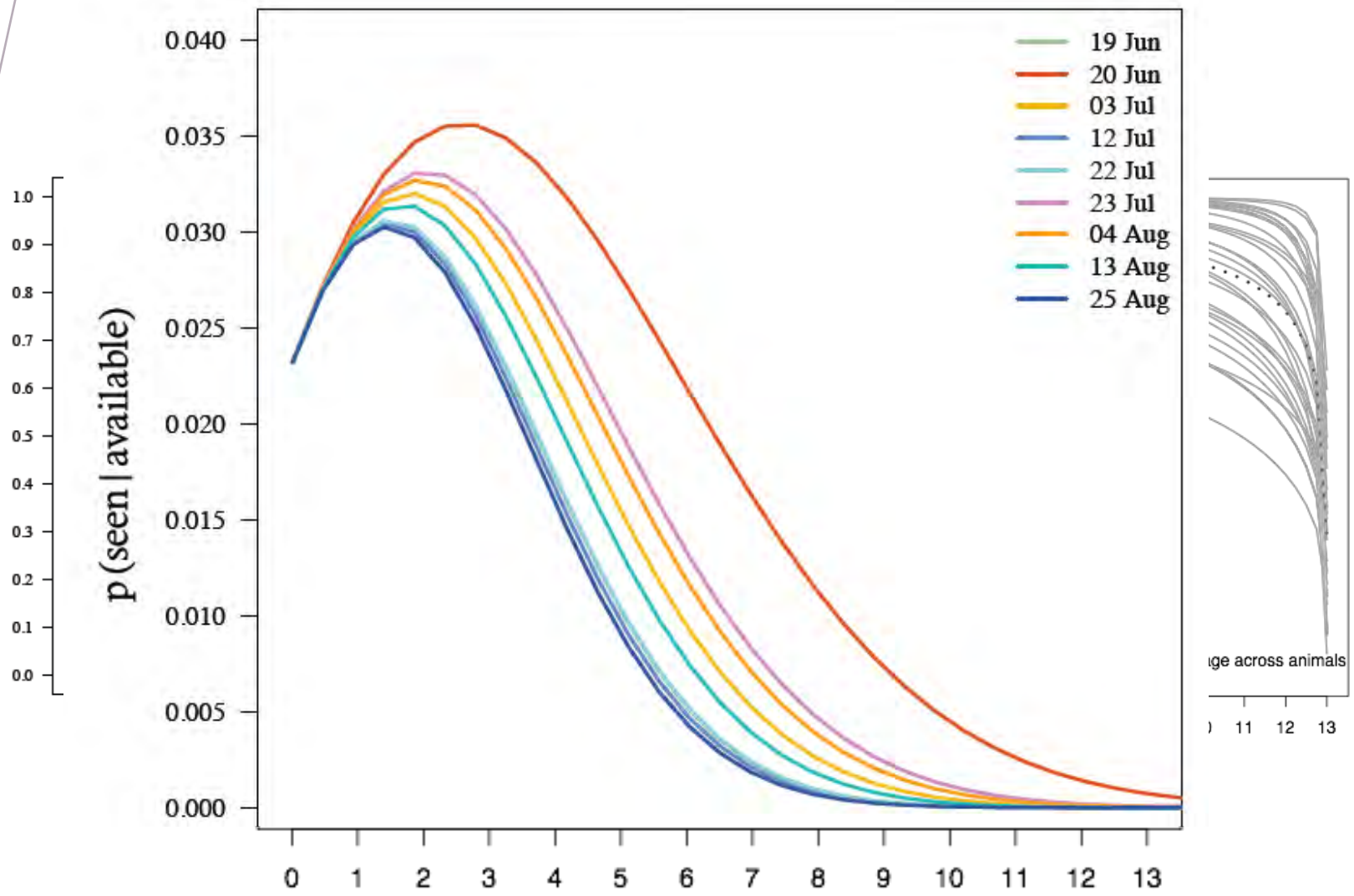
Methods

When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available
- Detectability adjusted for availability

Methods

When things start getting more complicated



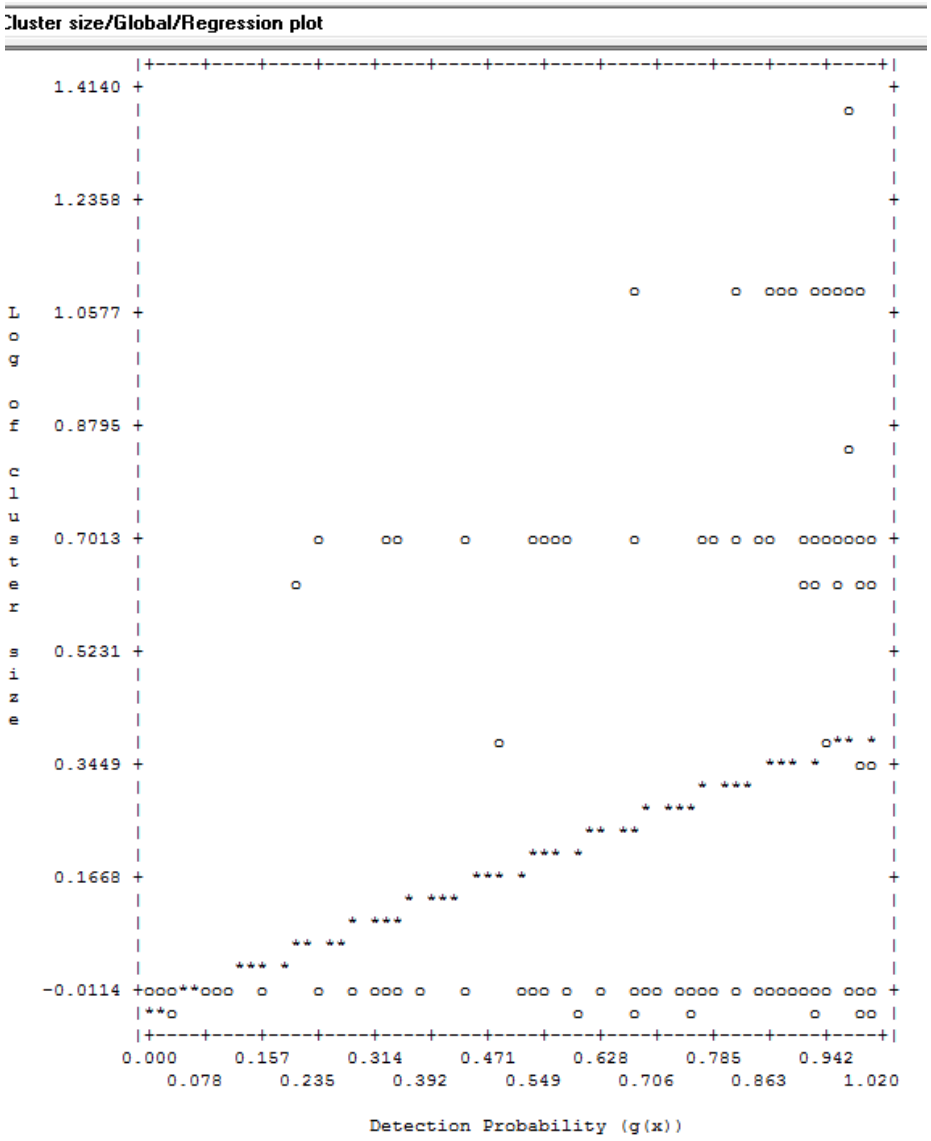
Methods

When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available
- Detectability adjusted for availability
- Pod sizes

Methods

When things get a little complicated



- Positive slope
- Negative bias
- **Smaller** pods ⊕ conspicuous at large distances

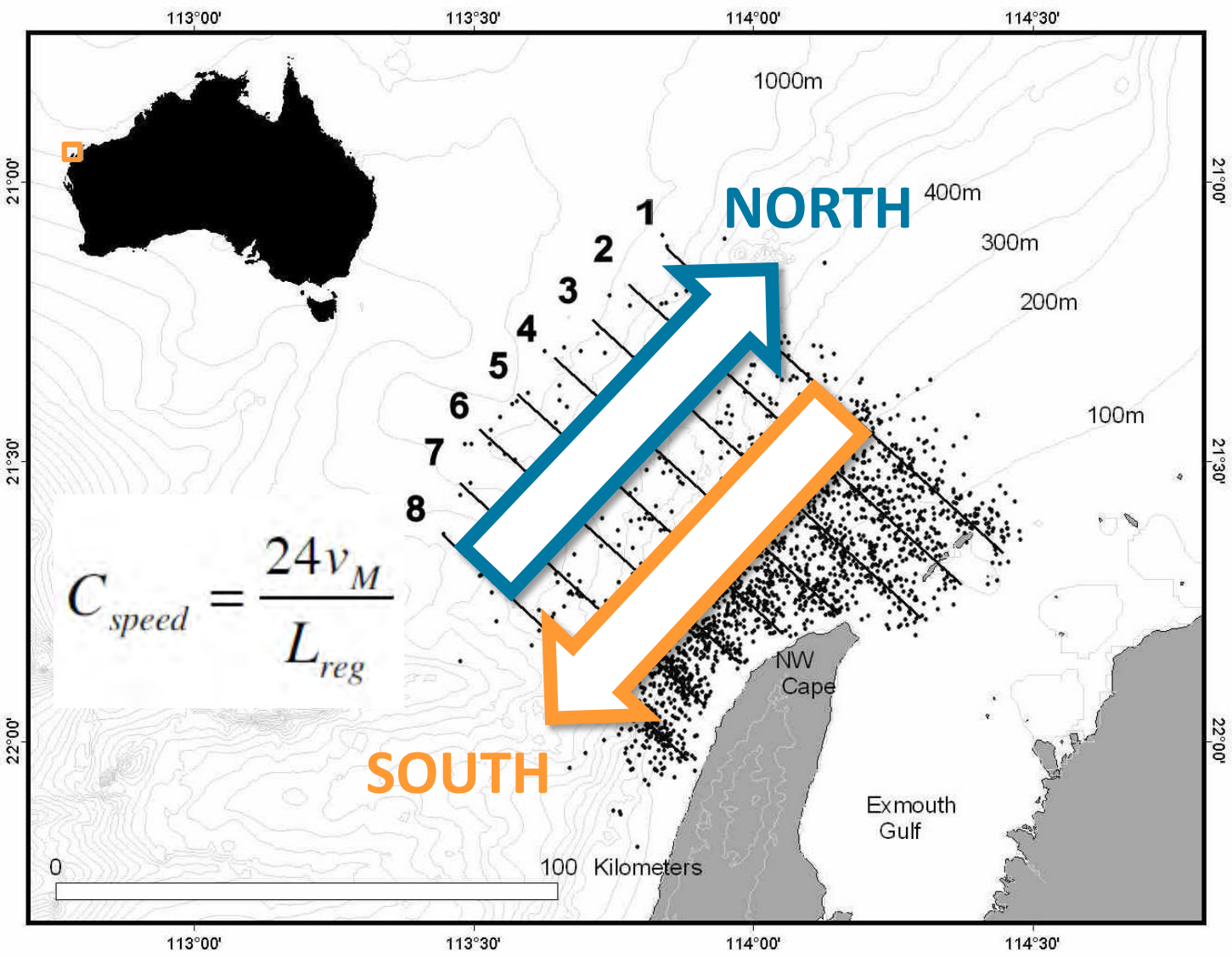
Methods

When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available
- Detectability adjusted for availability
- Pod sizes
- Migratory movements

Methods

When things start getting slightly more complicated



Methods

When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available
- Detectability adjusted for availability
- Pod sizes
- Migratory movements
- Daily abundance

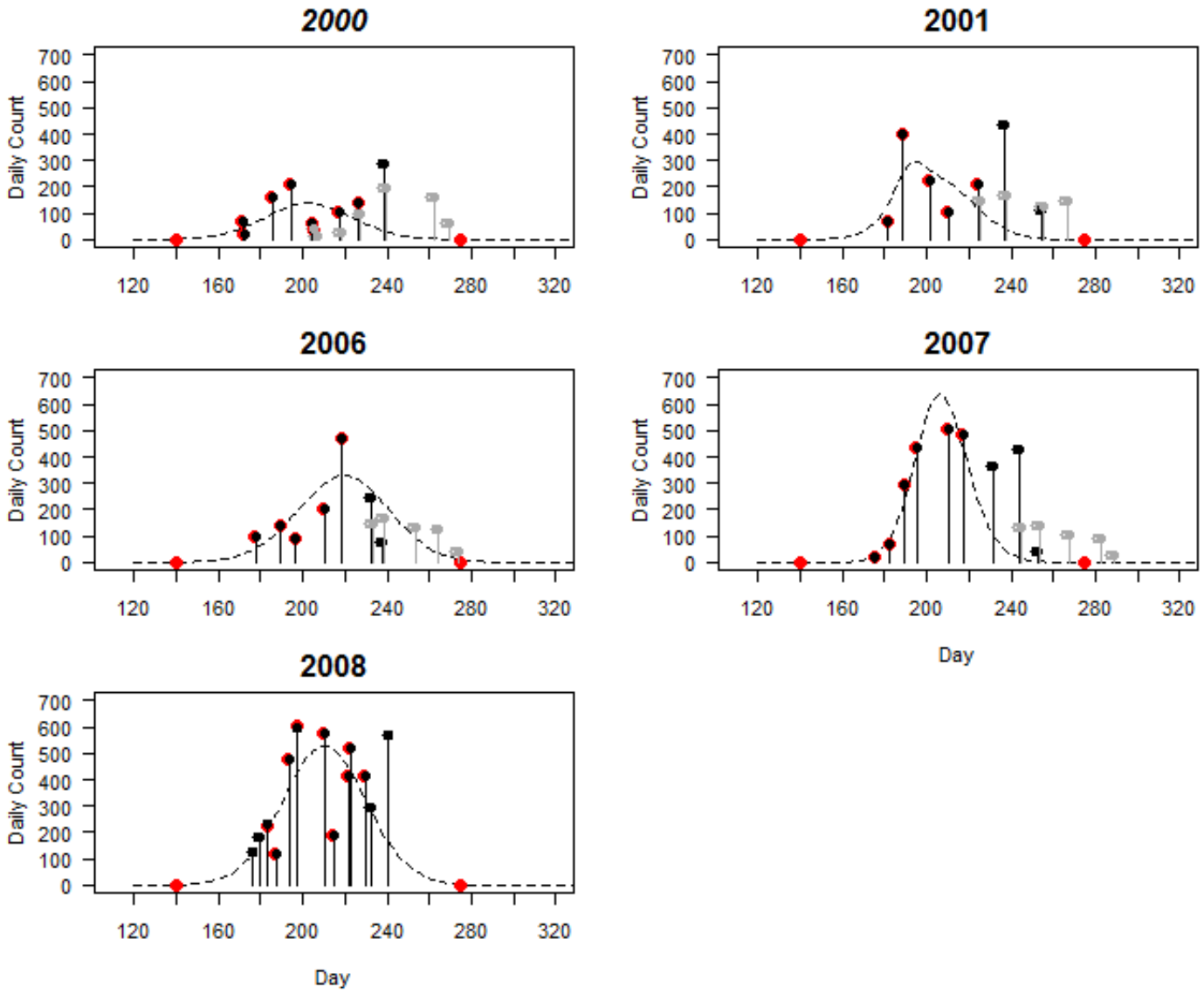
Methods

When things get a little complicated

- Perpendicular distances
- Swimming directions
- Sighting availability
- Detectability conditional on being available
- Detectability adjusted for availability
- Pod sizes
- Migratory movements
- Daily abundance
- Population abundance

Methods

When things get a little complicated



Running distance from R

When things get even more complicated

Tinn-R - [C:\Users\20878483\Documents\Data\Humpback project\Project\NWC-abundance estimation-16.12.2009.R]

File Project Edit Format Marks Insert Search Options Tools R View Window Web Help

R complex

NWC-abundance estimation-16.12.2009.R

```
for (m in 1:boot.iter){

begin<-numeric()

p.x <- numeric(length(res.boot[1,])/5)
n.covered <- numeric(length(res.boot[1,])/5)
n.covered.daily<-numeric(length(res.boot[1,])/5)
N.total.pod <- numeric(length(res.boot[1,])/5)
N.indiv <- numeric(length(res.boot[1,])/5)

# Takes a random sample of dive-surface pairs (with replacement) and calculates the average dive time and surfacing time.

temp.divesurface<-DShump[sample(nrow(DShump), replace=T),]
d.average <- mean(temp.divesurface["Dive"])
s.average <- mean(temp.divesurface["Surface"])

# Takes a random sample (with replacement) from the speed dataset.

temp.speed<-speed[sample(nrow(speed), replace=T),]
whales.speed<-mean(temp.speed$Km)
speed.correct<-daily*whales.speed
matrix.speeds[m]<-speed.correct

#  For each survey, computes the integral Eqn (1) of report, and uses that in the equation shown in
#  section 2.3 of report to produce survey-specific estimated number of humpback pods.
#  Adjusts up the estimated number of pods to estimated number of individuals using
#  size-bias adjusted expected cluster sizes.

nombre<-length(res.boot[1,])/5


for (survey in 1:nombre){


   p.x[survey] <- integrate(p.of.y, sigma.sq=res.boot[m,paste("S", survey, sep="")], trunc.dist=trunc.dist,
                    d.average=d.average, s.average=s.average, 0, trunc.dist)$value

   matrix.p.of.x[m,survey]<-p.x[survey]  # Fills in matrix of detectabilities.


   # If p.x[survey] is equal to 0 as a result of the Bootstrap loop having resampled empty lines only (by chance), then the
   # the total number of pods cannot be calculated (as dividing by p.x[survey] which is 0 returns an error).
   # This causes the migration curve fitting functions to crash.
   # To fix this, I introduced a conditional statement, which gives the value of 0 to the number of pods and individuals
   # if the probability p.x is itself 0.

   if (p.x[survey]==0){N.total.pod[survey]}
```

Variance estimation

When things get even more complicated

- Bootstrap procedure (with replacement, **B=1,000** pseudo-samples)
- Coefficients of variation (CVs)
- 95% confidence intervals (CIs) using the **percentile method** (Buckland *et al.* (2001)).
- Overall CV using the **Delta method** (Buckland *et al.* (2001)).

$$CV_{\hat{N}_{POP}} = \sqrt{\left(CV_{\frac{n}{L}}\right)^2 + \left(CV_{p(x)}\right)^2 + \left(CV_{speed}\right)^2 + \left(CV_{cluster}\right)^2 + \left(CV_{MLE}\right)^2}$$

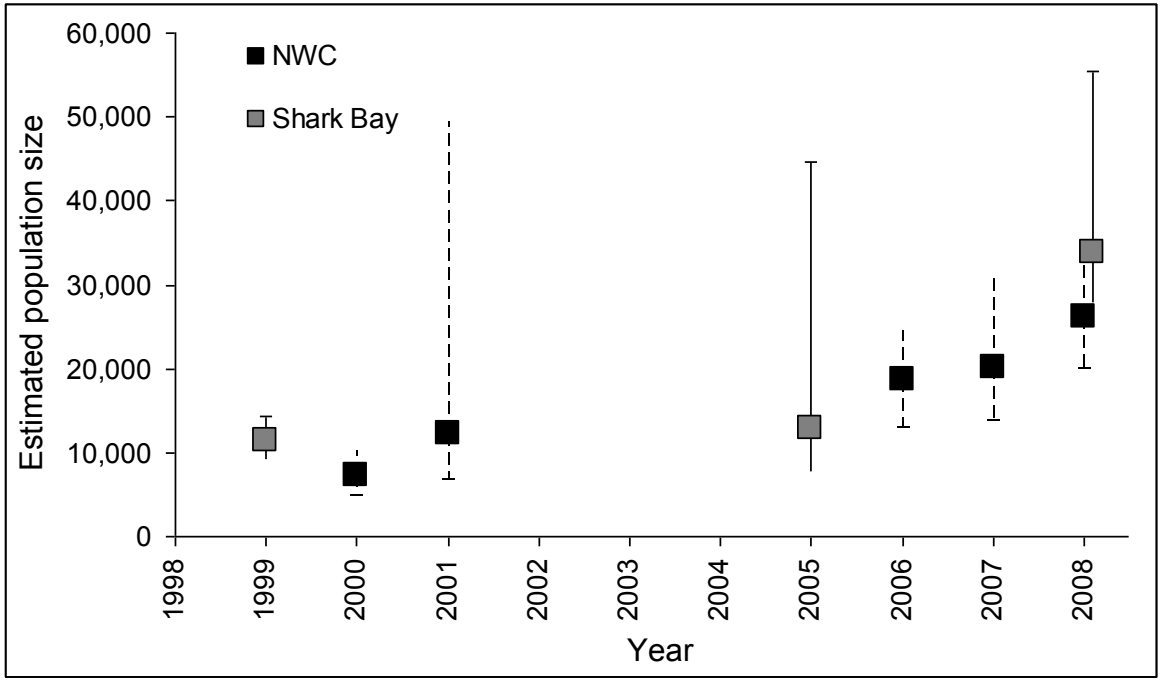
Results

2000: **7,276** (CI = 4,993-10,167)
2001: **12,280** (CI = 6,830-49,434)
2006: **18,692** (CI = 12,980-24,477)
2007: **20,044** (CI = 13,815-31,646)
2008: **26,100** (CI = 20,152-33,272)

Uncorrected for PB

2000: 9,281
2001: 15,663
2006: 23,842
2007: 25,566
2008: **33,291**

PB correction



Conclusions and future directions

- Population recovering well (13% per annum)
- Sample sizes (number of flights) = limit accuracy
- Need for more adequate g(0) protocol
- Investigating the possibility of combined aerial and land-based surveys

Useful references

• **Bannister, J.L., 1994.** Continued increase in humpback whales off Western Australia. *Report of the International Whaling Commission,* 44: 309-310.

• **Bannister, J.L., Hedley, S.L., 2001.** Southern hemisphere group IV humpback whales: Their status from recent aerial surveys. *Memoirs of the Queensland Museum,* 47(2): 587-598.

• **Borchers, D.L., Buckland, S.T., Zucchini, W., 2002**. Estimating animal abundance: Closed populations (Statistics for biology and health). London, Springer-Verlag, 314 p.

• **Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2004**. Advanced distance sampling: Estimating abundance of biological populations. Oxford University Press, 416 p.

• **Hedley, S.L., Bannister, J.L., Dunlop, R.A., (in press).** Abundance estimates of southern hemisphere breeding stock 'D' humpback whales from aerial and land-based surveys off Shark Bay, Western Australia. *Journal of Cetacean Research and Management*.

• **Lerczak, J.A., Hobbs, R.C., 1998.** Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science,* 14(3): 590-599.

• **Noad, M., Paton, D., Cato, D., 2005.** Absolute and relative abundance estimates of Australian east coast humpback whales *(Megaptera novaeangliae)*. *Report of the International Whaling Commission,* SC/A06/HW27, 15 p.

• **Salgado Kent, C., Jenner, K.C.S., Jenner, M.-N., Bouchet, P., Rexstad, E., (in press).** Southern Hemisphere breeding stock "D" humpback whale population estimates from North West Cape, Western Australia. *Journal of Cetacean Research and Management*.

• **Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A., Burnham, K.P., 2010.** Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology,* 47: 5-14.