Curtin University of Technology

CMST seminar - November 2, 2010

Visibility bias in aerial surveys of cetaceans

An application to breeding stock "D" humpback whales

Centre for WHALE RESEARCH WESTERN AUSTRALIA

Phil Bouchet
Centre for Whale Research (WA) Inc.
PO Box 1622 - Fremantle, WA 6959
phil.bouchet@cwr.org.au

University of St Andrews

SMRU

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1. How many out there ?

Estimating marine mammal abundance - a topical issue

- **Critical** for conservation and management
- **Various tools** available to scientists

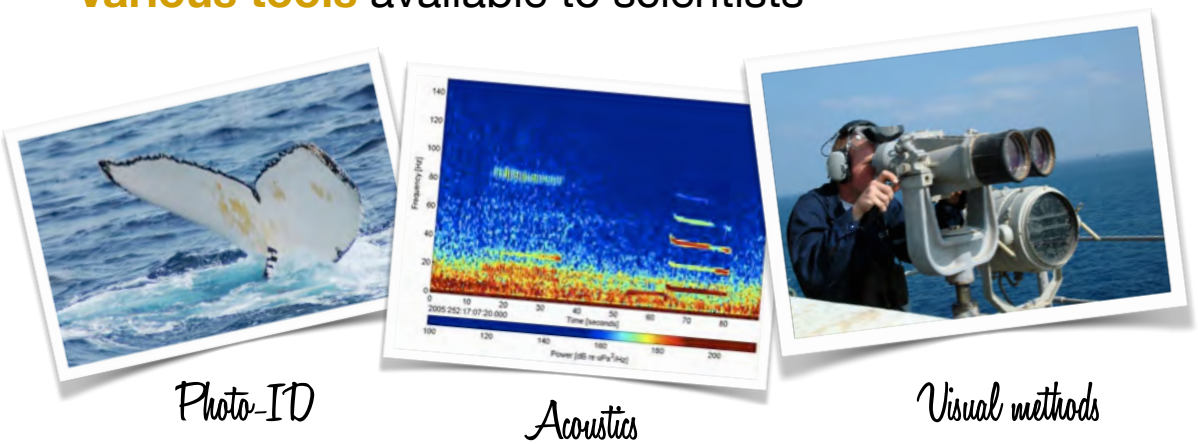

Photo-ID | Acoustics | Visual methods

- **Distance Sampling** widely used

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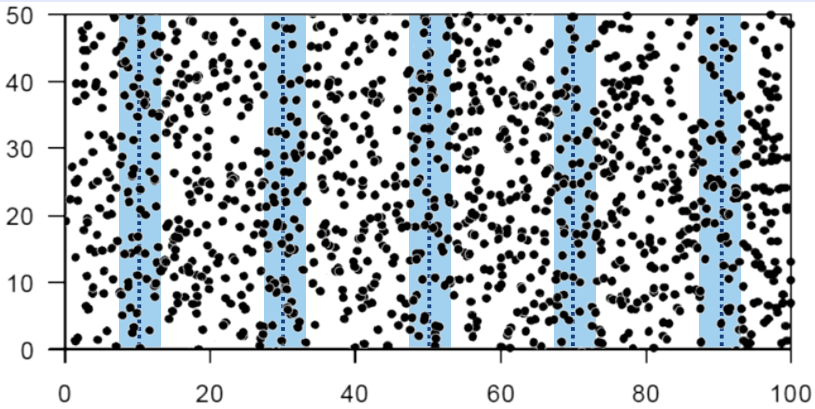
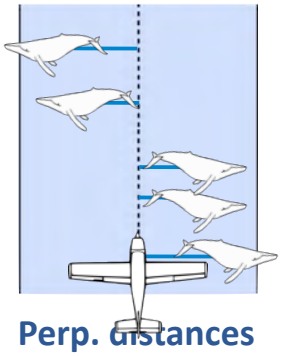
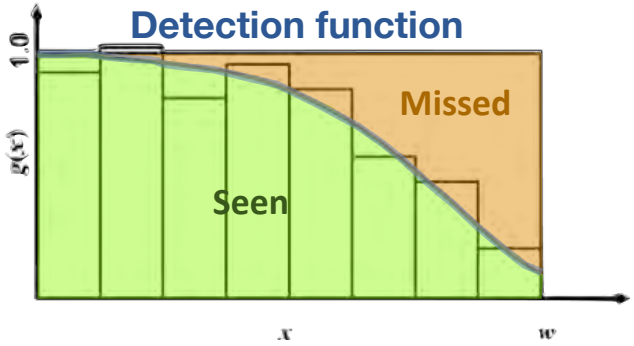
2. Distance sampling 101

A brief refresher on the underlying theory





Perp. distances



1. g(0) is unity

2. No responsive movement

3. Distr. independently of line

4. Measurements are exact

5. Detections are independent

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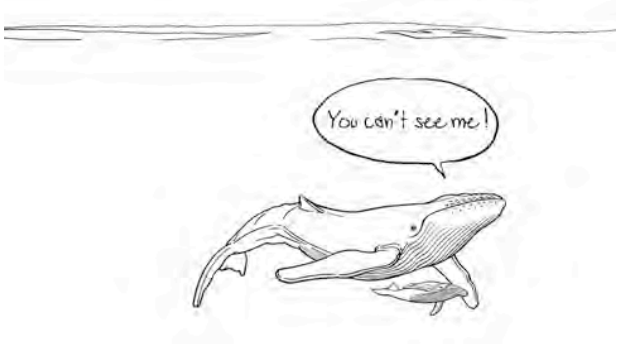
3. Availability & perception bias

Or the art of missing animals in the field

Availability

Whales at depth so cannot be detected



Perception

Whales at surface but limited detectability

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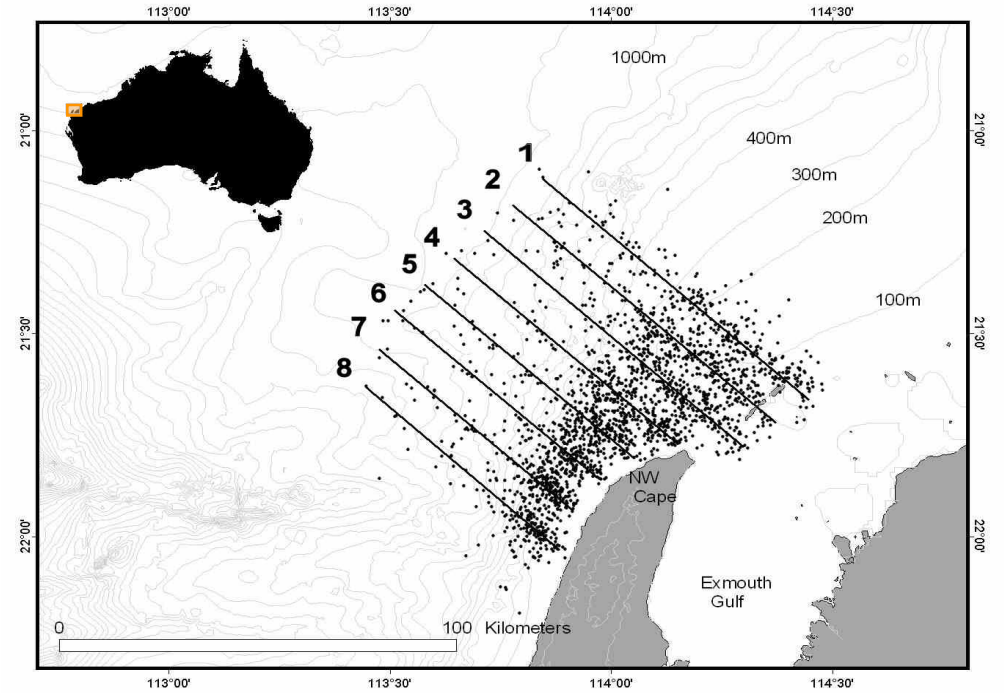
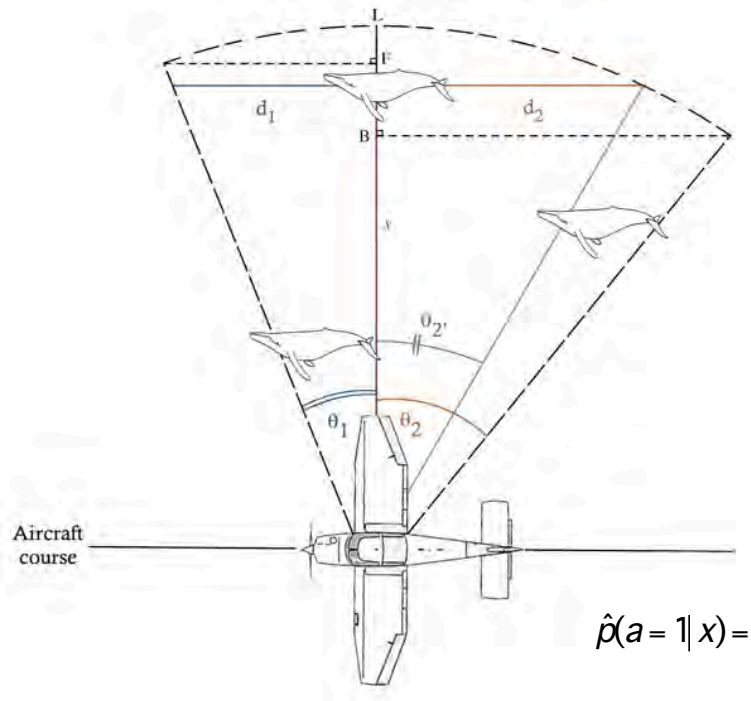
4. North West Cape 2000-2008

Applying Distance Sampling to WA



5. Coping with availability bias

Accounting for humpback whales' diving behaviour



θ_1 = fore angle of view
θ_2 = aft angle of view
$\theta_{2'}$ = aft angle to whale when it leaves the field of view
x = perpendicular distance to the sighting
L = outer limit of viewing range
d_1+d_2 = total distance within range

Time window:

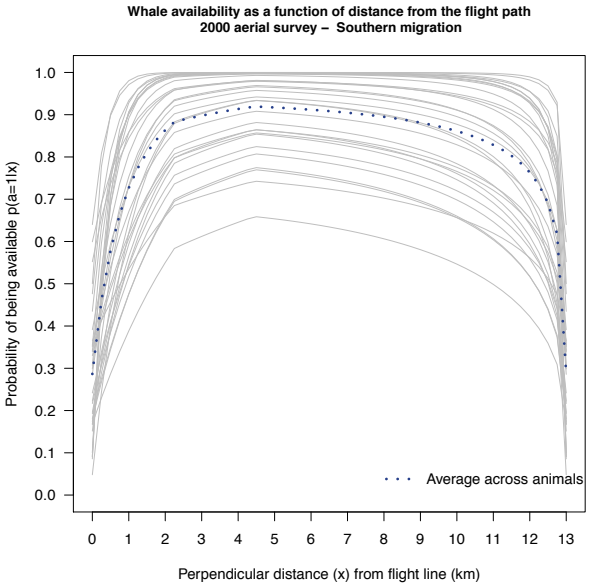
$$t = \frac{d_1 + d_2}{v} \quad [1]$$

Probability of being available:

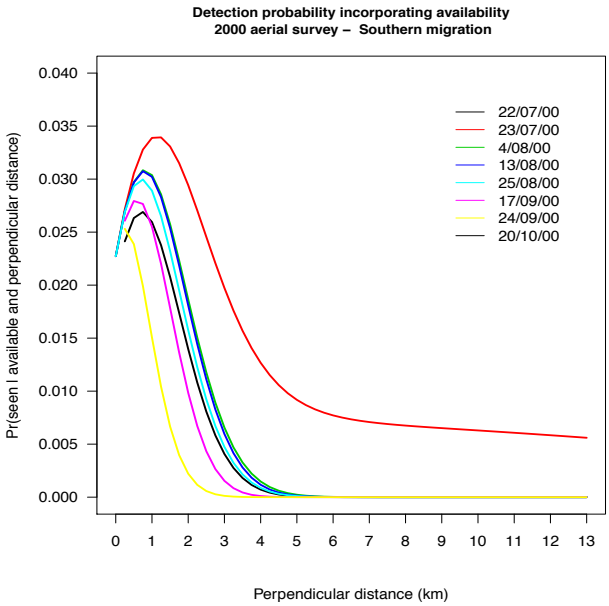
$$\hat{p}(a=1|x) = \frac{E[s]}{E[s]+E[d]} + \frac{E[d](1-e^{\frac{-t}{E[d]}})}{E[s]+E[d]} \quad [2]$$

5. Coping with availability bias

Accounting for humpback whales' diving behaviour



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)

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6. Coping with perception bias

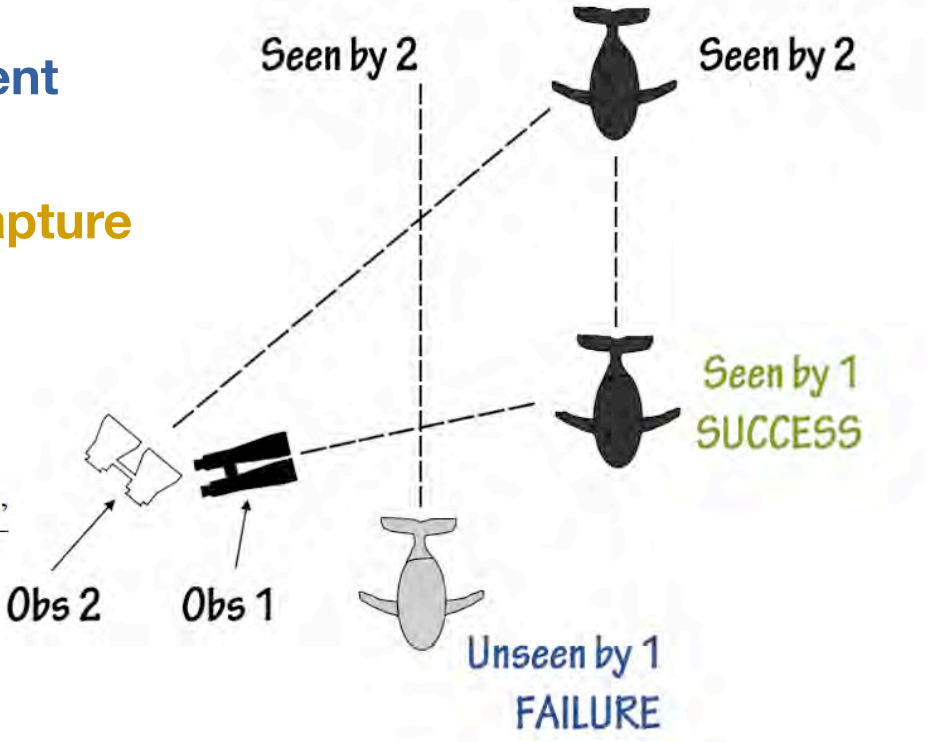
Accounting for limited detectability of available animals

- **Independent** observers
- **Mark-recapture** theory

Pr(Obs 1 sees) =

$$\hat{p}_1 = \frac{1}{2} = \frac{n_{12}}{n_2}$$

= number "duplicates" / number seen by 2



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7. Observer configurations

One or two-way independence

TRIAL-observer

Observer 2
↓
Sets up trials for
↓
Observer 1
↓
To estimate p_1

$$\hat{N} = \sum_{\text{all i seen by 1}} \frac{1}{\hat{p}_1(x_i,\ldots)}$$

INDEPENDENT-observer

To estimate p_2
↑
Observer 2
↓ ↑
Sets up trials for
↓ ↑
Observer 1
↓
To estimate p_1

$$\hat{N} = \sum_{\text{all i seen}} \frac{1}{\hat{p}_\bullet(x_i,\ldots)} \qquad p_\bullet = p_1 + p_2 - (p_1 p_2)$$

8. Complications

When things start getting a little trickier

- **It's not all** about the **trackline !**



- **Not all** animals are **equally detectable !**

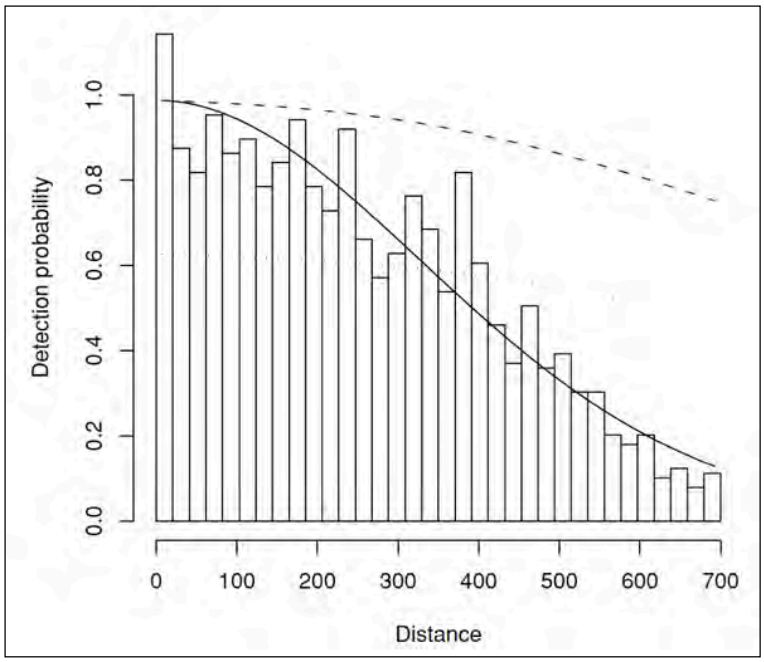
UNMODELLED HETEROGENEITY

✓ Logistic form - binary regression
✓ Incorporate covariates into model

Photo courtesy
(from left to right):
www.listsoplenty.com;
www.mirror.co.uk;
Micheline Jenner

9. Levels of independence

Full and point (or trackline conditional) models



—— **Point** independence

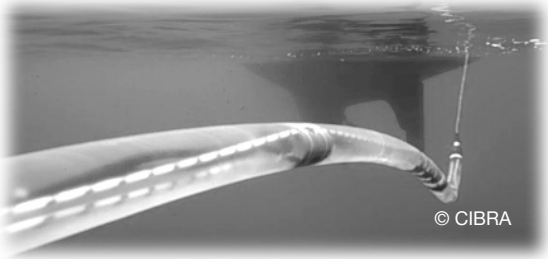
------ **Full** independence

..... **FI curve scaled** so that the area under it is equal to that under the PI curve

10. Surfacing behaviour

To be or not to be short of breath

- **Cue counting** methods
- **Design out** heterogeneity
- **Tandem** formation
- Combine **acoustics and visual** platforms



11. Duplicate identification

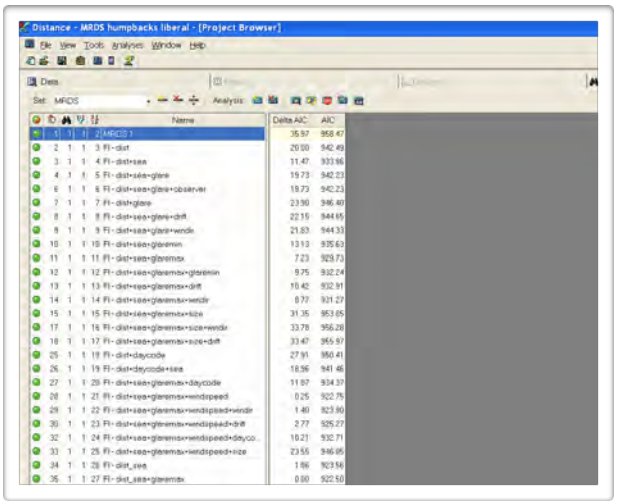
Snap ! or maybe not ...

- **Intermediary** observer onboard
  - *salary costs*
  - *safety and practical considerations*
  - *not that simple !*
- Classify duplicates **subjectively**
  - *'definite', 'probable', 'possible'*
  - *effect of uncertainty in duplicate ID*
- Define **objective** rules
  - *time window*
  - *horizontal separation*
- Use **probability** models

12. Methods

p(0) in aerial surveys of breeding stock 'D' humpbacks

- Modified **duplicate identification** routine
  - *range of "legality" criteria*
  - *3 requirements to be met*
  - *2 scenarios tested*
  - *great circle distances*
- **Covariate** values **averaged**
- Data imported **into DISTANCE 6.0** => MRDS



- **75 contending** models tested
  => various combinations of covariates

13. Results

p(0) in aerial surveys of breeding stock 'D' humpbacks

- **271** detections collected over **6** survey days
- Visual recaptures = **56** (liberal) & **28** (strict)
- **Pod size** estimation found to be **messy**
- Presence of **bias** in distance measurements ?
- Model of **best fit (AIC = 900.86)**

*distance * sea state + max glare + wind dir + observer*

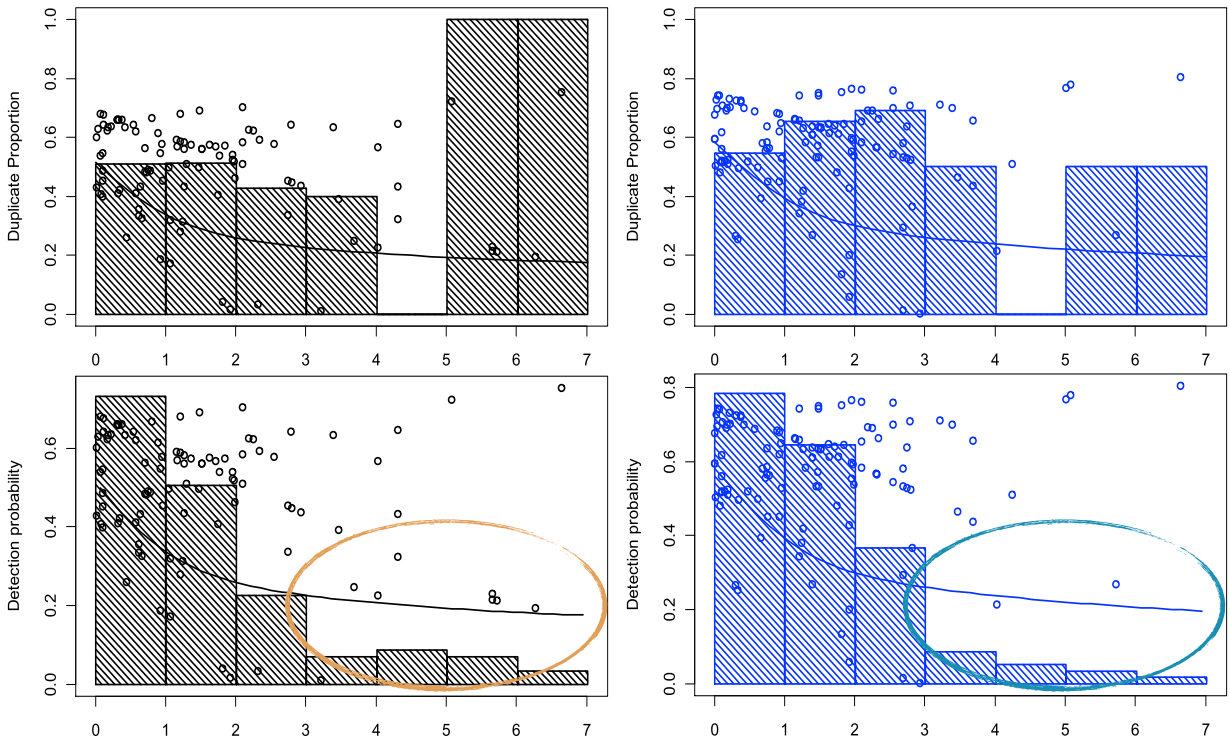
p(0) Obs 1 = **0.514**
p(0) Obs 2 = **0.583**
Combined p(0) = **0.784**

p(0) Obs 1 = **0.0262**
p(0) Obs 2 = **0.0262**
Combined p(0) = **0.0435**

13. Results

p(0) in aerial surveys of breeding stock 'D' humpbacks

11. Duplicate identification
12. Methods
13. Results
14. Conclusions
15. Reading



14. Conclusions

Quick summary

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

- Aerial surveys are **problematic**
- **2 processes** introduce bias
- Rely on **external** data
- Combine **MR** and **DS = MRDS**
- Cameras, life-size models, IR ...

15. Reading

Useful references

Borchers, D.L., Laake, J.L., Southwell, C., Paxton, C.G.M., 2006. Accommodating unmodeled heterogeneity in double-observer distance sampling surveys. *Biometrics*, 62(2): 372-378.

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Questions?