

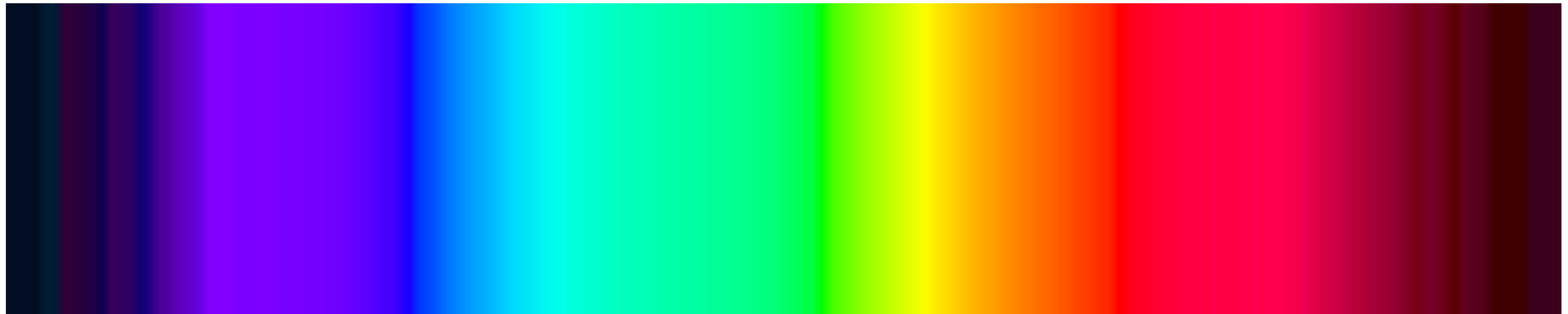
# Pedigree-Informed Estimates of Abundance and Trends for the North Atlantic Right Whale

Timothy R. Frasier, *Kayla Fitzgerald*, Philip K. Hamilton, Moira W. Brown, Scott D. Kraus, Bradley N. White

# How Many North Atlantic Right Whales Are There?

- How “complete” is the photo-identification catalogue?
- How well do we understand distribution, movement patterns, and everything else?

# How many individuals are not photo-identified?

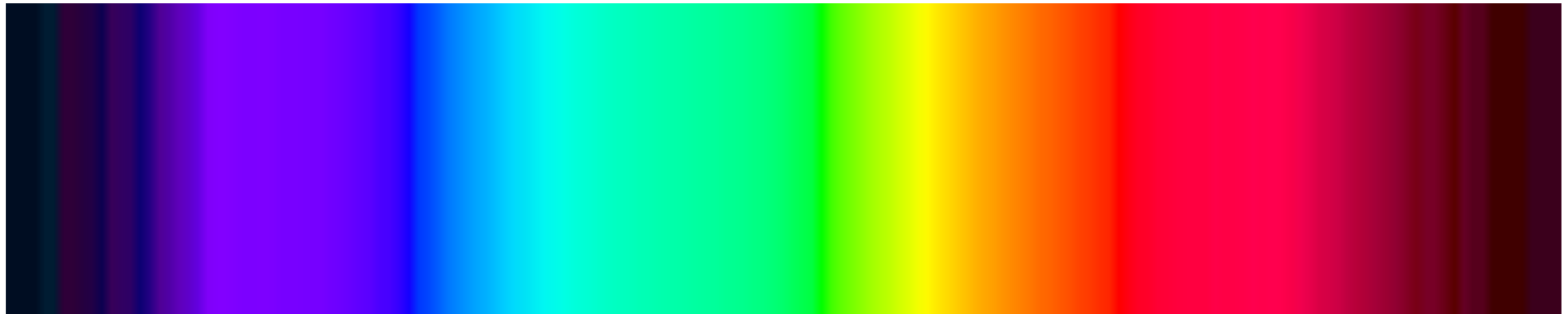


Not enough  
to change the  
big picture

Don't  
Know

Potentially  
a lot

# How many individuals are not photo-identified?

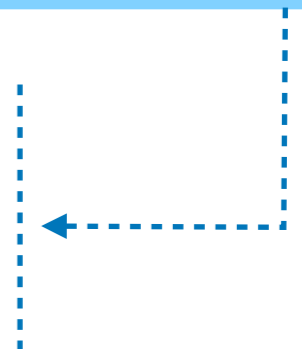


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a lot

1. "Irregular whales" described in Hamilton et al. (2007)<sup>1</sup>
2. Paternity analyses from Frasier et al. (2007)<sup>2</sup>



1. Hamilton et al. (2007) p. 75-104 In: *The Urban Whale* (Kraus SD, Rolland RM, eds.) Harvard University Press.  
2. Frasier et al. (2007) *Molecular Ecology* **16**: 5277-5293.

How can we incorporate the genetic inference of individuals in a statistically robust way?



# Ecology and Evolution

Open Access

## **Using pedigree reconstruction to estimate population size: genotypes are more than individually unique marks**

Scott Creel<sup>1,2</sup> & Elias Rosenblatt<sup>1,2</sup>

<sup>1</sup>Department of Ecology, Montana State University, Bozeman, Montana, 59717

<sup>2</sup>Zambian Carnivore Programme, Box 80, Mfuwe, Eastern Province, Zambia

$$\hat{N} = N_s + N_{in} + N_{iv}$$

$$\hat{N} = N_s + N_{in} + N_{iv}$$



Number of individuals *sampled*

- Just a count

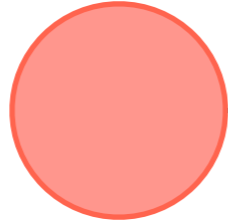
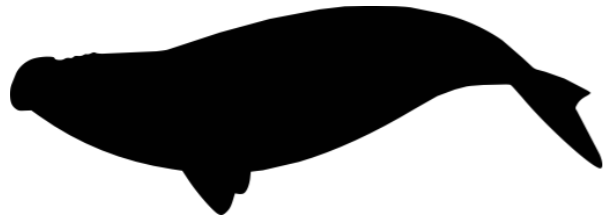


$$\hat{N} = N_s + N_{in} + N_{iv}$$

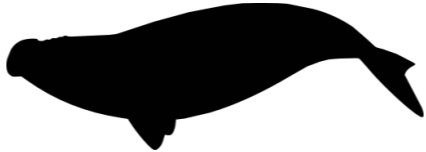
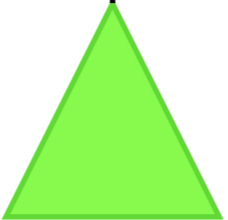


Number of individuals *inferred*

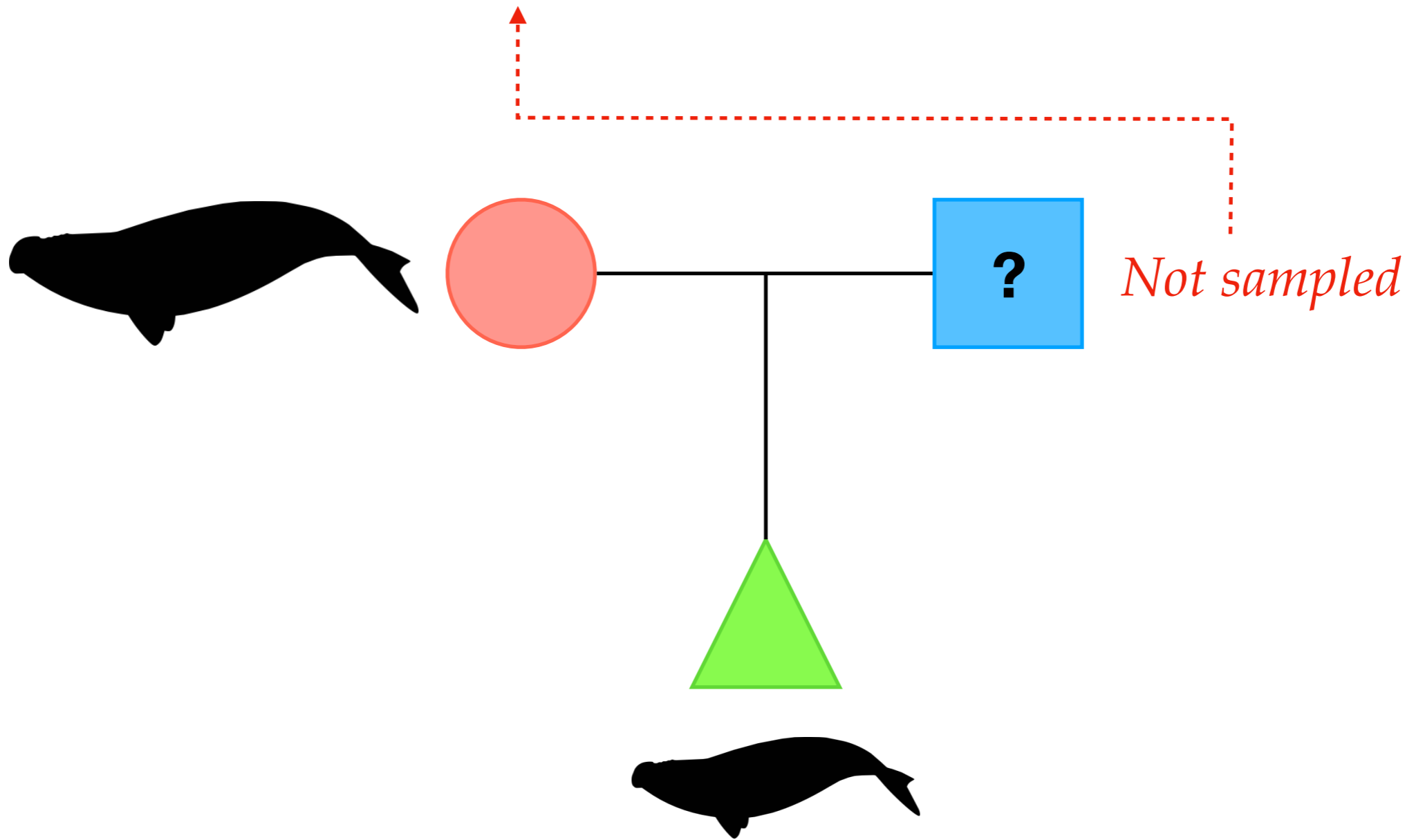
- Based on pedigree data
- Also a count



*Not sampled*

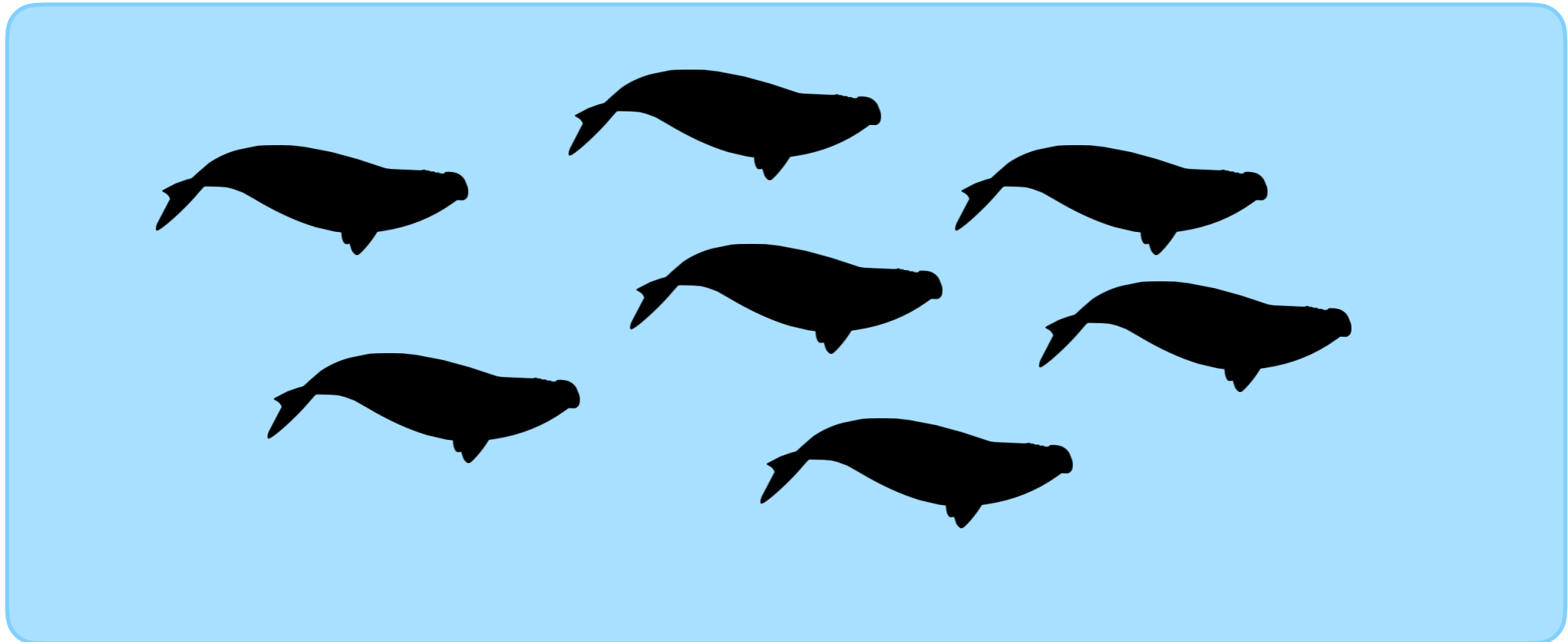


Infer 1 male? Not so simple



## Calves without sampled fathers (suppose $n = 7$ )

- DadShare by Bill Amos
- How related are they?
- How related would we expect them to be if:
  - Fathered by 7 males?
  - Fathered by 6 males?
  - etc?



$$\hat{N} = N_s + N_{in} + N_{iv}$$



Number of individuals *inferred*

- Based on pedigree data
- Also a count
- Can be used to infer both males *and females*

$$\hat{N} = N_s + N_{in} + N_{iv}$$



Number of individuals that are *invisible* to the pedigree analyses

- Where things get interesting!
1. Non-sampled non-breeders ( $N_{nsnb}$ )
    - Adults that aren't sampled and haven't bred
    - Juveniles and calves that aren't sampled
  2. Breeders who are not sampled and not inferred ( $N_{bnsni}$ )

$$\hat{N} = N_s + N_{in} + N_{iv}$$



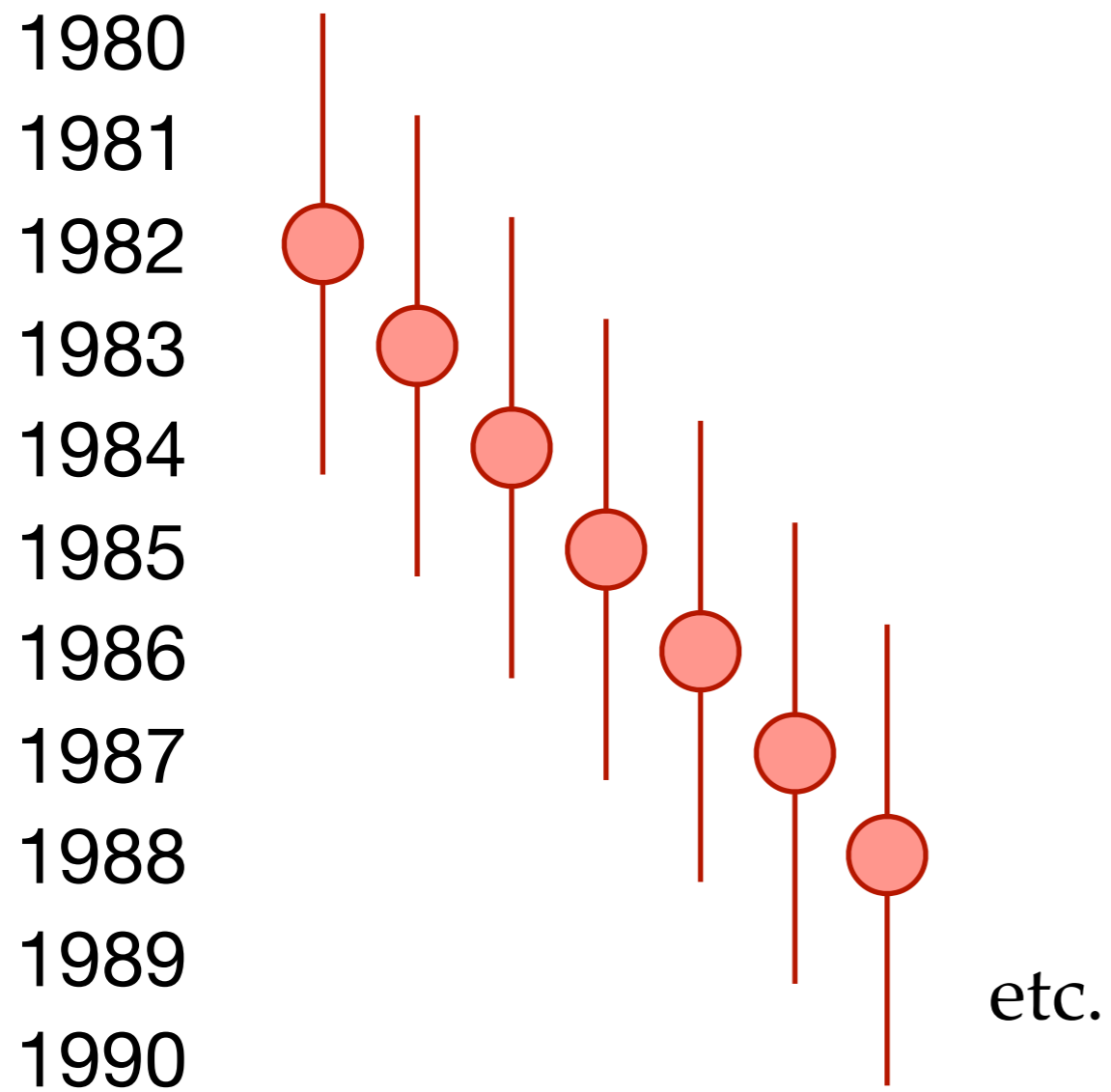
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- Require estimating:
    - Probability of being sampled ( $P_{sampled}$ )
    - Probability of being a breeder ( $P_{breeder}$ )

A blue dashed arrow originates from the right side of the list of probabilities. It extends horizontally to the right, ending in a solid blue arrowhead pointing towards the text 'Bayesian estimation with Stan'.

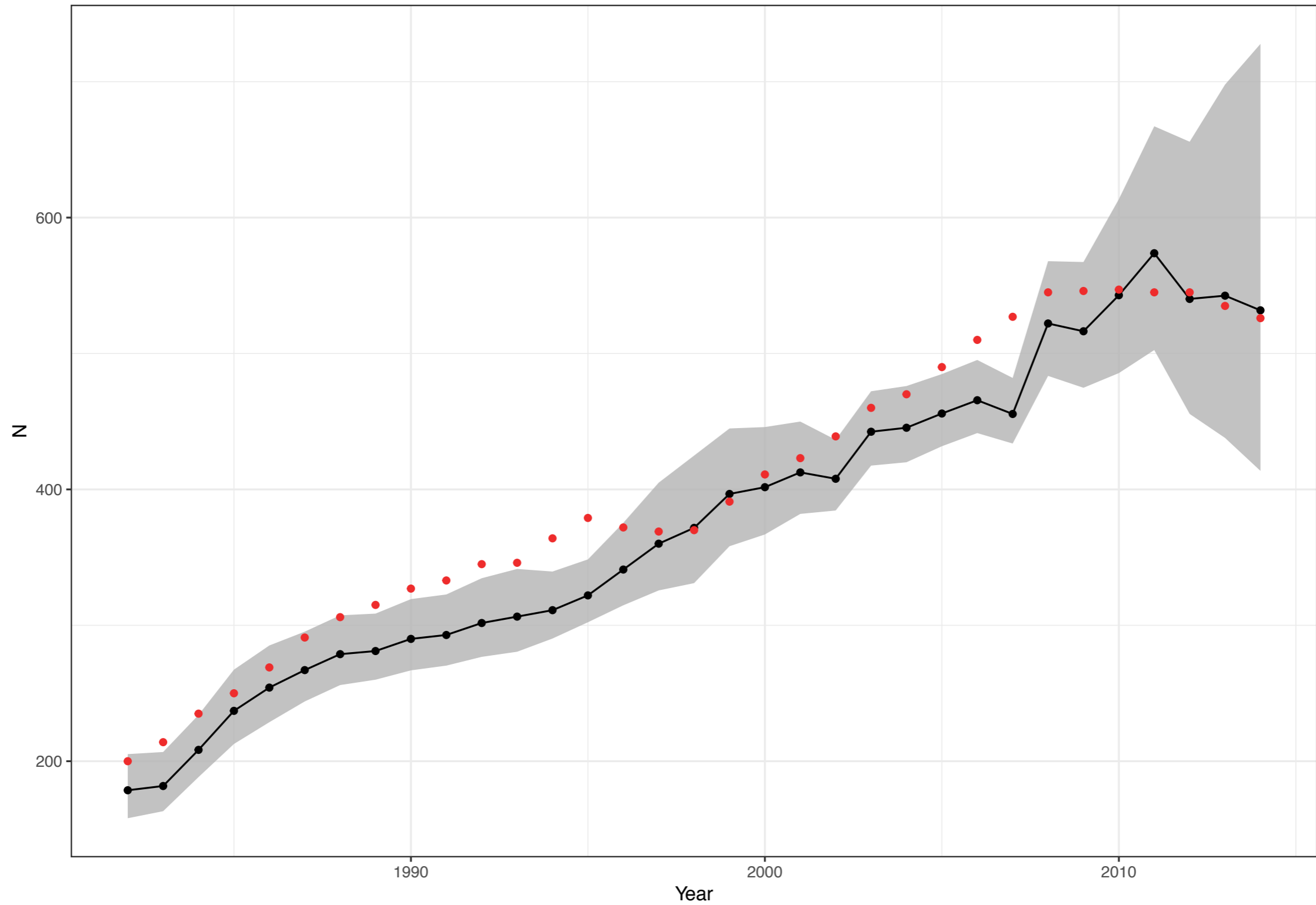
*Bayesian estimation  
with Stan*

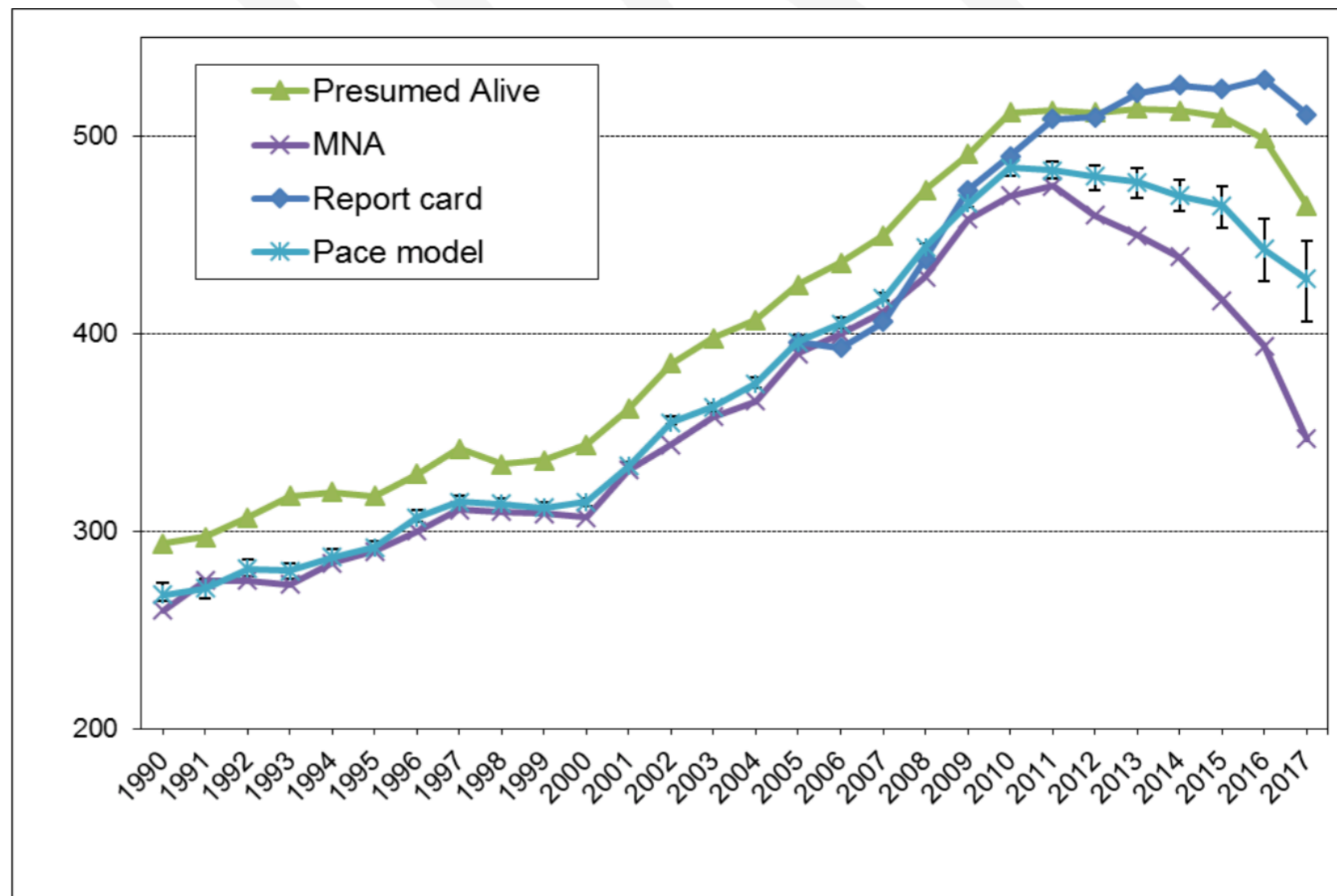
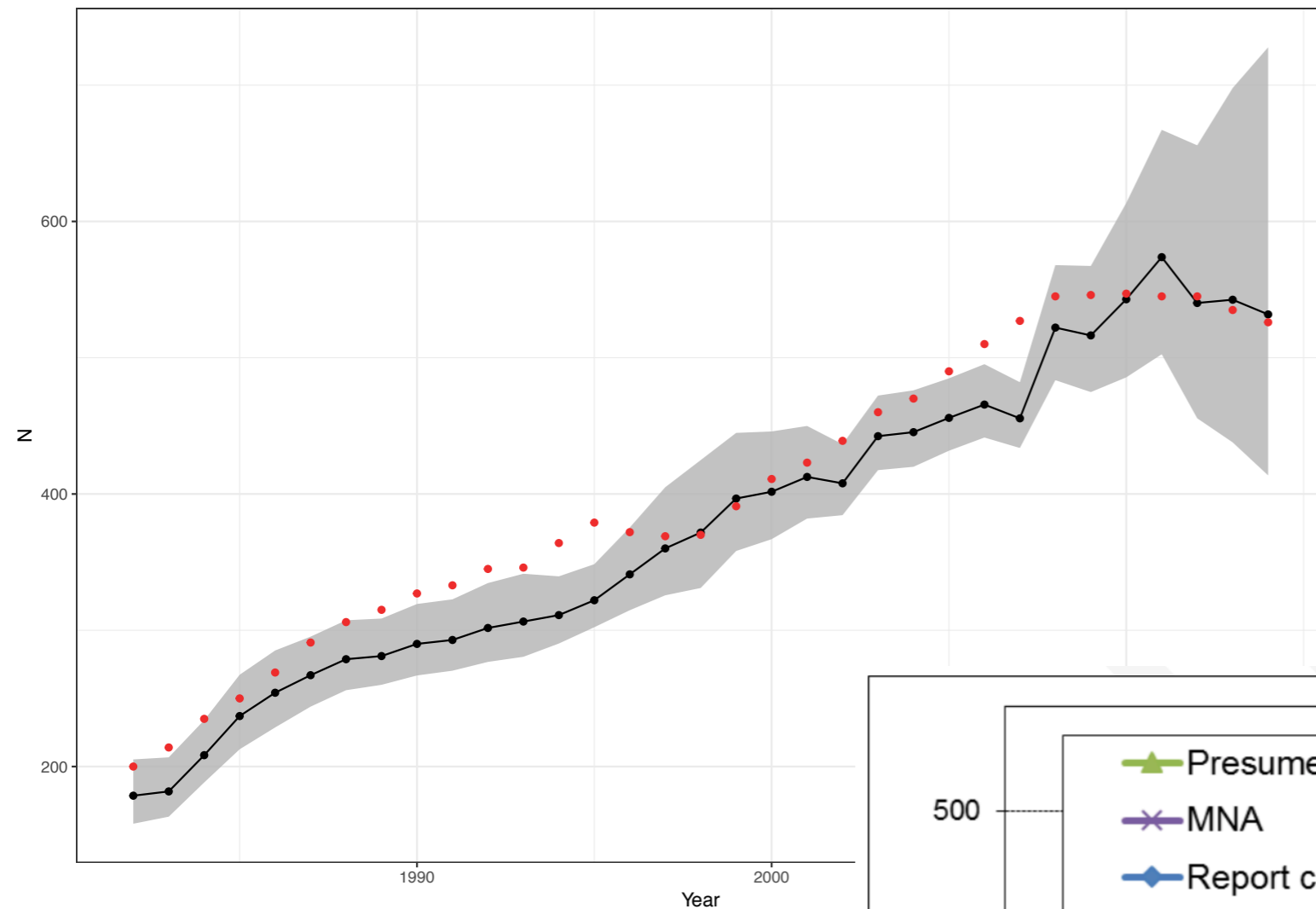
# Enough already, what about right whales?



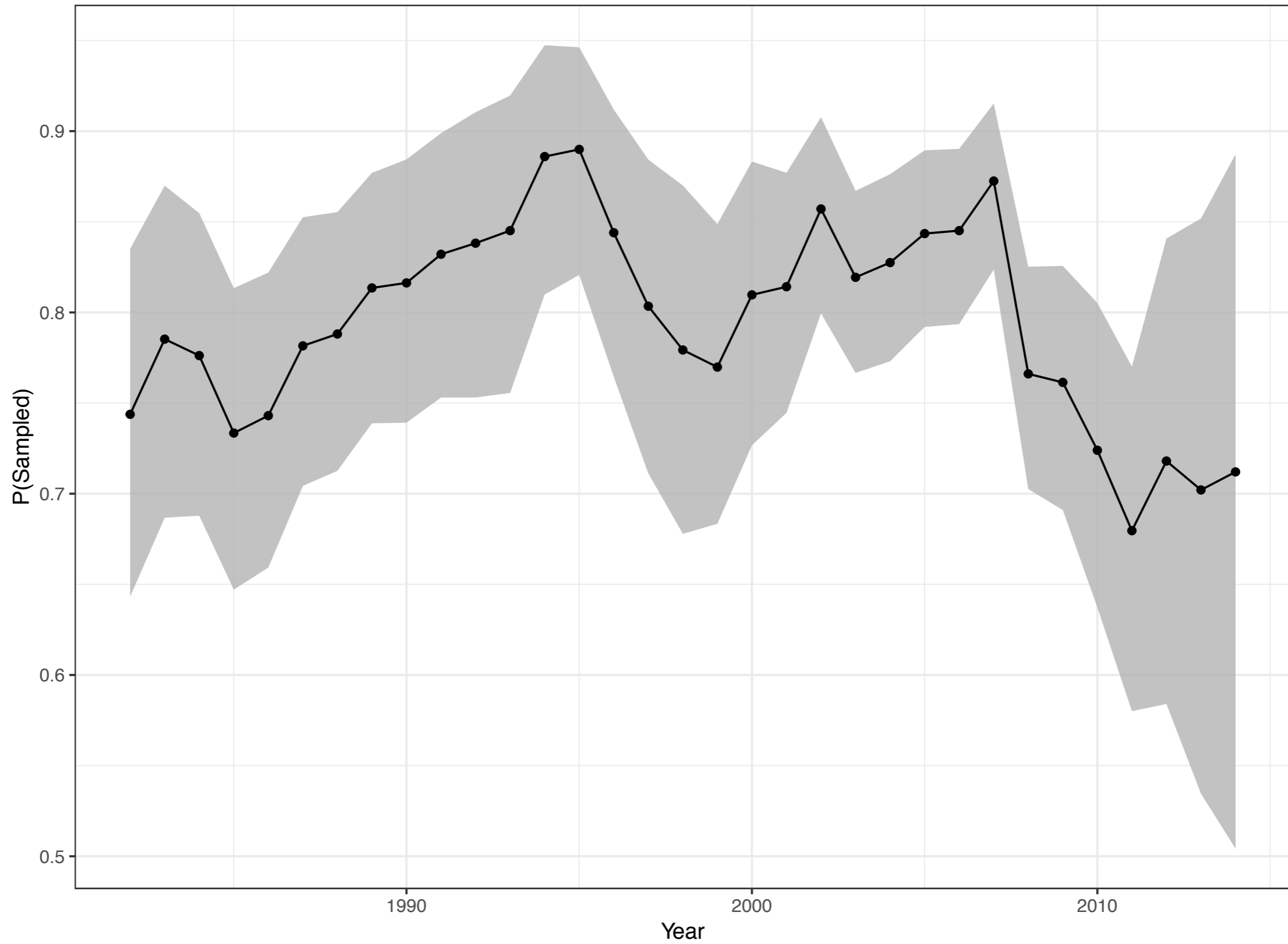


# Abundance

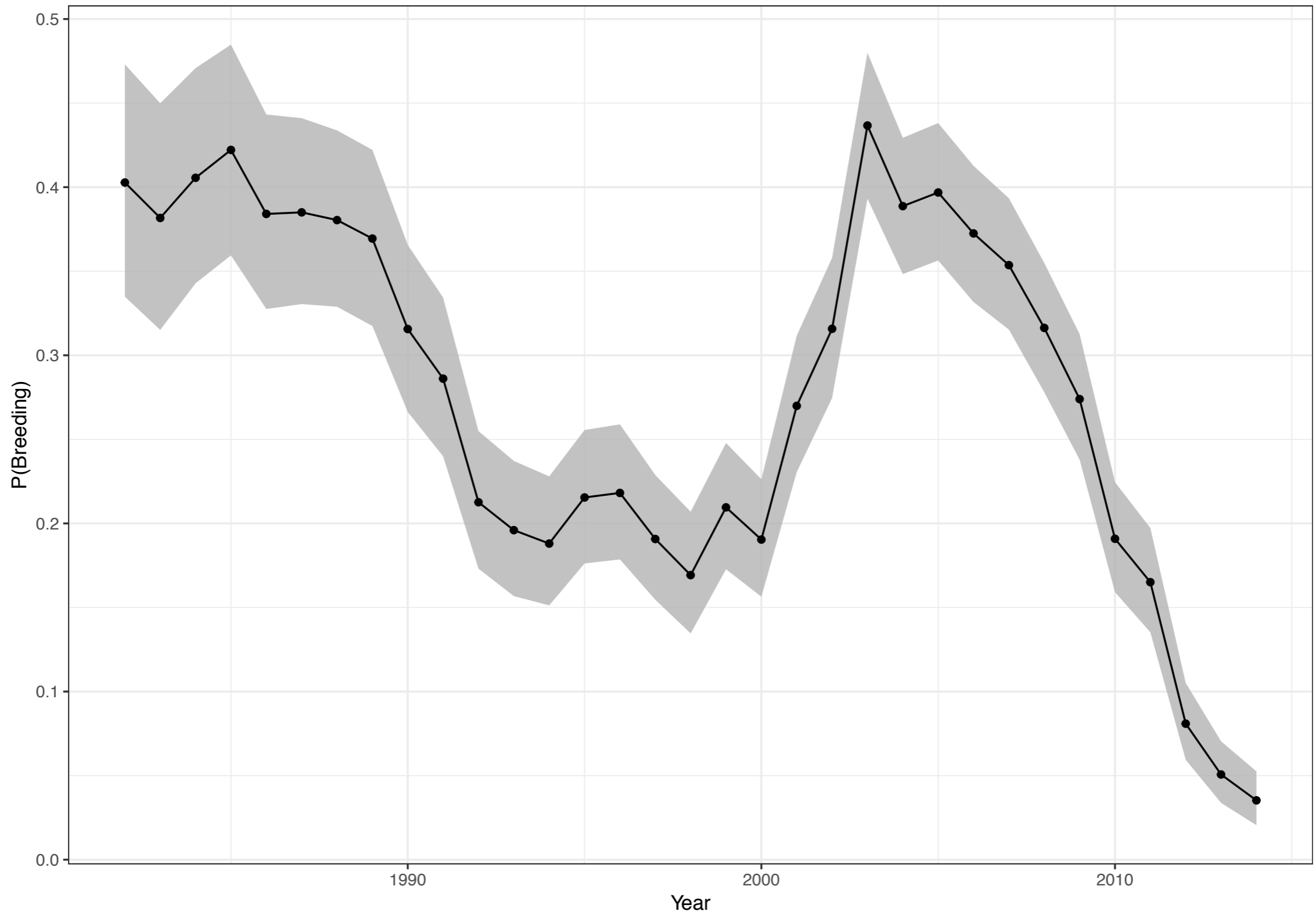




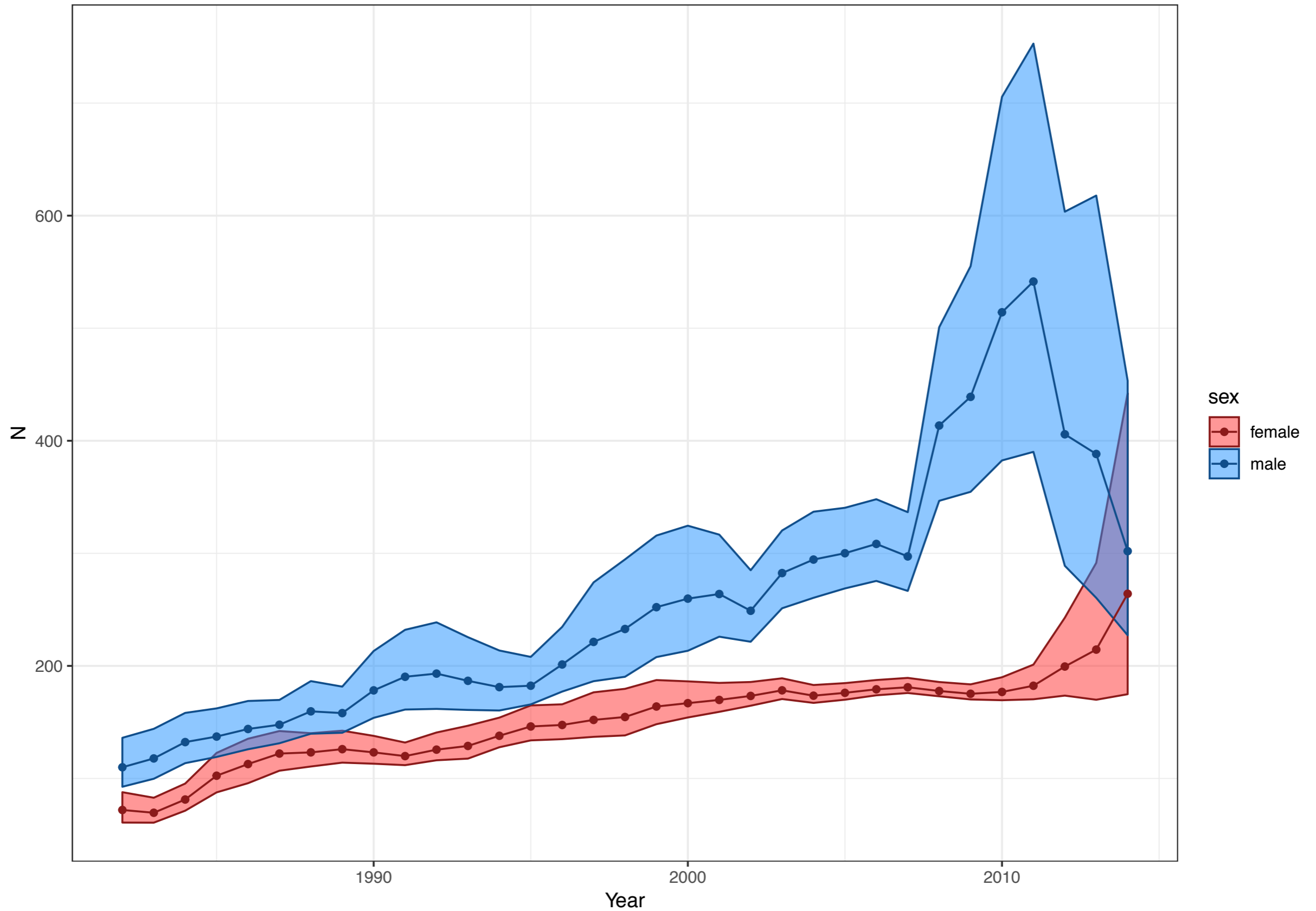
# Probability of Being Sampled

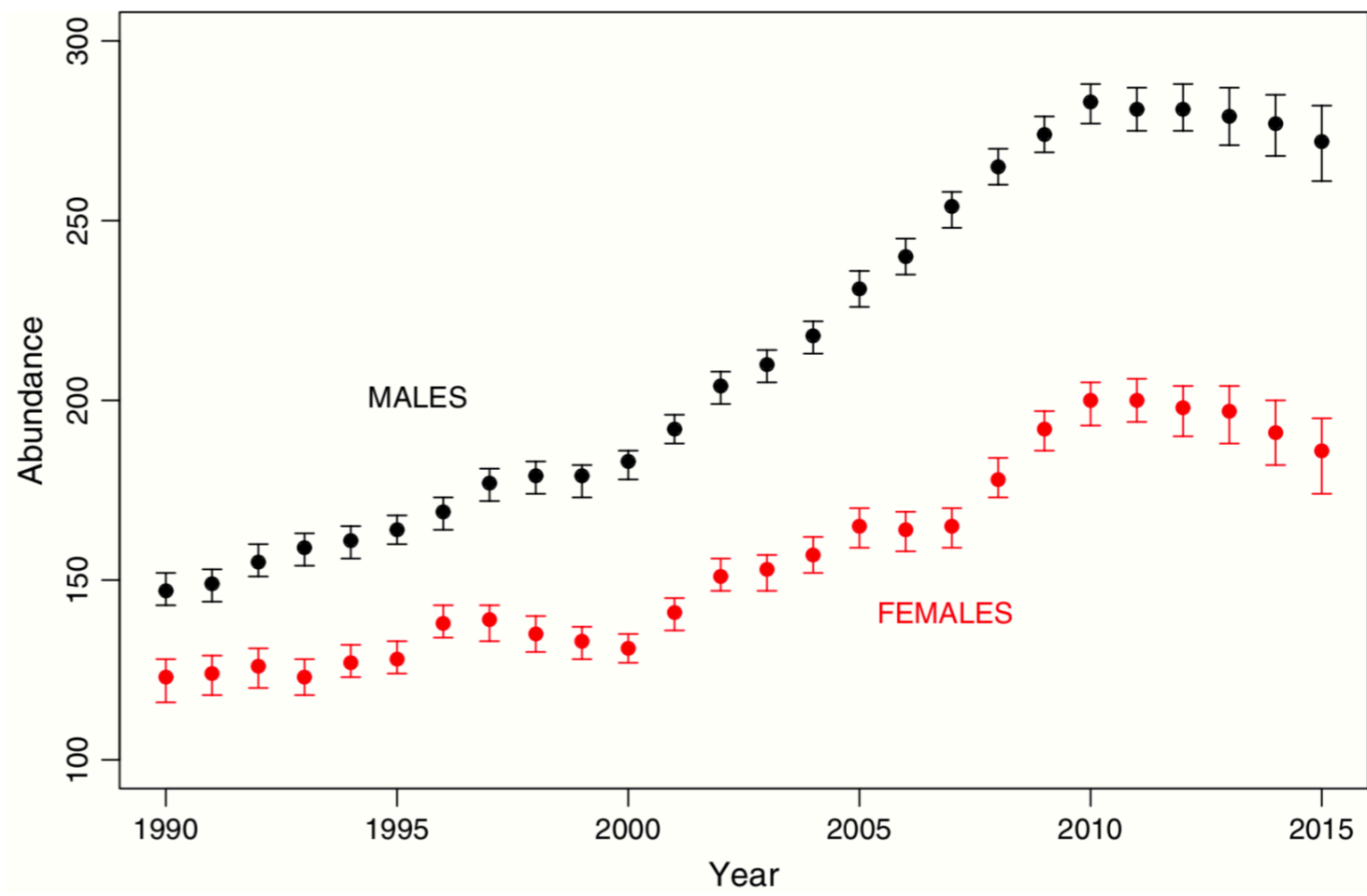
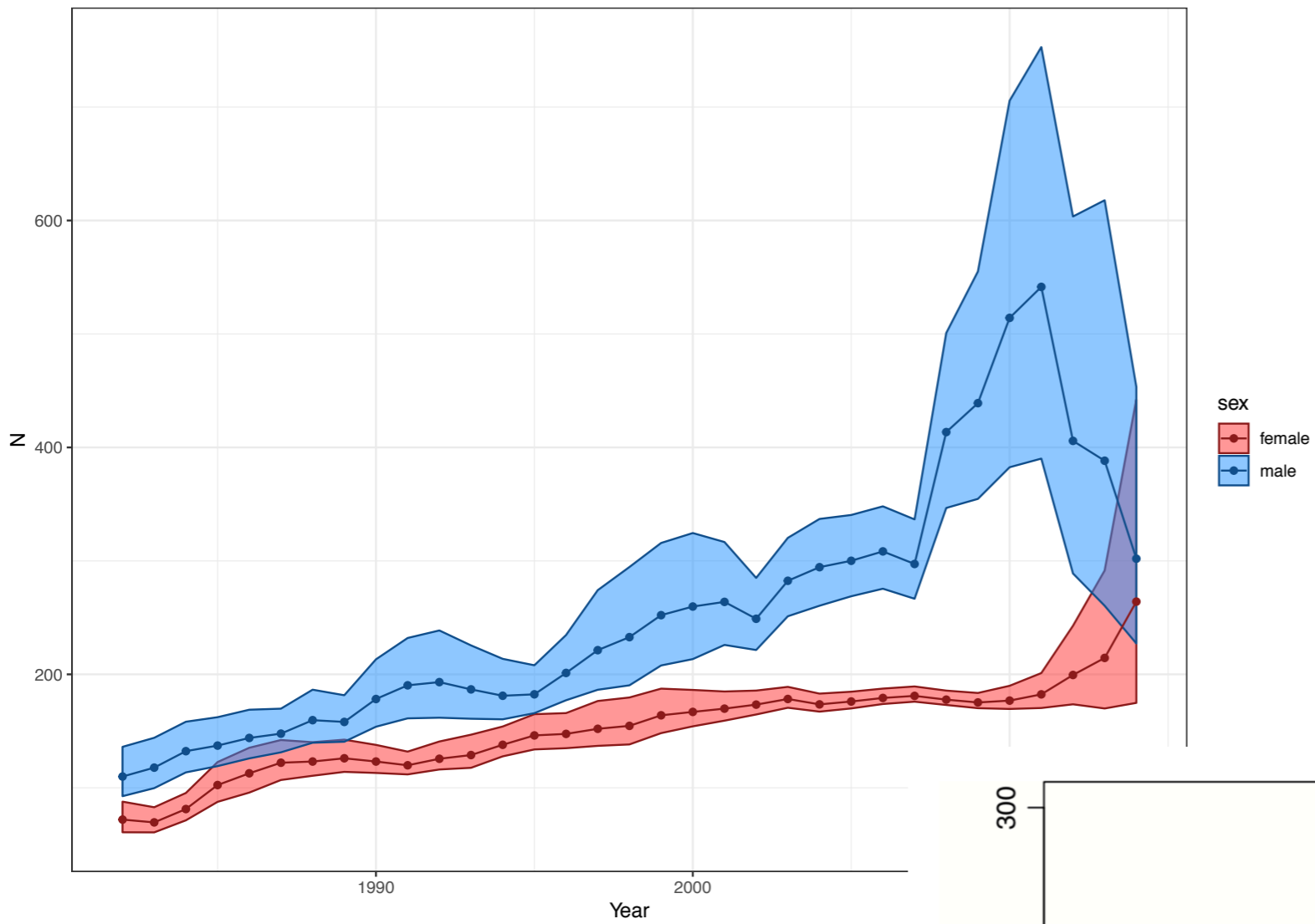


# Probability of Being a Breeder

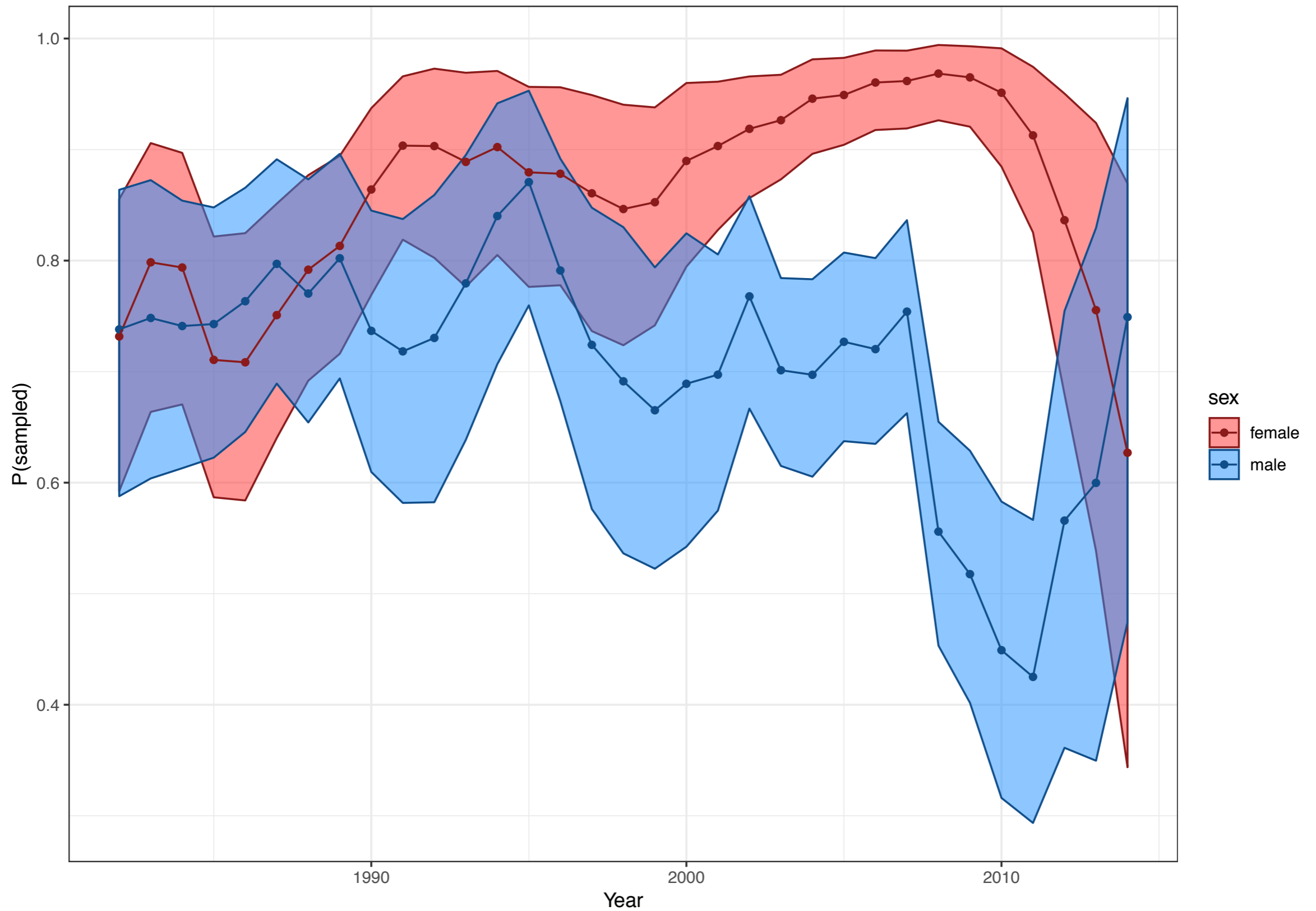


# Abundance

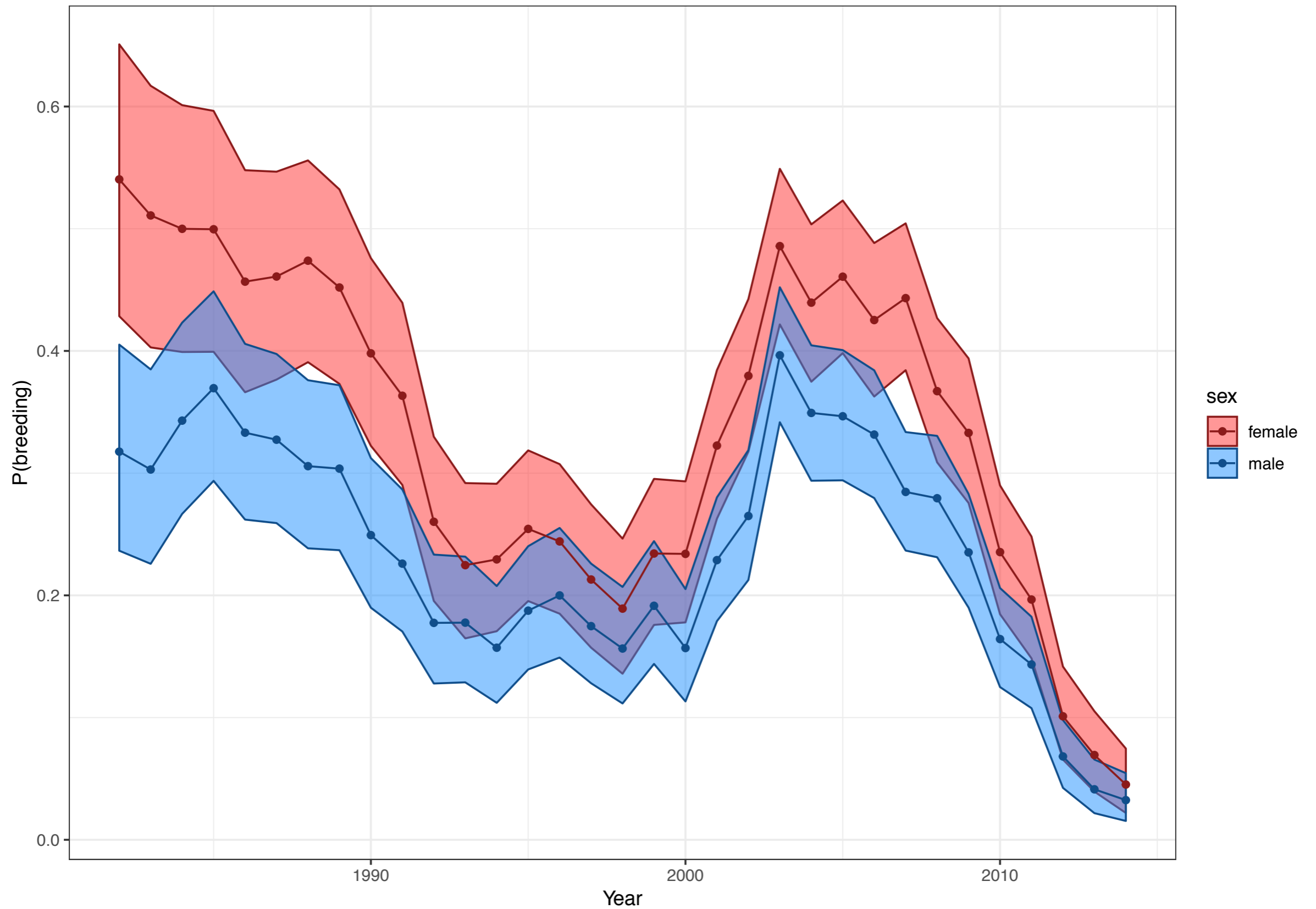




# Probability of Being Sampled



# Probability of Being a Breeder





# Interpretation

1. A valuable tool for “checking in” on the photo-ID data
  - a. A fairly independent method of abundance estimation
  - b. Pedigree estimates slightly lower than photo-ID
    - Seems OK:
      - Presumed alive an over-estimate
      - Model of Pace et al. does it too!!

# Interpretation

2. Does not appear to be a large number of “missing” whales



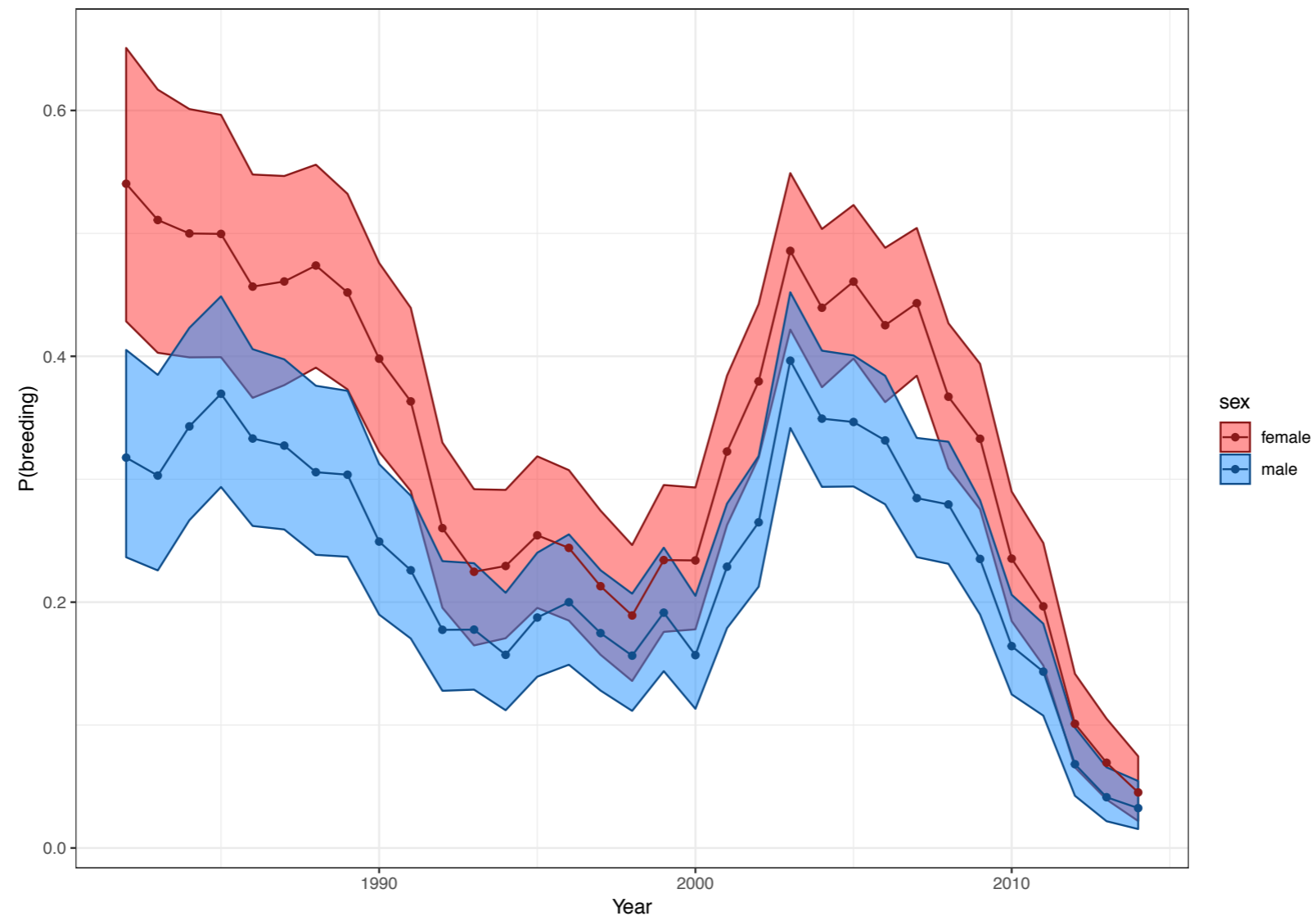
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# Interpretation

3. Great way to assess & monitor patterns of reproductive success
  - a. Peak in mid-2000s was similar to 1980s
  - b. Reproduction, on a per-whale basis, declining



# Thank you!

- North Atlantic Right Whale Consortium
- All sample collectors and collaborators!!!!!!
  - Thanks for your help, persistence, and patience

Lisa Conger = CITES ninja!

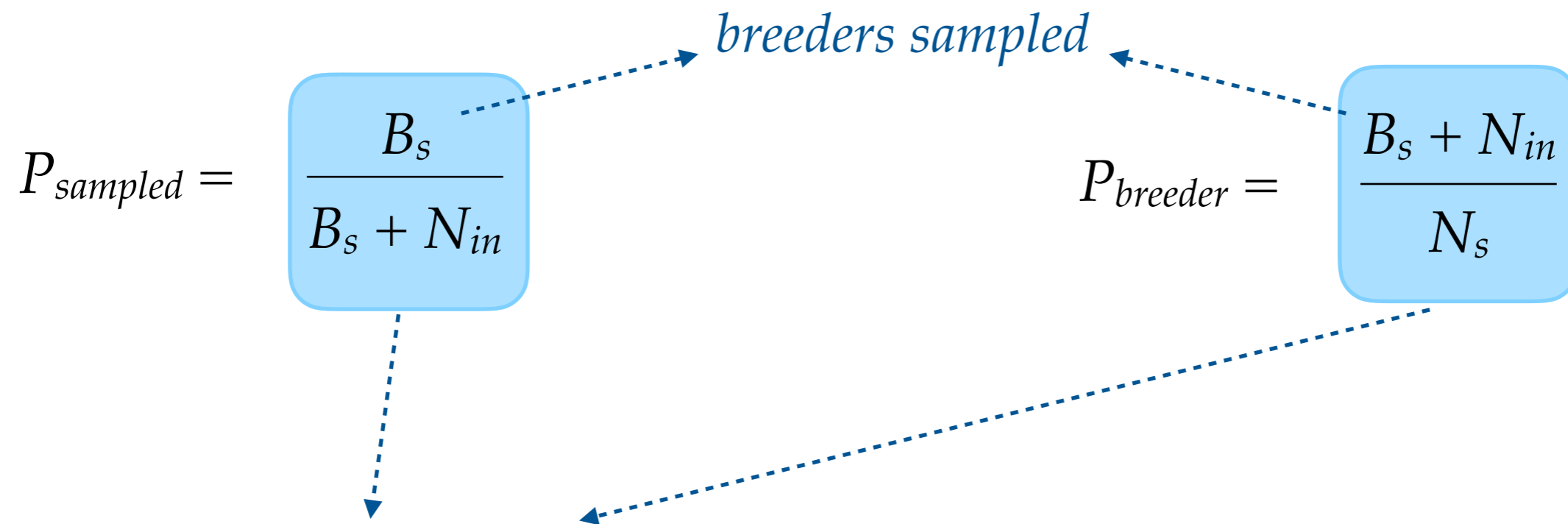
Phil Hamilton, Brenna Frasier, & Lisa Conger = Keeping samples & info organized

Nguyen Nguyen - laboratory assistance

# 1. Non-sampled non-breeders ( $N_{nsnb}$ )

$$P_{sampled} = \frac{B_s}{B_s + N_{in}} \quad \text{breeders sampled} \quad P_{breeder} = \frac{B_s + N_{in}}{N_s}$$


# 1. Non-sampled non-breeders ( $N_{nsnb}$ )



- A fair amount of uncertainty here
- Account for this via Bayesian estimation with Stan
  - Logistic regression



$$P_{\text{not-sampled}} = 1 - P_{\text{sampled}}$$

$$P_{\text{not-breeder}} = 1 - P_{\text{breeder}}$$

## 1. Non-sampled non-breeders ( $N_{nsnb}$ )

$$\hat{N}_{not-sampled} = \frac{N_s}{P_{sampled}} - N_s$$

$$\hat{N}_{nsnb} = \hat{N}_{not-sampled} \times P_{not-breeder}$$

## 2. Breeders who are not sampled and not inferred ( $N_{bnsni}$ )

$$\hat{N}_{bns} = \hat{N}_{not-sampled} \times P_{breeder}$$

$$\hat{N}_{bnsni} = \hat{N}_{bns} - N_{in}$$



$$\hat{N} = N_s + N_{in} + N_{iv}$$



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