New Zealand sea lion pupping rate

Project: POP2006

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Goal:
to estimate proportion of cows that breed as a function of age

Definition of breeder

Cow that gives birth, including when the pup dies or is stillborn

Identification of breeders

Codify behaviour comment field and use a criterion or fit a mixture of breeder and non-breeder distributions to frequencies

Main behaviour frequencies

SEASON	BIRTH	CALLING	DEAD	NURSING	WITH PUP	NOTHING
2000	15	12	4	250	264	1132
2001	17	16	12	245	296	1276
2002	22	10	28	237	344	2121
2003	3	34	3	393	612	2186
2004	31	34	1	509	617	2510
2005	35	1	2	127	191	2063
2006	22	11	-	299	278	1974
2007	29	13	-	473	351	2129

Use of behaviour comment field

Behaviour was codified into:

Birth observations: BIRTH, STILLBIRTH, DEADPUP

Breeder observations: NURSING, WITHPUP, CALLING

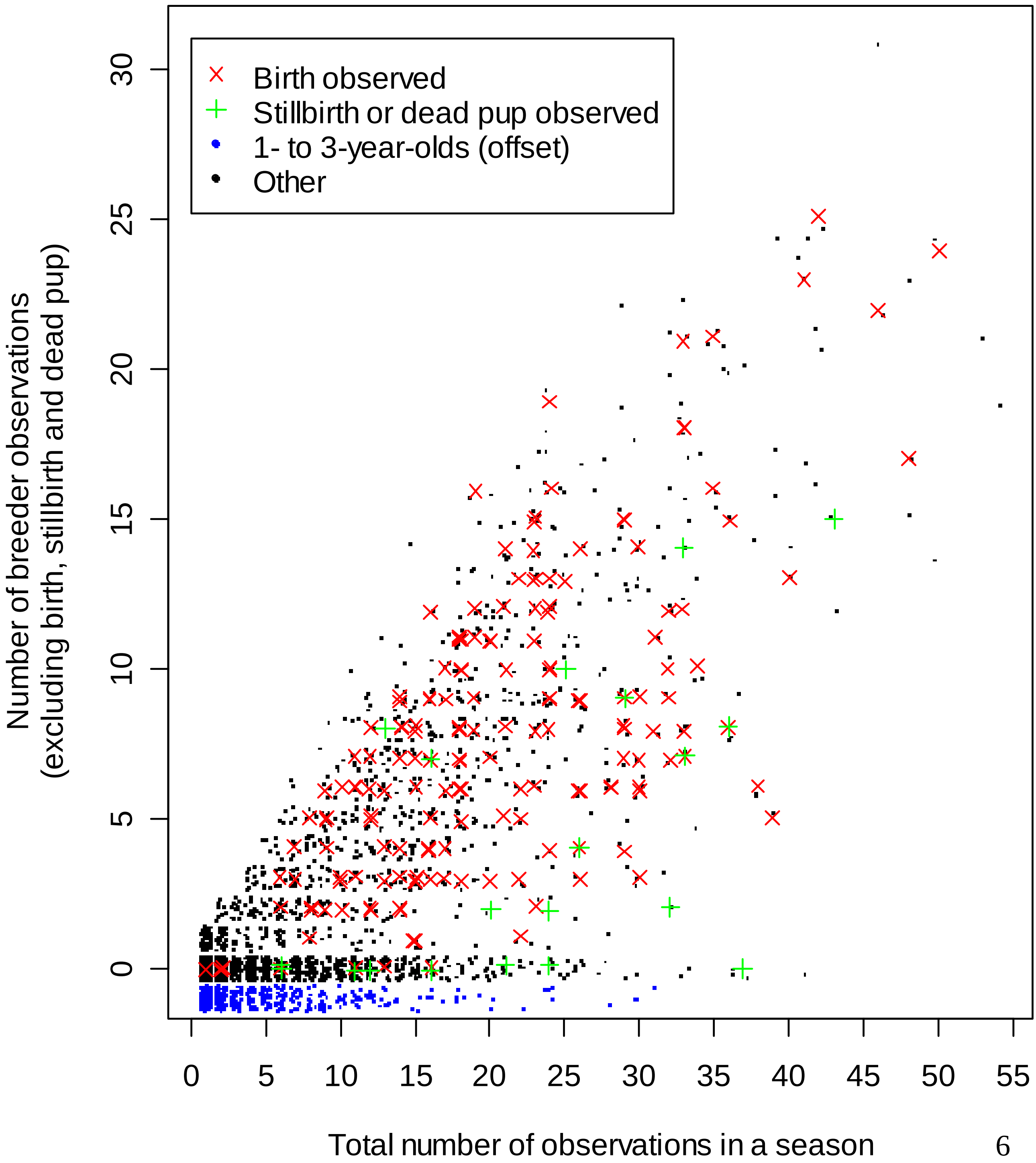
Nothing: NURSINGYEARLING, SUCKLINGFROMCOW, DEAD, NOTHING, PREGNANT

For each cow we know:
Season it was tagged
whether tagged or branded

How do we distinguish exactly which cows pupped and which were alive but didn't?

- There are a few definite breeders
- Most breeders could be identified if observed for long enough
- 1–3-year-olds are definite non-breeders
- 37% of observations are breeder observations
- Occasionally non-breeders produce breeder observations

Probable breeder observations

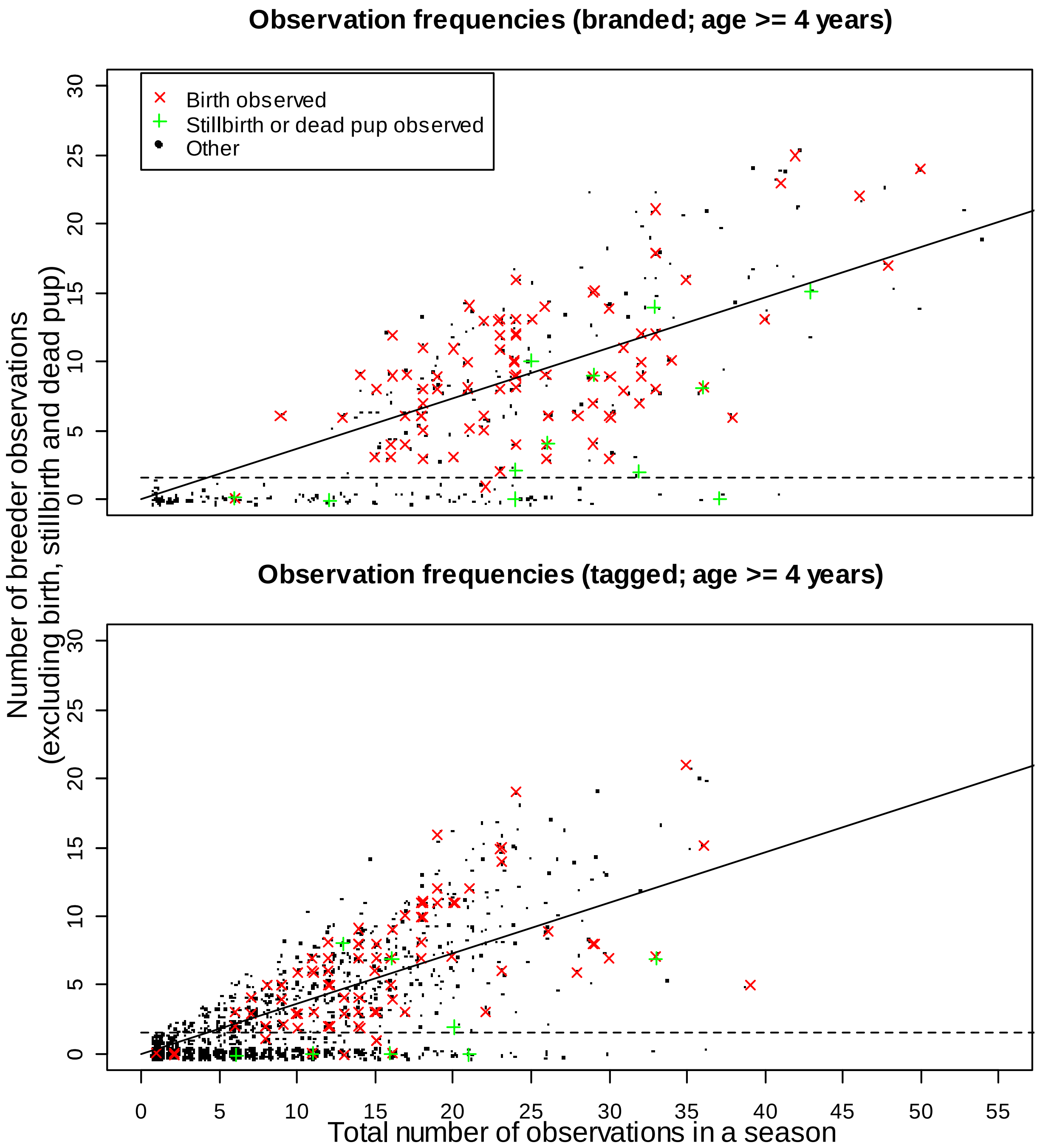


Two methods to estimating pupping rate

1. Specify a criterion that categorises each cow each season as a breeder or non-breeder (e.g. a birth observation or at least 2 breeder observations)

2. Estimate probability density functions to explain observation frequencies that depend on whether a cow breeds. Estimate the proportion of breeders and non-breeders in the mixture

Breeder observations proportions



Error caused by criterion method

Because the probability of getting a breeder observation each time a breeding cow is observed is only 0.37, some breeders will not be identified

E.g. if a breeder is seen 4 times the probability of getting zero breeder observations is

$$0.63^4=0.16$$

These observations will be indistinguishable from those of a non-breeder seen 4 times and the criterion method will wrongly identify it as a non-breeder

Method 2
Scenario mixtures

Example scenario out of 256:

2000 breed

2001 breed

2002 breed

2003 non-breed

2004 non-breed

2005 non-breed

2006 breed

2007 non-breed

Need to calculate the likelihood of the actual observations under each scenario, multiply it by the likelihood of that scenario and add them

Method 2
Another scenario

Another scenario :

2000 breed

2001 non-breed

2002 breed

2003 non-breed

2004 breed

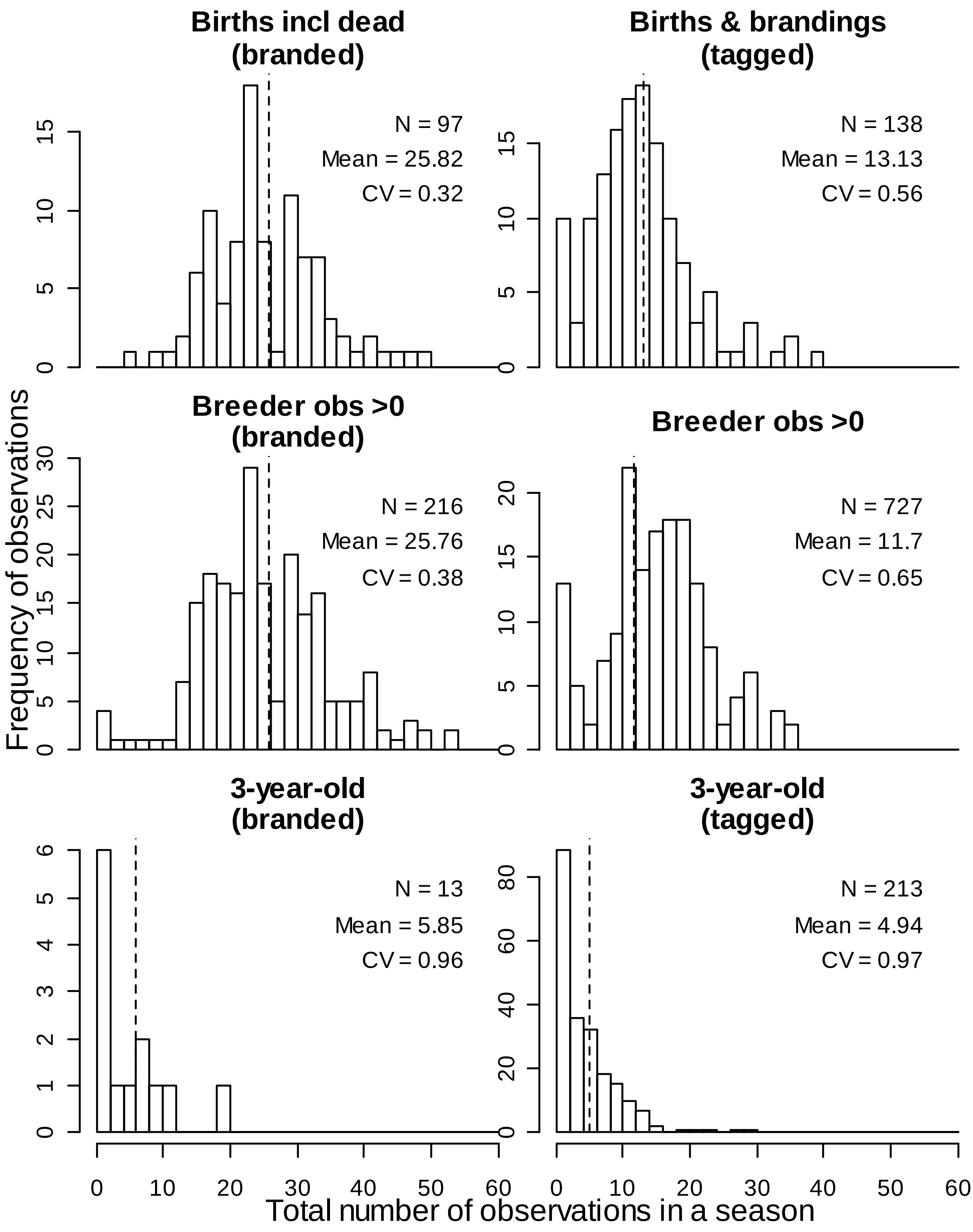
2005 non-breed

2006 breed

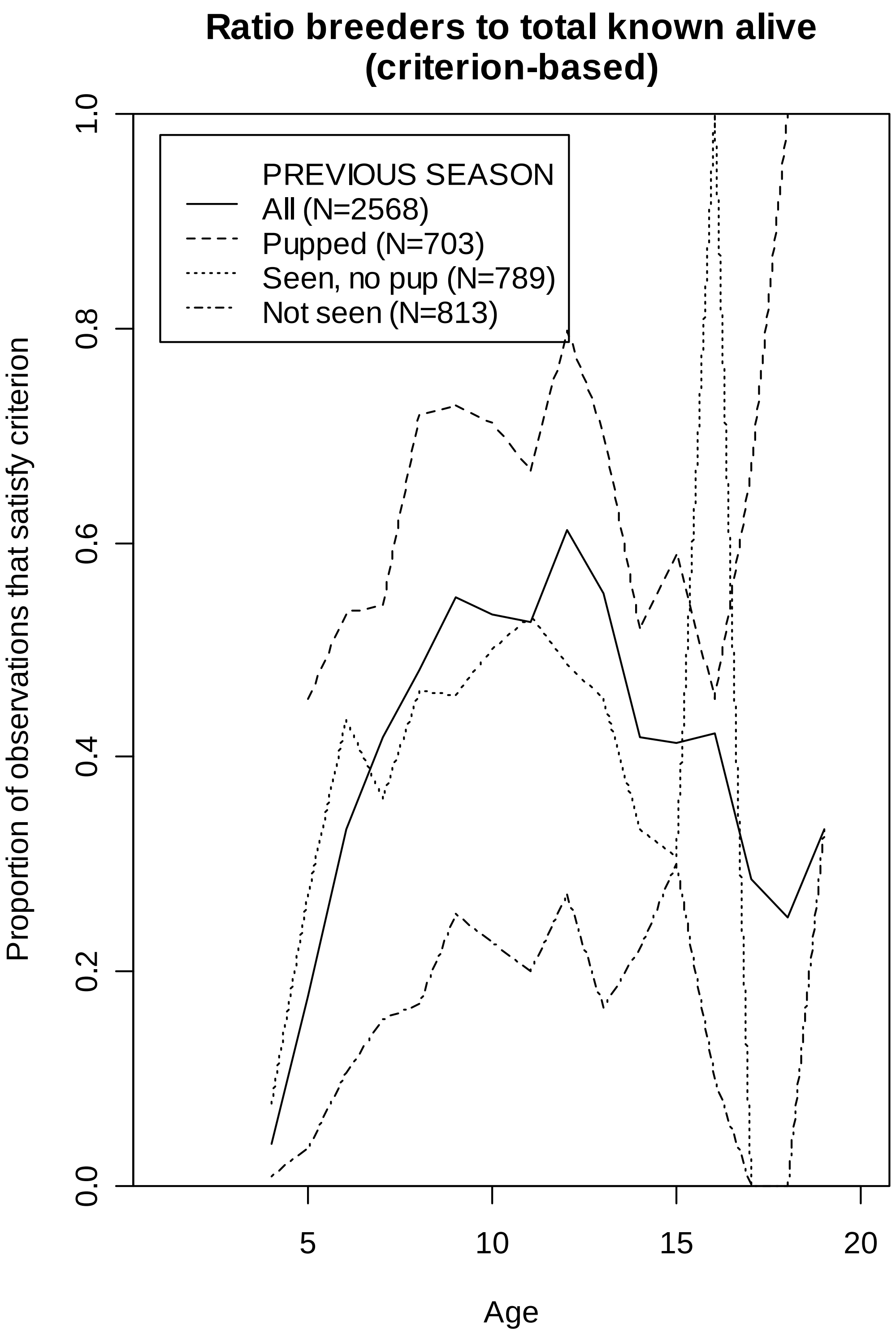
2007 non-breed

The likelihood of a scenario depends on age, branded/tagged and the sequence, i.e. this one is less likely than the previous because of the serial correlation

Total observation frequencies



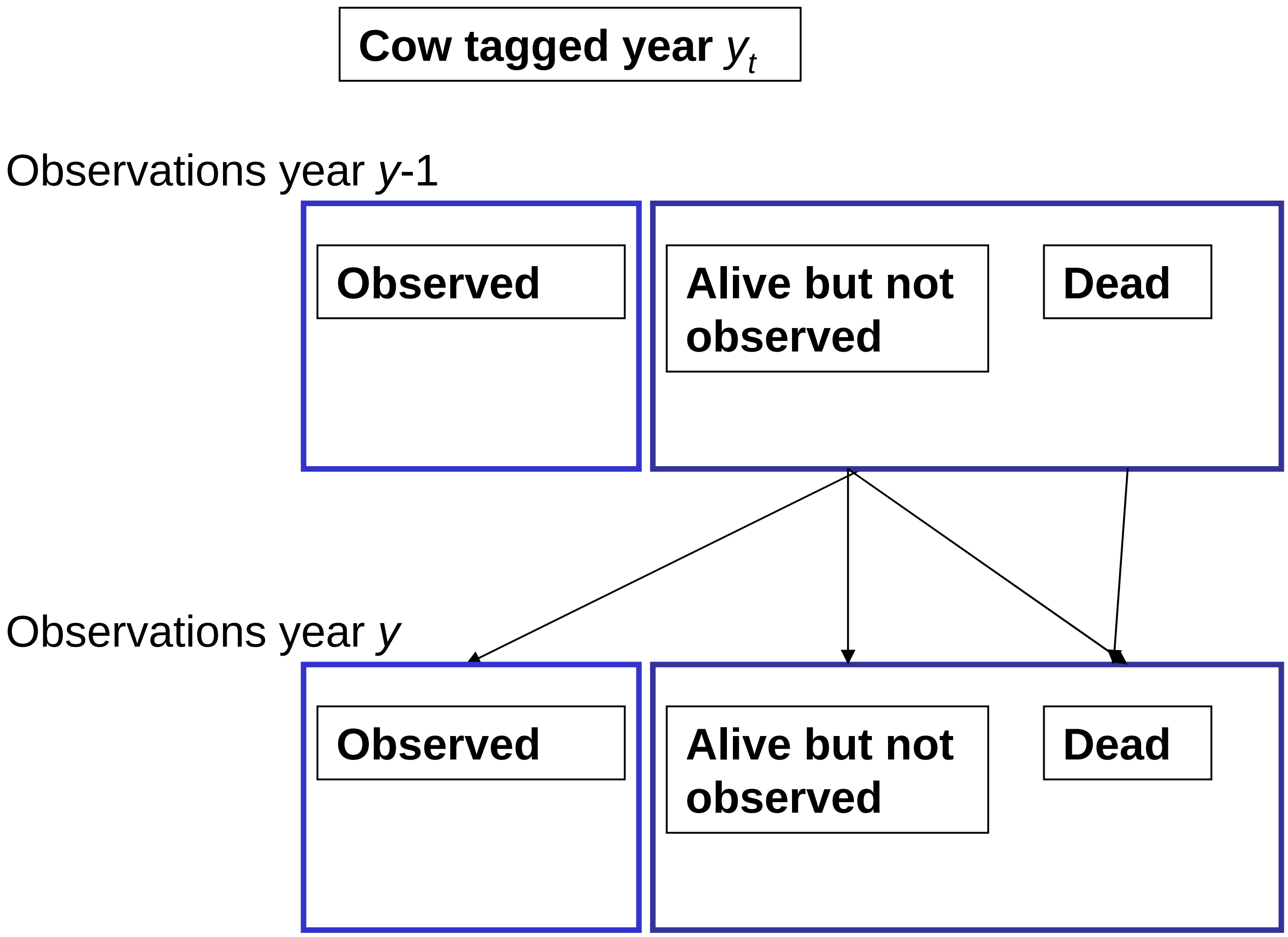
Pupping rate conditional on last year



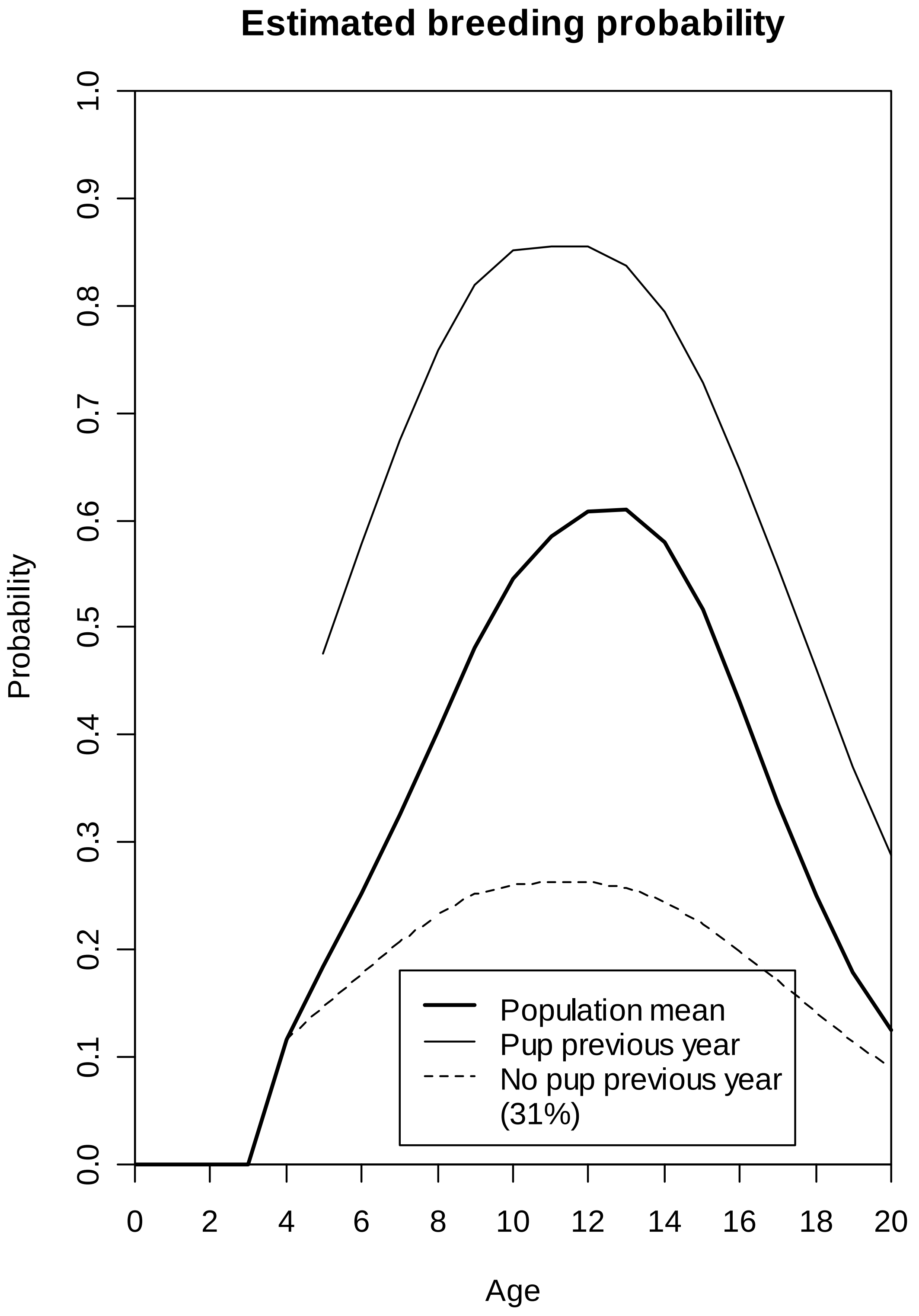
Died or not observed?

- Need to account for non-breeders that are alive but not sighted
- Can be done easily for individuals for the years before the last sighting
- If last sighting was before 2007 the cow may be dead or alive but not sighted
- We therefore estimate mortality parameters and treat the unseen cows as a mixture of dead, non-observed non-breeders and a very few non-observed breeders

Mortality and non-observability mixture

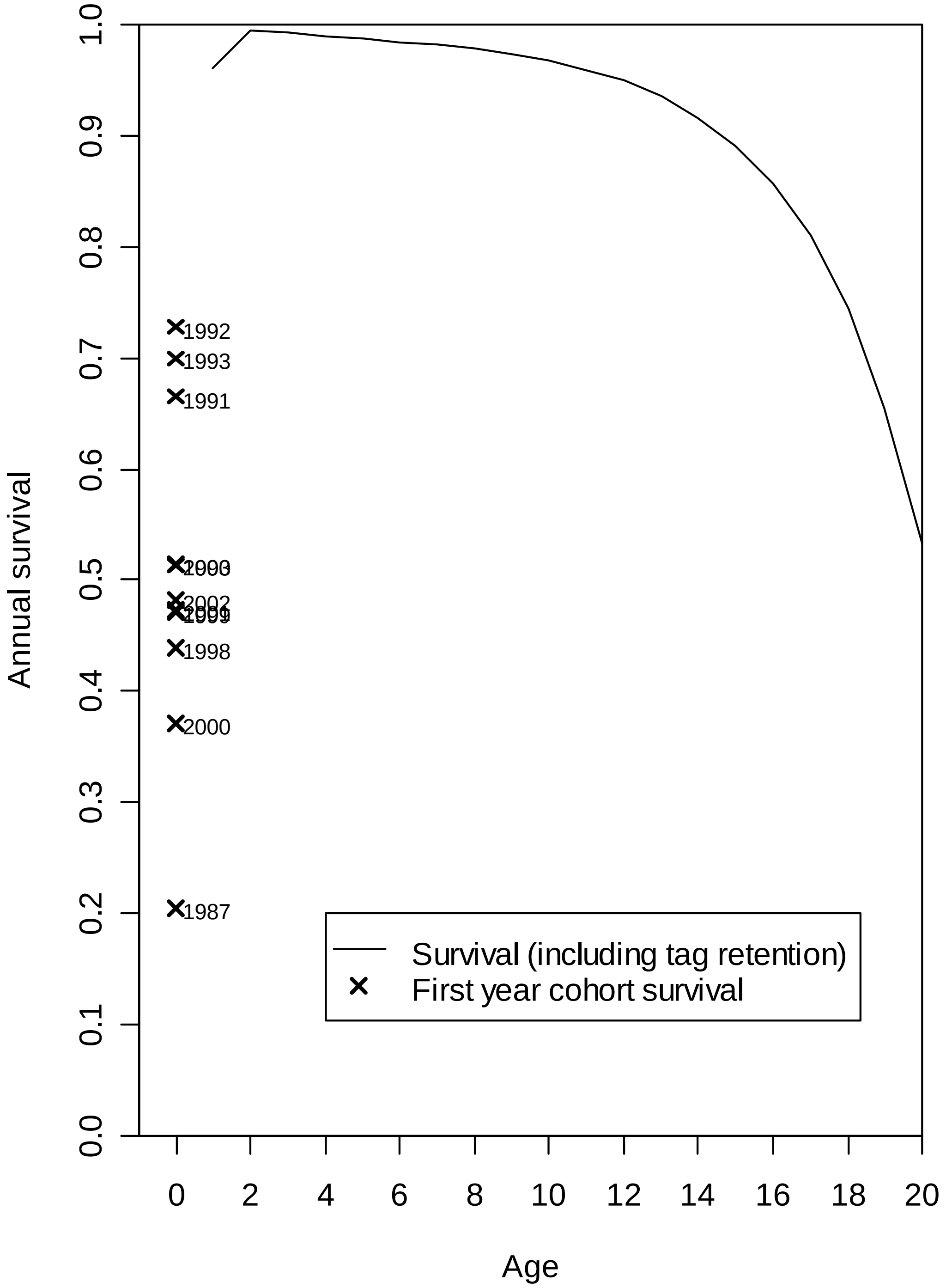


Pupping rate



Survival and tag retention

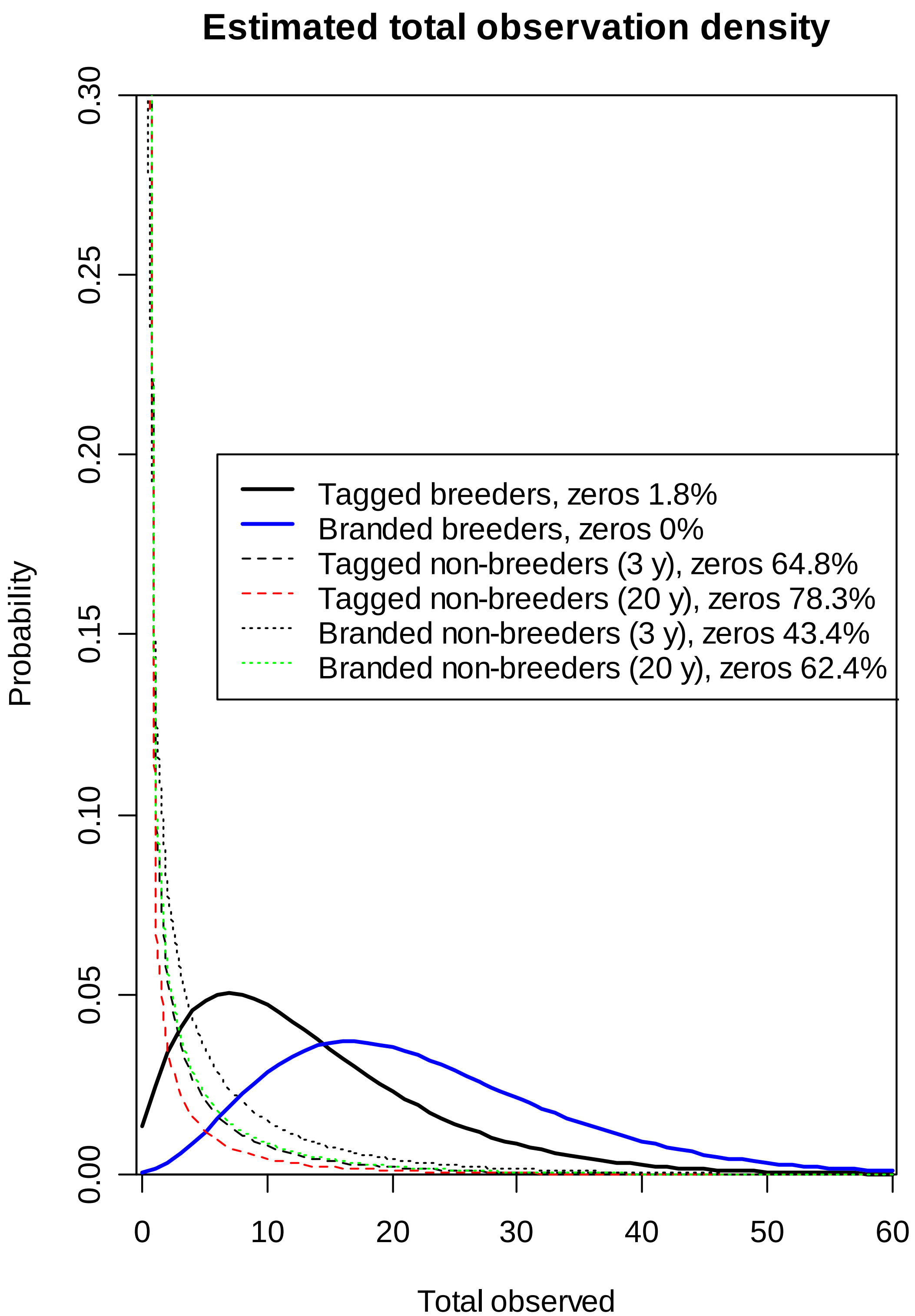
Probability of surviving following year



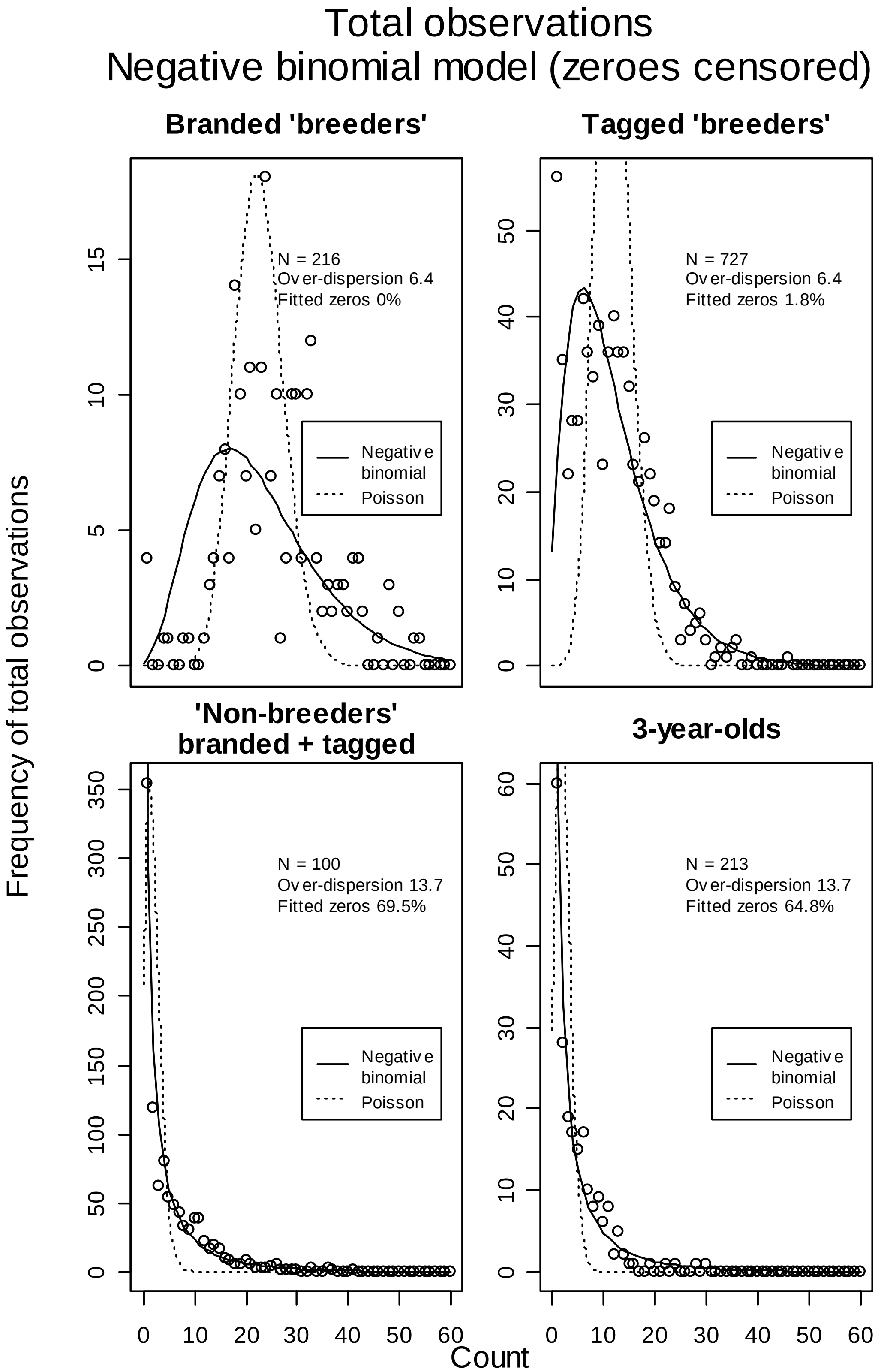
Estimated observation proportions

Group	Total obs = 0	Breeder obs = 0	Breeder obs = 1	Breeder obs ≥ 2
	Percent	Percent of observed cows		
Branded breeders	0	2.3	4.9	92.8
Tagged breeders	1.8	10.3	15.1	74.6
Branded non-breeders	50.4	99.2	0.5	0.3
Tagged non-breeders	70.1	99.3	0.4	0.3

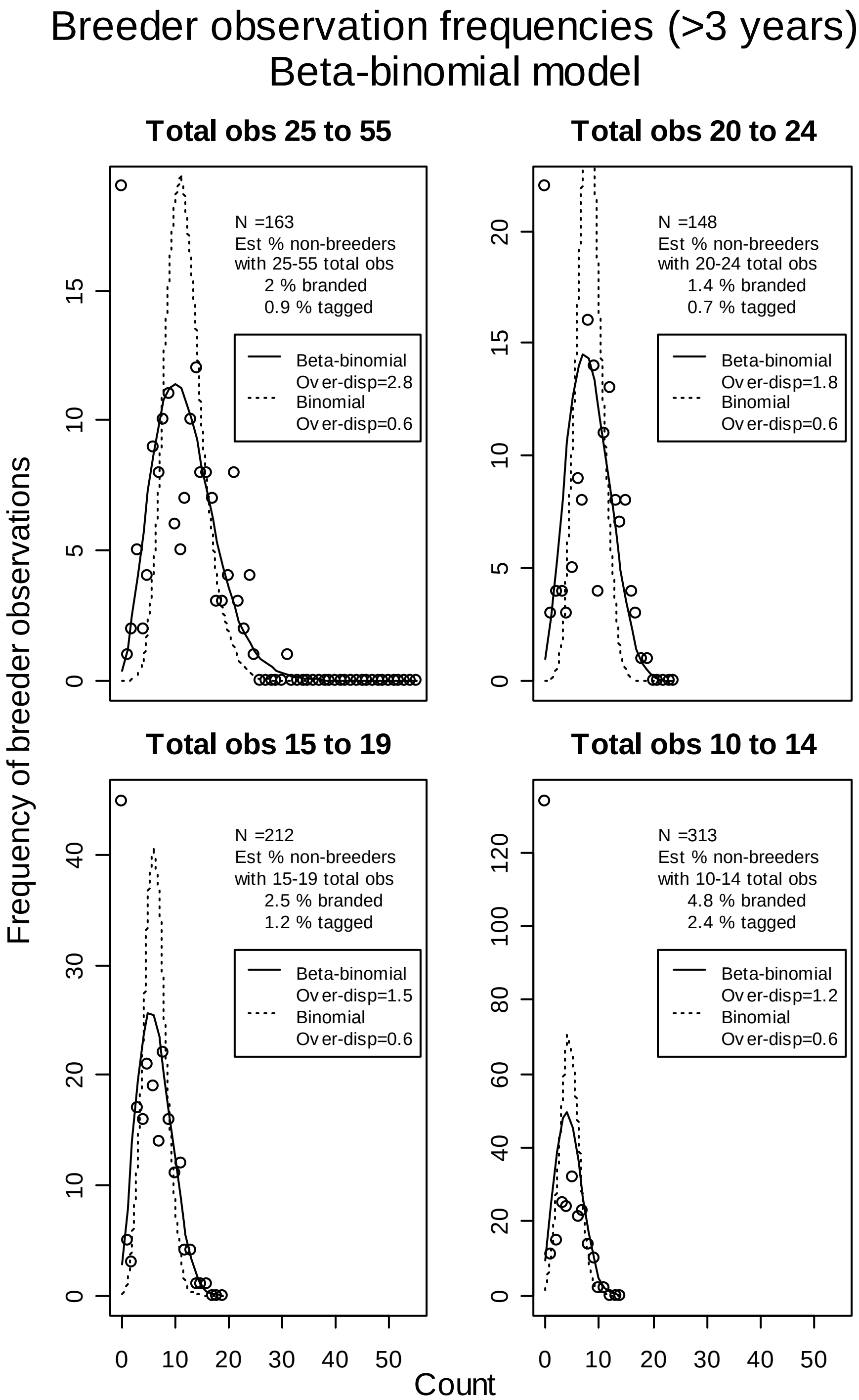
Total observation distributions



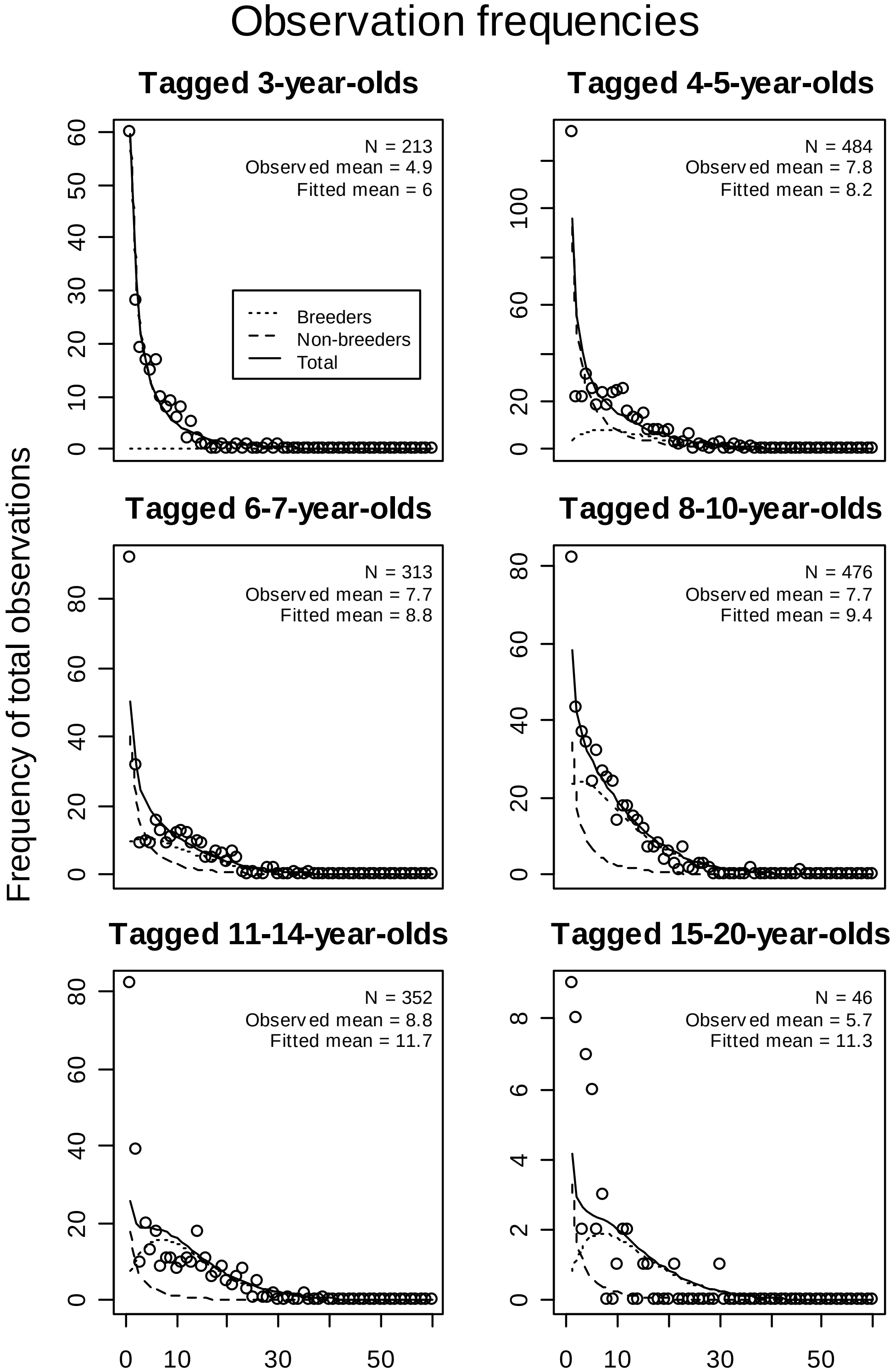
Total observations



Breeder observation frequencies



Total observations as mixtures



Some parameter values

Parameter	Est
Max pupping rate (average)	0.61
Max pupping rate (prev breeder)	0.85
Max pupping rate (prev non-breeder)	0.26
Age max pupping (y)	13
Prob of a breeder obs (breeder)	0.37
Prob of a breeder obs (non-breeder)	0.001
Mean total obs/season (breeder)	11.7
Mean total obs (branded breeder)	22.6
Mean total obs (3 y, non-breeder)	2.1
Mean total obs (20 y, non-breeder)	1.2

More parameter values

Parameter	Est
Pupping rate reaches half max (y)	7
Pupping rate falls to half max (y)	17
Max survival & tag retention	0.99
Age at max survival (y)	2
Mean 1st year survival (excl 1987)	0.54
Survival at age 20 y	0.55
Max observability (2003)	1.20
Min observability (2000)	0.49
Neg-binom overdispersion (breeders)	6.4
Neg-binom overdispersion (non-breeders)	13.7

Conclusions

- Necessary to estimate breeders with no breeder observations by using a mixture model (12% tagged breeders not identified)
- High breeding serial correlation (breeders 3 times as likely to breed following year)
- Maximum population pupping rate is 61% at age 13 y
- Possibly 20% of cows do not return to rookery each year (not modelled)
- First year survival varies a lot (37-73%)
- Observations over-dispersed (excessive zeros and ones)

Conclusions