Estimation of Demographic Parameters for New Zealand Sea Lions Breeding on the Auckland Islands

POP2007/01 Obj 3:
1997/98 – 2008/09

May 2010

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Outline

- Estimation of survival and reproduction probabilities

- Estimation of “population” size

Survival and Reproduction

- 2 key demographic processes
- Can be estimated from tag-resight data using mark-recapture methods
- Previous report highlighted importance of accounting for tag-loss
  - Artificially inflates mortality rates
- Sightability may be different for breeders/non-breeders, branded animals, number of flipper tags

Survival and Reproduction

- 4 components to model tag-resight data
  - Number of flipper tags each year
  - Survival from one year to next
  - Whether female breeds in a year
  - Number of sightings in a year

Survival and Reproduction

- Number of flipper tags in year *t* is multinomial random variable with 1 draw and category probabilities (π's) that depends on number of tags in previous year (allows for non-independent tag loss)

Number of tags in year *t*

Number of tags in year *t*-1		0	1	2
	0	1	0	0
	1	$1-\pi_{1,1}$	$\pi_{1,1}$	0
	2	$1-\pi_{1,2}-\pi_{2,2}$	$\pi_{1,2}$	$\pi_{2,2}$

Survival and Reproduction

- Given female is alive, it's age and breeding status in year *t*-1, whether it is alive in year *t* is a Bernoulli random variable where probability of success (survival) is $S_{age,t-1,bred}$

Survival and Reproduction

- Given female is alive in year *t*, it's age and breeding status in year *t*-1, whether it breeds in year *t* is a Bernoulli random variable where probability of success (breeding) is $B_{age,t,bred}$

Survival and Reproduction

- 3 age-classes used for survival/reproduction: 0-3, 4-14, 15+
- Survival and breeding probabilities = 0 for “breeders” in 0-3 age class

- 3 models considered with respect to nature of annual variation in demographic parameters

Survival and Reproduction

- 3 age-classes used for survival/reproduction: 0-3, 4-14, 15+
- Survival and breeding probabilities = 0 for “breeders” in 0-3 age class

- 3 models considered with respect to nature of annual variation in demographic parameters

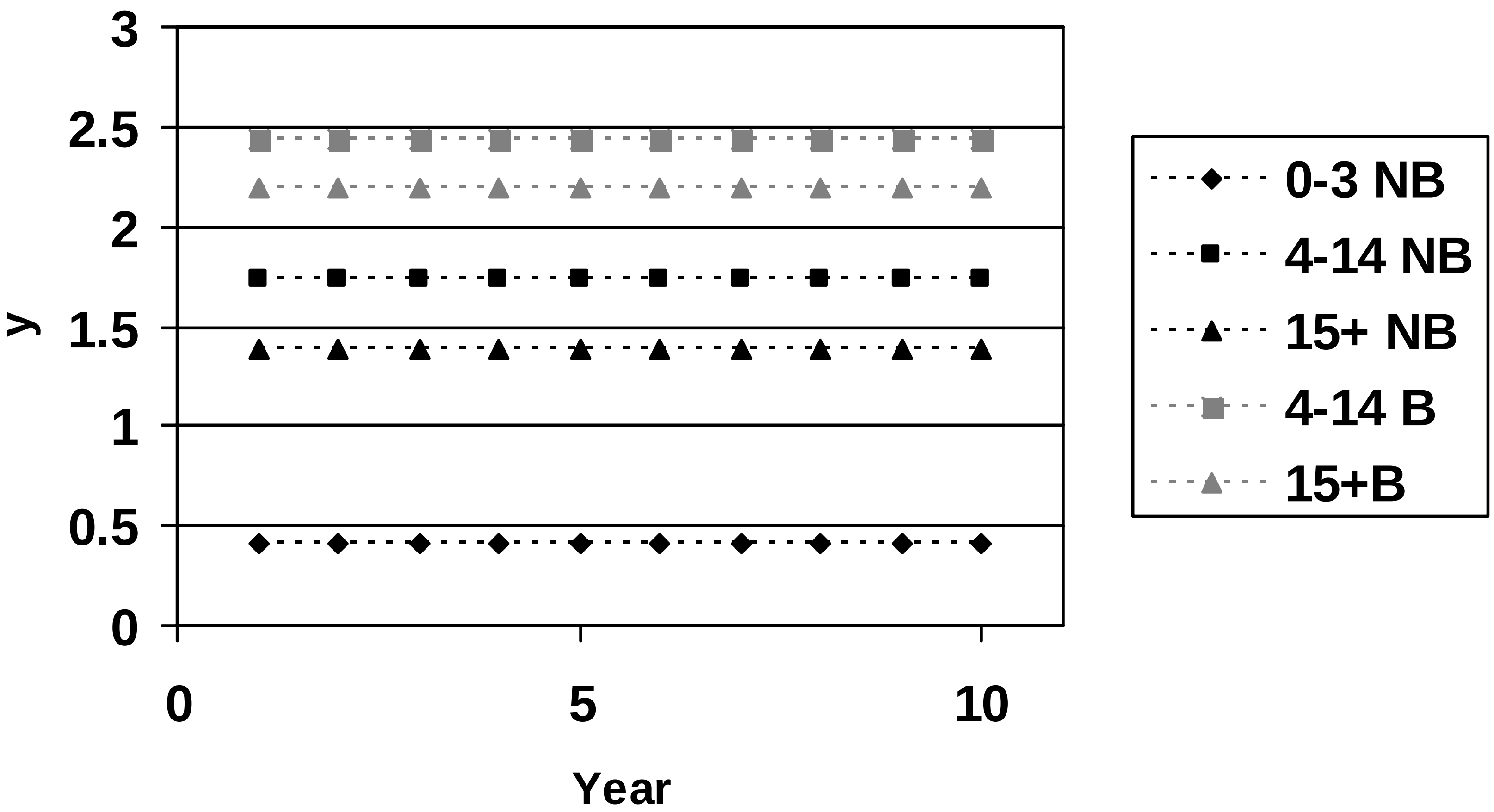
Survival and Reproduction

$$y_{a,t,b} = \mu_{a,b} + \varepsilon_{a,t,b}, \quad \varepsilon_{a,t,b} \sim N\left(0, \sigma^2_{a,b}\right)$$

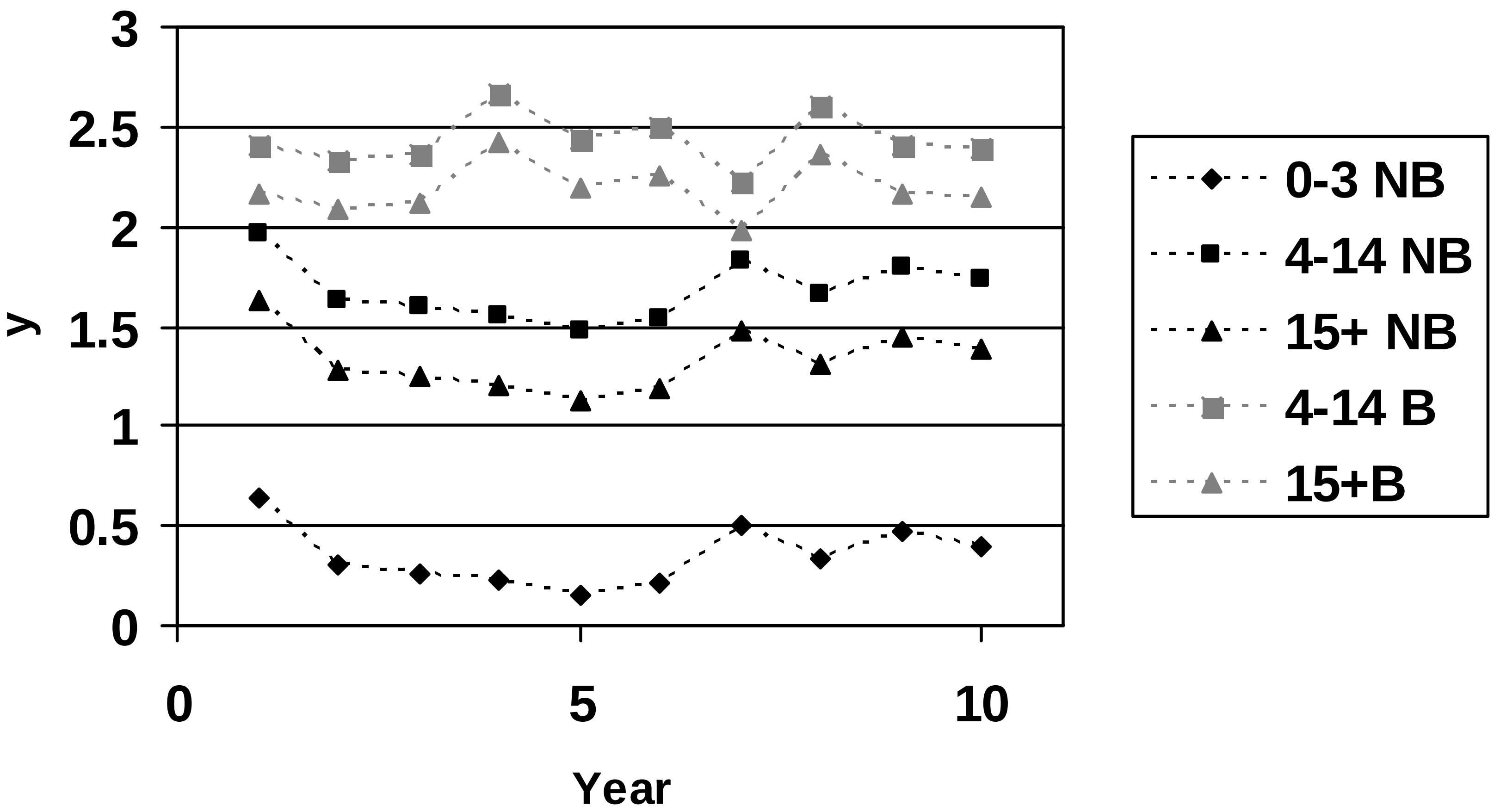
$$\theta_{a,t,b} = \frac{e^{y_{a,t,b}}}{1 + e^{y_{a,t,b}}}$$

1. No annual variation
2. Annual variation that depended upon previous breeding status
3. Annual variation that depended upon age and breeding status

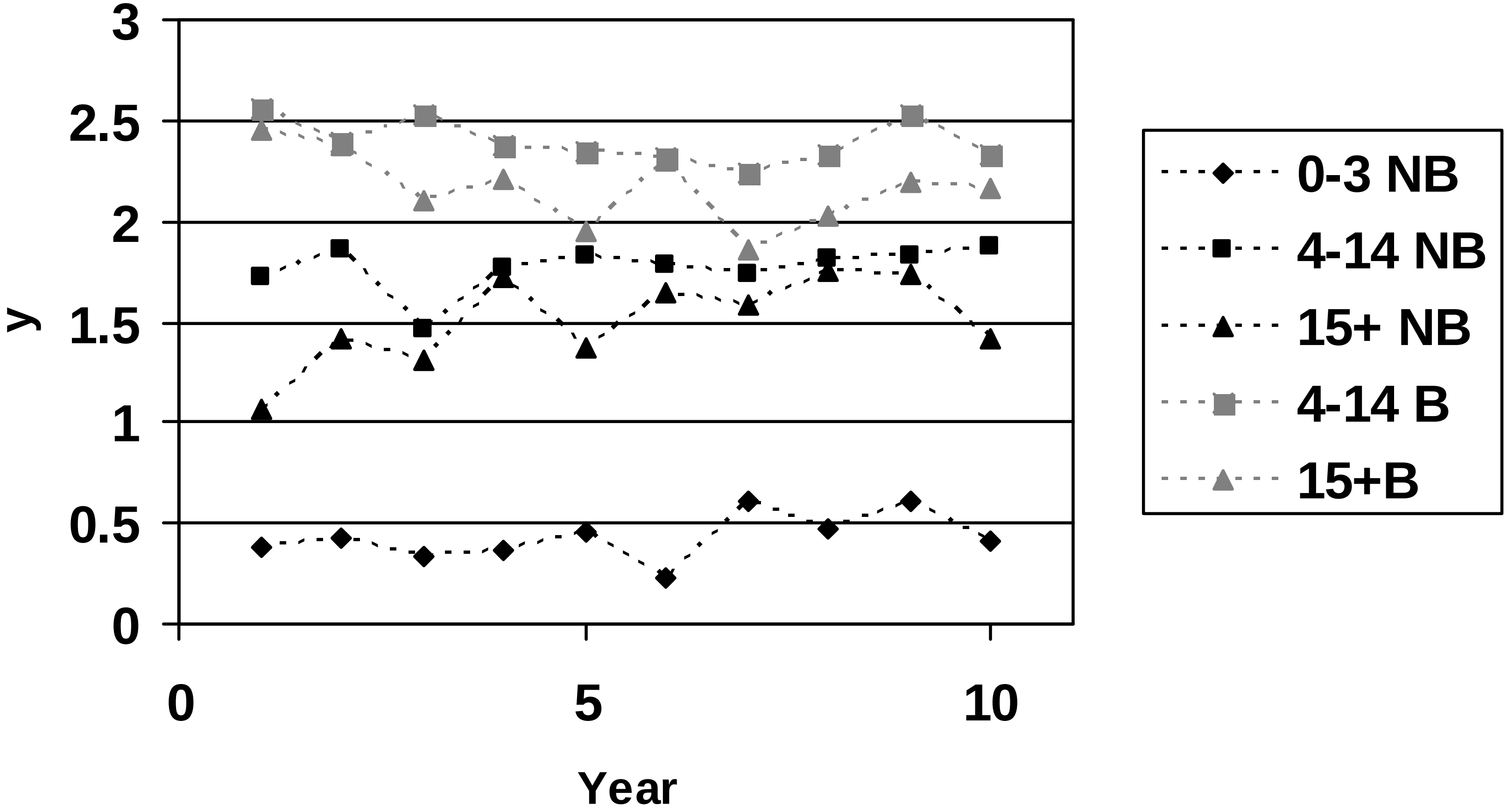
Model 1



Model 2



Model 3



Survival and Reproduction

- Given female is alive, it's breeding status, presence of a brand, PIT tag and number of tags in year *t*, the number of times it's sighted during a field season is a binomial random variable with a daily resight probability $p_{t,bred,brand,tags}$

Survival and Reproduction

- Branded animals have the same resight probability regardless of number of flipper tags.
- Animals with no flipper tags can only be resighted if they are chipped or branded.
- PIT tags have no effect on the resight probability if the unbranded animal has 1 or more flipper tags.
- There is a consistent odds ratio (δ) between resighting animals with 1 and 2 flipper tags.
- Resight probabilities are different for breeding and non-breeding animals.
- Resight probabilities vary annually.

Survival and Reproduction

$p_{t,bred,brand}$ - applies to all females with brand

$p_{t,bred,chip}$ - applies to unbranded females with no flipper tags

$p_{t,bred,T1}$ - applies to unbranded females with one flipper tags

$p_{t,bred,T2}$ - applies to unbranded females with two flipper tags

Survival and Reproduction

- Posterior distributions for parameters can be approximated with WinBUGS by defining a model in terms of the 4 random variables
- Some outcomes are actually latent (unknown) random variables, but their ‘true’ value can be imputed by MCMC
- Equivalent to a multi-state mark-recapture model

Survival and Reproduction

- 2 chains of 25,000 iterations
- First 5,000 iterations discarded as burn-in
- Prior distributions:
    - μ's ~ $N(0,3.78^2)$
    - σ's ~ $U(0,10)$
    - Other probabilities ~ $U(0,1)$
    - $\pi_{X,2}$ ~ Dirichlet(1,1,1)
    - $\ln(\delta)$ ~ $N(0,10^2)$
- Chains demonstrated convergence and good mixing

Survival and Reproduction

- Model deviance can be calculated and compared for each model
- Same interpretation as for maximum-likelihood methods (e.g., GLM), but has a distribution not single value
- Comparison of distributions a reasonable approach to determine relative fit of the models

Survival and Reproduction

- Fit of model to the data can be determined using Bayesian p-values with deviance as test statistic
- For each interaction in MCMC procedure, a simulated data set is created using current parameter values, and the deviance value calculated
- Frequency of simulated deviance values > observed deviance values provides a p-value for model fit

Survival and Reproduction: Data

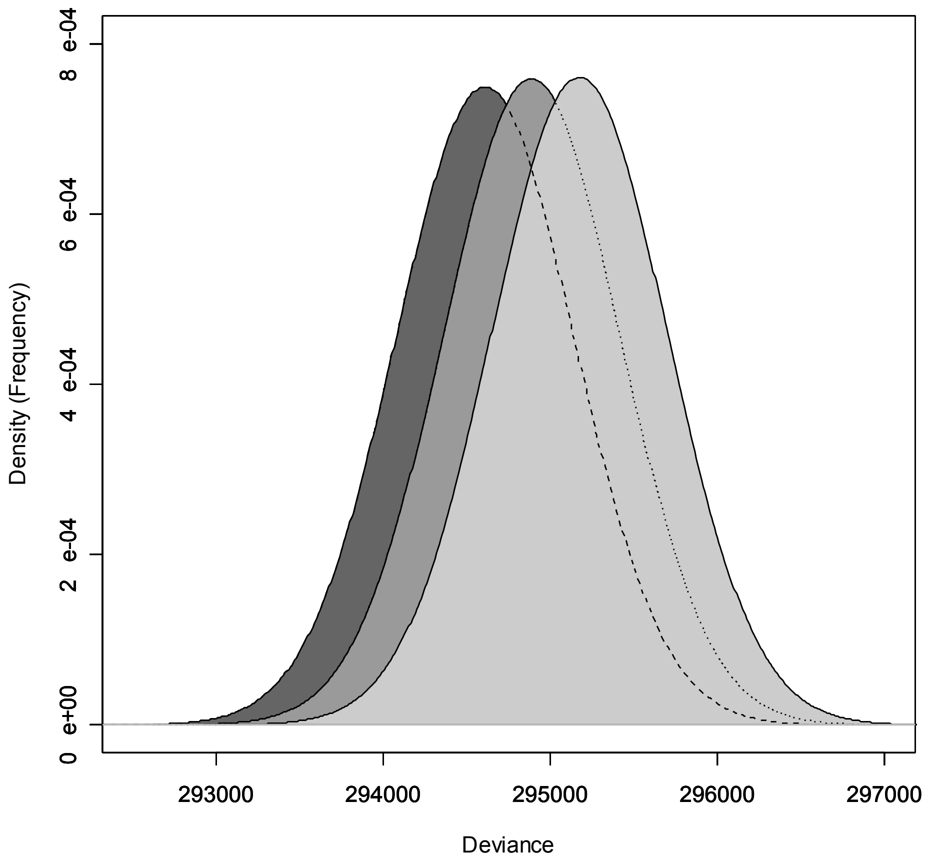
- 1990-2004 tagging cohorts
- Resights from 1997/8-2008/9 in main field season at Enderby Island
- 2 definitions considered for breeder according to assigned status in database
  - Confirmed breeders (status = 3)
  - Probable breeders (status = 3 or 15)

Survival and Reproduction: Data

- Retagged females dealt with using the Lazarus approach
- Approximately 1920 tagged females included in analysis

Results (stricter defn.)

- Summary of posterior distribution for deviance values and Bayesian p-values



Results (stricter defn.)

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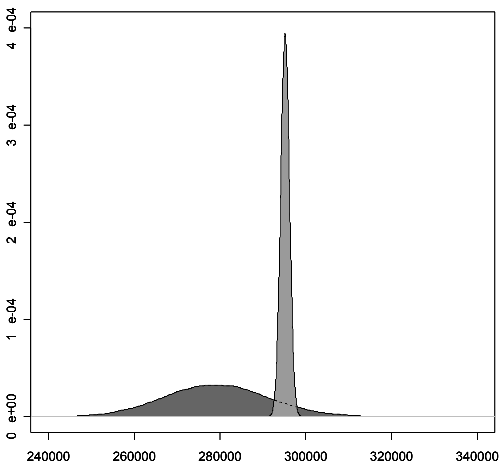
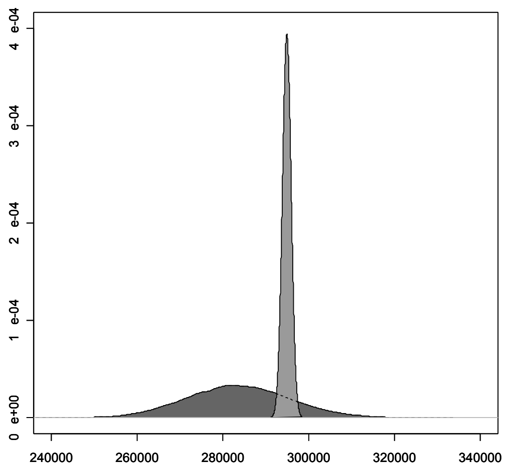
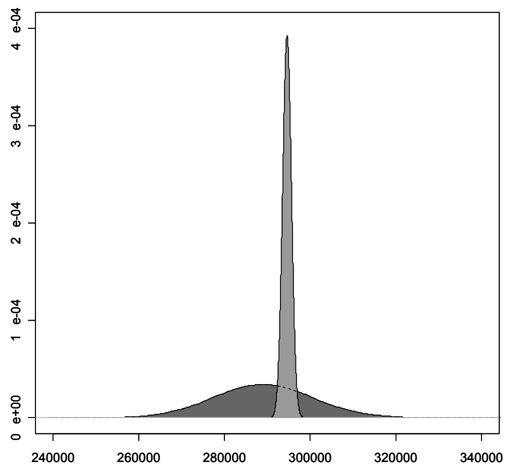


p-value = 0.095



p-value = 0.173



p-value = 0.315

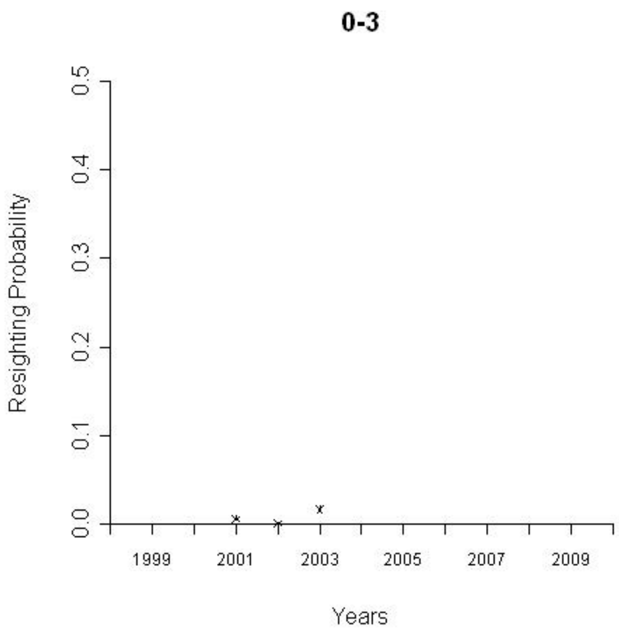
Results (strict defn.)

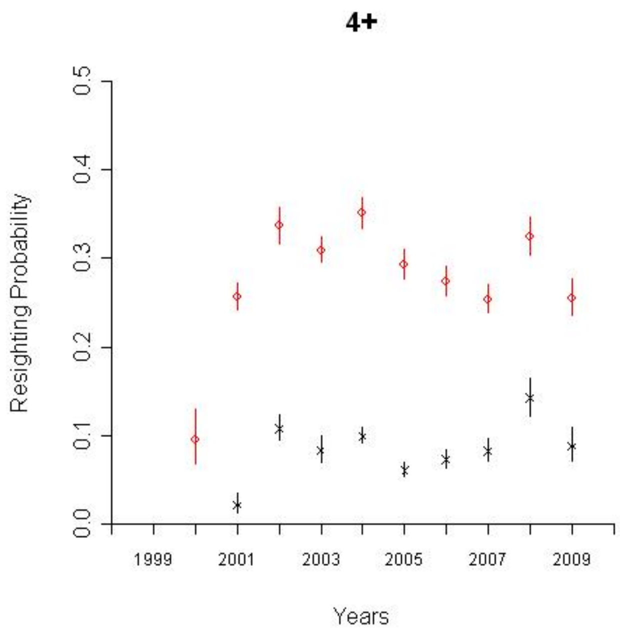
- Tag loss

Tags at *t*-1	Tags at *t*	Probability
1	0	0.09 (0.08, 0.11)
	1	0.91 (0.89, 0.92)
2	0	0.07 (0.05, 0.09)
	1	0.15 (0.13, 0.17)
	2	0.78 (0.76, 0.80)

Results (strict defn.)

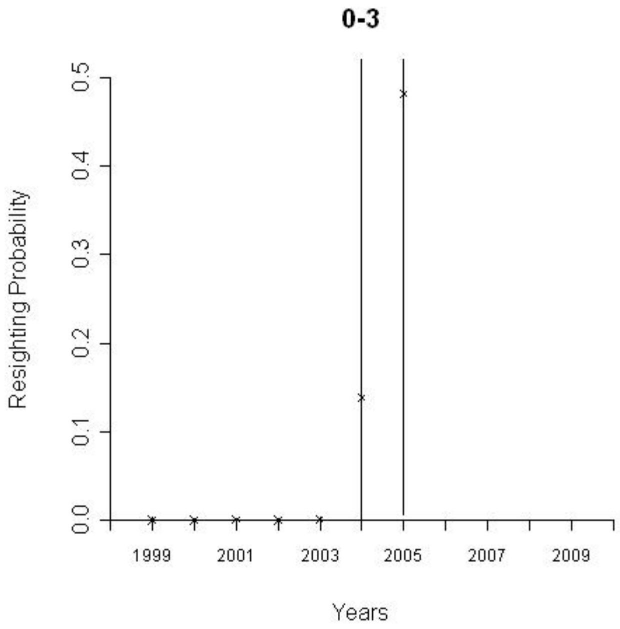
- Resight probabilities very similar from different models
- Branded animals

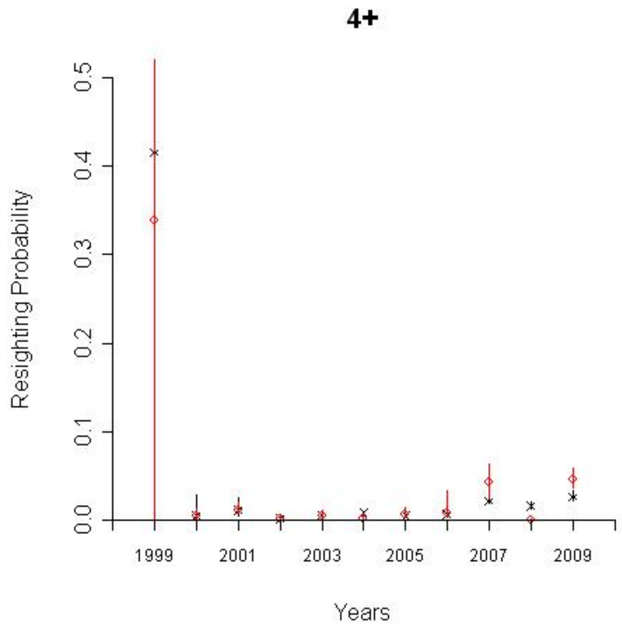




Results (strict defn.)

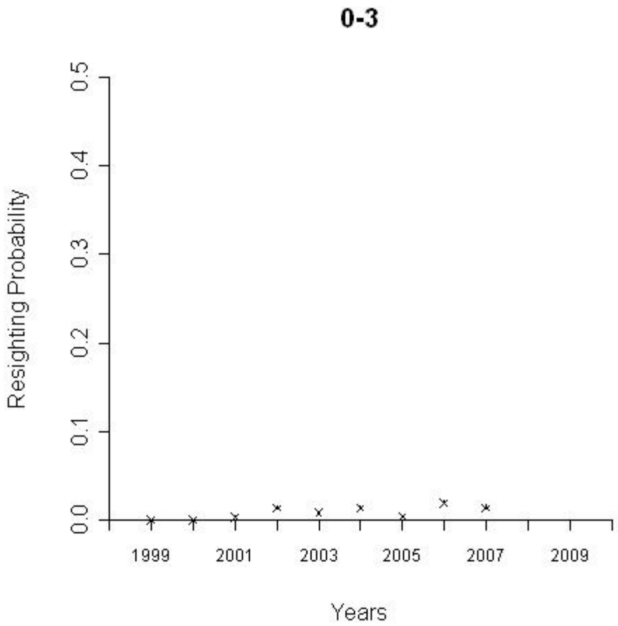
- PIT-tagged only animals

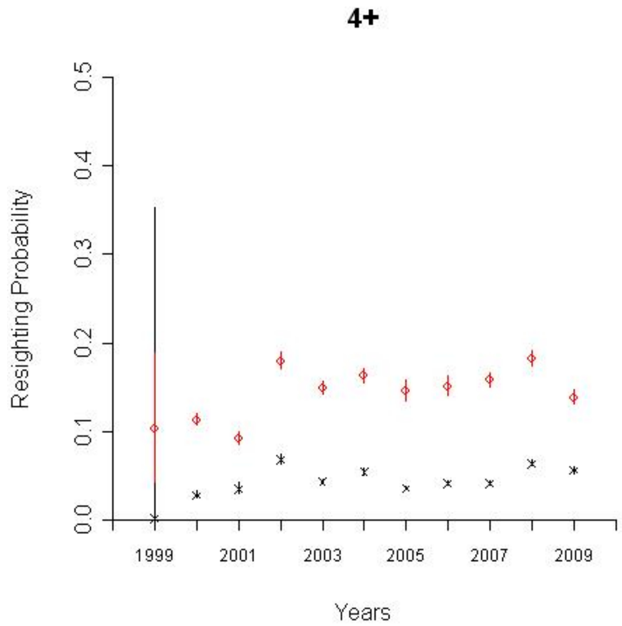




Results (strict defn.)

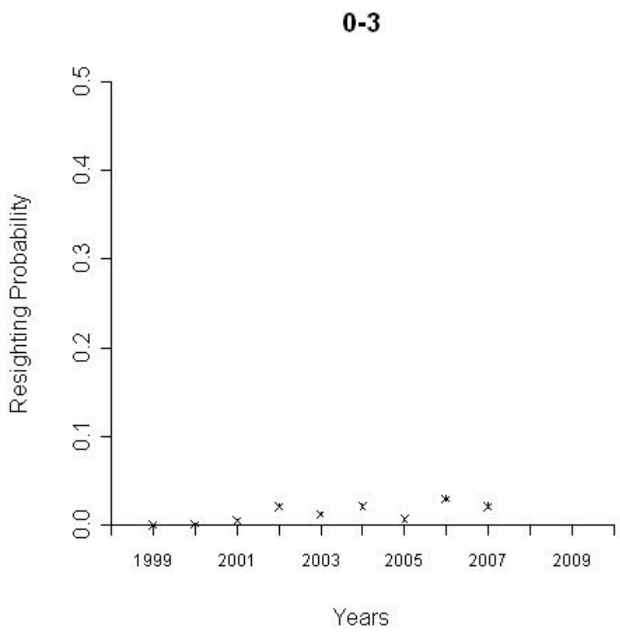
- 1 flipper tag

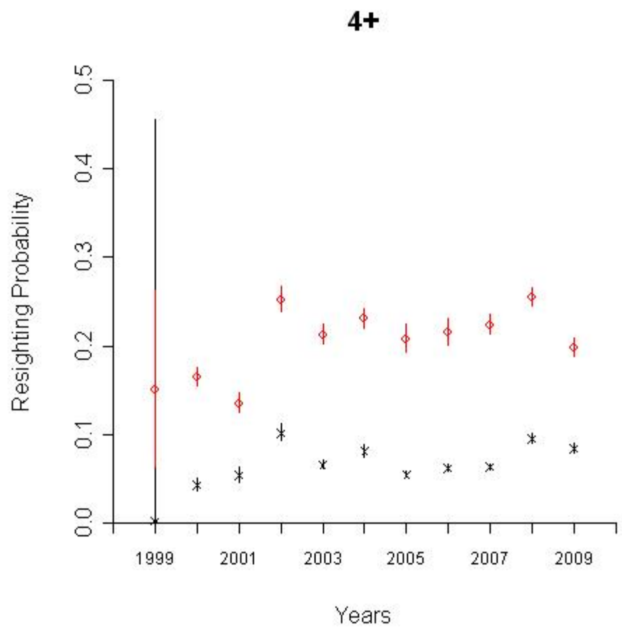




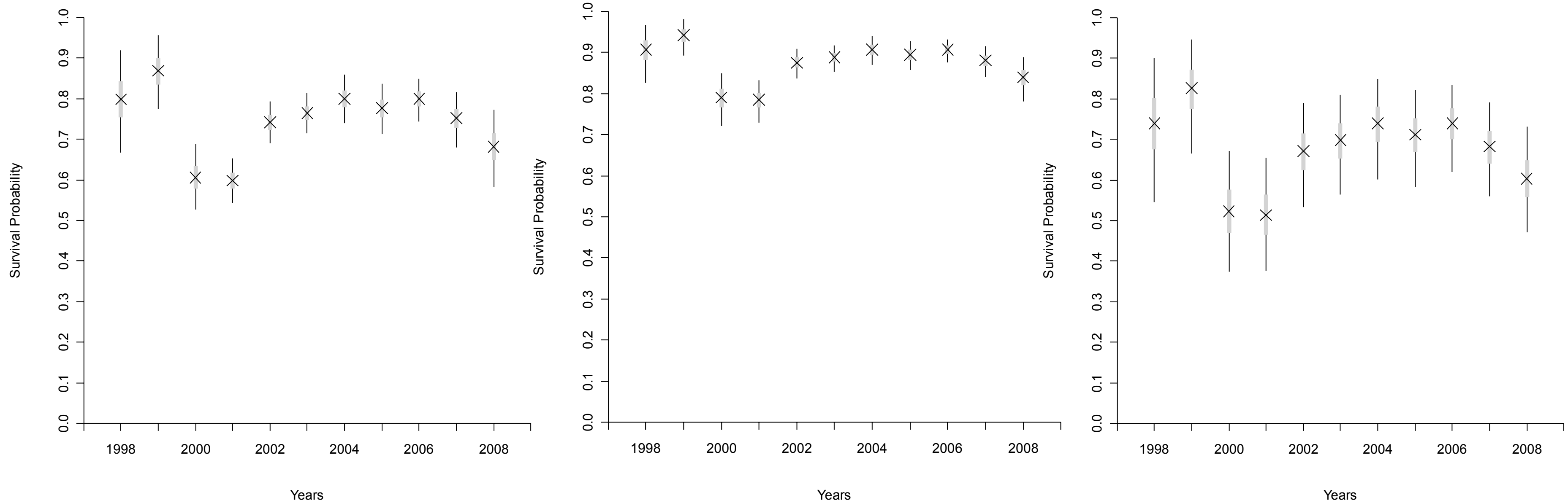
Results (strict defn.)

- 2 flipper tags

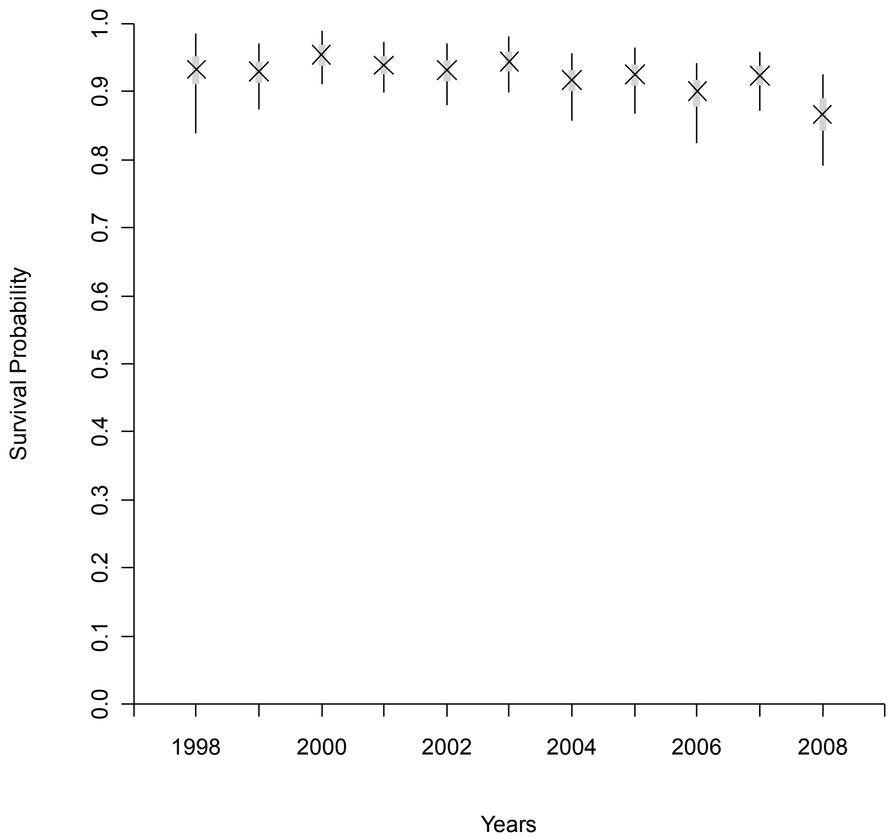


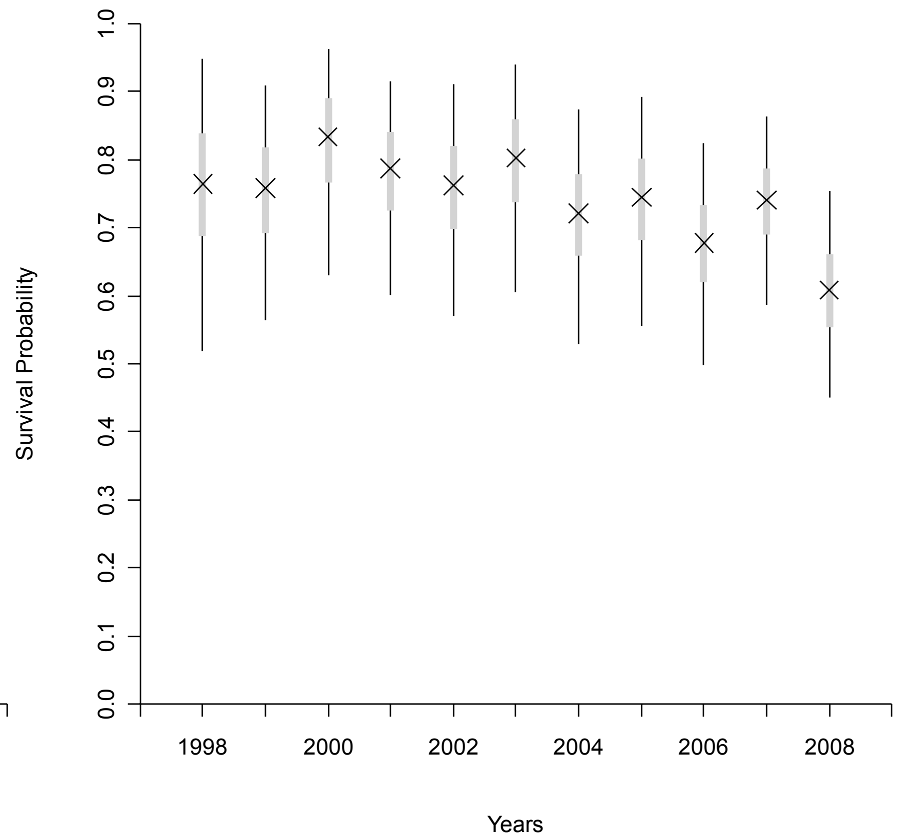


Non-breeder in *t*-1 survival

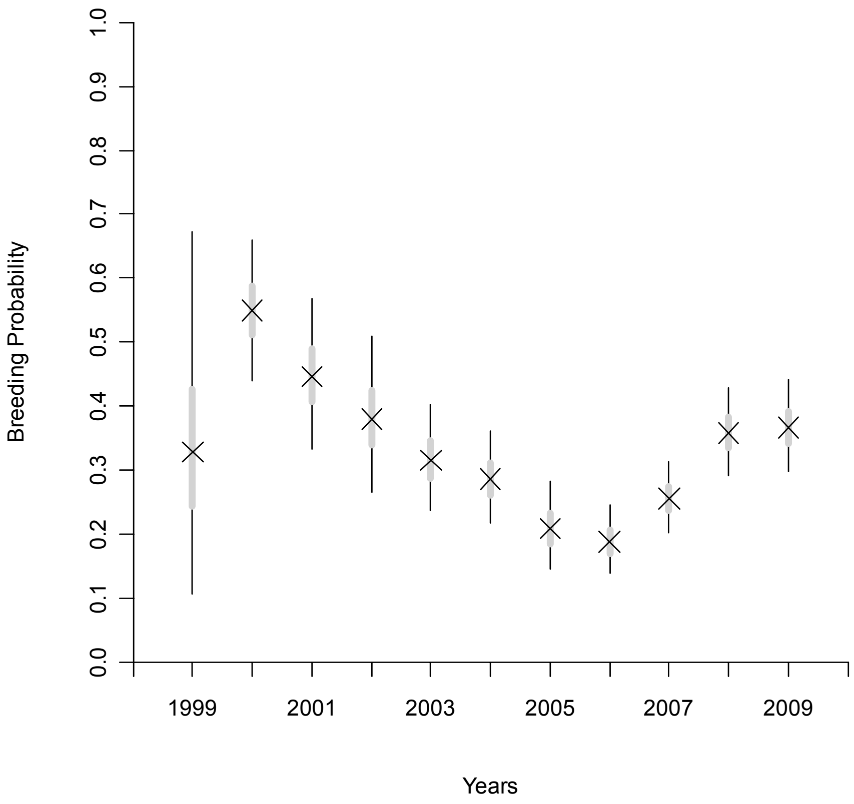


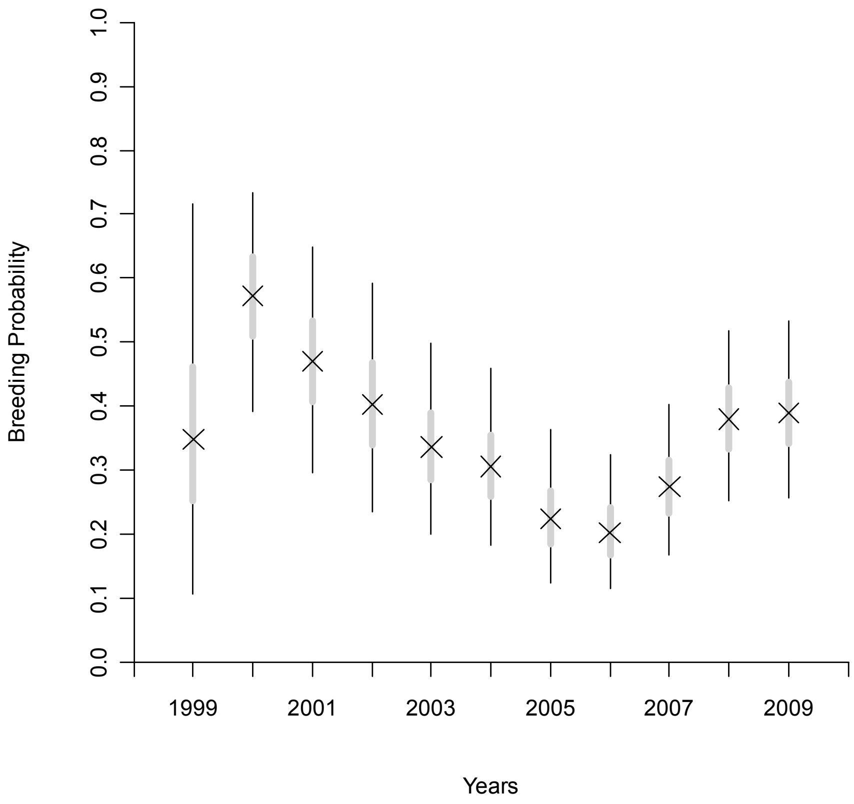
Breeder in *t*-1 survival



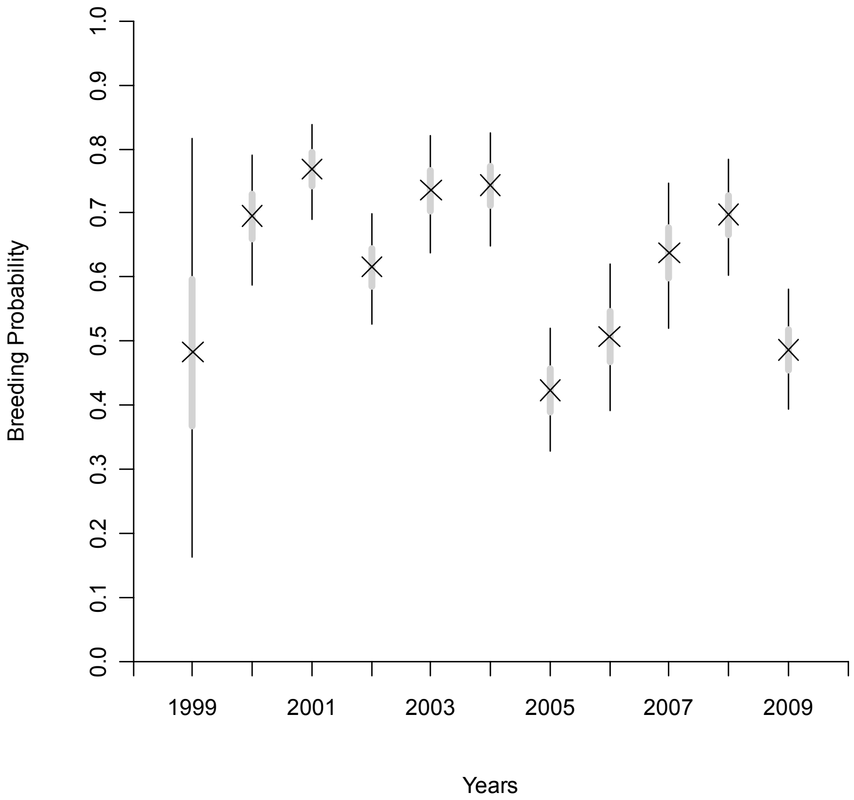


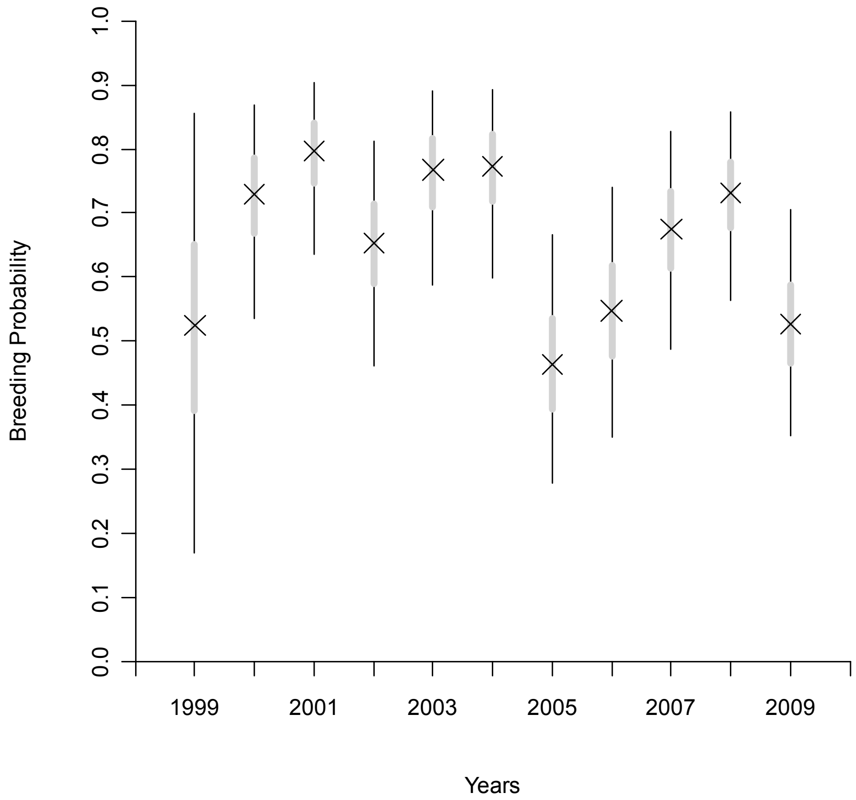
Non-breeder in *t*-1 repro.





Breeder in *t*-1 repro.





Discussion Points

- Age and annual effects may be (partially) confounded

- Apparent dip in survival across all age-classes of approx. 0.05 in 2008/09

Population Size

- Direct estimation not possible given available data.

- Can predict number of survivors from each pupping cohort using estimated survival and reproduction rates.

Population Size

- Given age and breeding status of a female in year *t*, in *t*+1 a female maybe:
  - – Alive and breeding
  - – Alive and not breeding
  - – Dead

$$N_{cohort,t+1,bred|age,t,bred} \sim multinomial\left(N_{cohort,t,bred}, \boldsymbol{\psi}_{age,t,bred}\right)$$

$$N_{cohort,t+1,bred} = \sum_{age,t,bred} N_{cohort,t+1,bred|age,t,bred}$$

Population Size

- Previous applied to 1994/95 pupping cohorts onwards.

- Also older known-age females from early 1990's - different approach used for them

Population Size

$$N_t^{4+,*} = \sum_{\substack{age,bred \\ 4 \le age \le t}} N_{cohort,t,bred}$$

- Is number of females from 1997/98 pupping cohorts aged 4+ in year *t*

$$f_t = \frac{n_t^{4+,*}}{N_t^{4+,*}}$$

- Where $n_t^{4+,*}$ is number observed in Sandy Bay

Population Size

- Estimated number of early 1990's pups alive in Auckland Islands

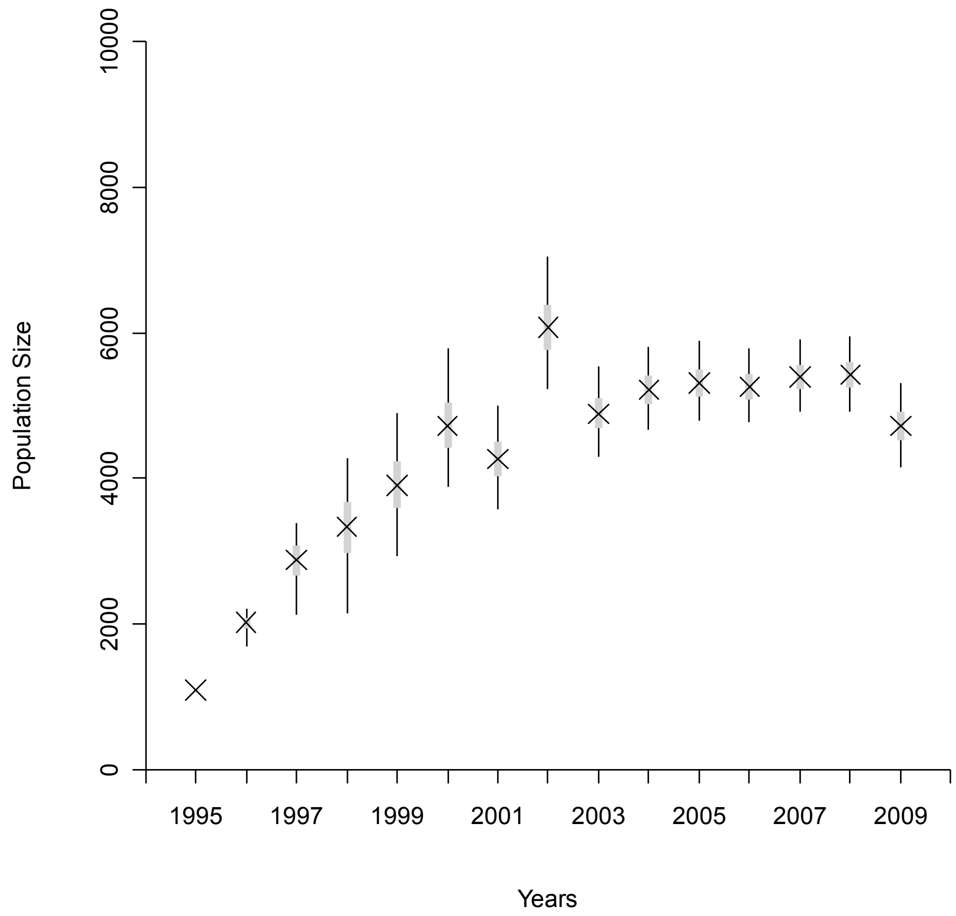
$$N_t^{4+,\#} = \frac{n_t^{4+,\#}}{f_t}$$

- Where $n_t^{4+,\#}$ is number of early 1990's pups observed in Sandy Bay

Population Size

- Correction for older females only possible after 2001/02.
- By 2008/09 ‘population’ consists of pupping cohorts 1989/1990-1992/92 and 1994/95-2008/09.

Population Size



Discussion Points

- Population size estimates should be a key demographic parameter to fisheries/sea lion management
- Dynamic rates provide important information about how populations change, don’t provide information on current state of population
- Current state of population likely to be a primary driver of management actions to achieve clearly defined management objectives