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

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1997/98 – 2009/10

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Darryl MacKenzie

Proteus
wildlife research consultants

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+
- OR, constant for 0-3, and logit-linear for age 4+

- Survival and breeding probabilities = 0 for “breeders” in 0-3 age class

Survival and Reproduction

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

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

- Annual variation depends upon previous breeding status

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 zero-inflated binomial random variable with a daily resight probability $p_{t,bred,brand,tags}$

- 3 models: no inflation, time constant inflation, time varying inflation

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)
  - $\ln(\delta) \sim N(0,10^2)$
- 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

- 1990-2005 tagging cohorts
- Resights from 1997/8-2009/10 in main field season at Enderby Island
- Only considered confirmed breeders at this stage (status = 3)

Survival and Reproduction: Data

- Retagged females dealt with using the Lazarus approach

- Approximately 2300 tagged females included in analysis

Results (stricter defn.)

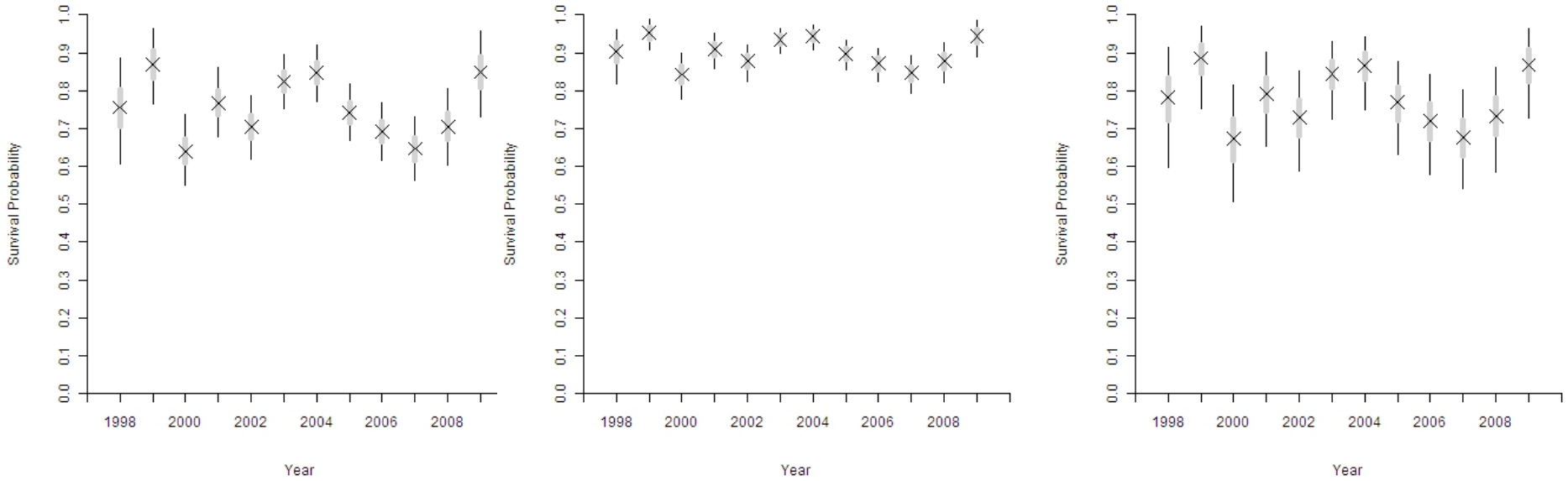
Model	2.5th Percentile	Median	97.5th Percentile	B. p-value
AC $\psi_{a,t,b}$	330381	330872	331335	0.21
AC $\psi_{a,b}$	330700	331100	331500	0.22
AC $\psi = 1$	340397	340775	341138	0.02
Linear $\psi_{a,t,b}$	330389	330843	331292	0.23
Linear $\psi_{a,b}$	330600	331036	331437	0.25
Linear $\psi = 1$	340372	340753	341118	0.03

Results (strict defn.)

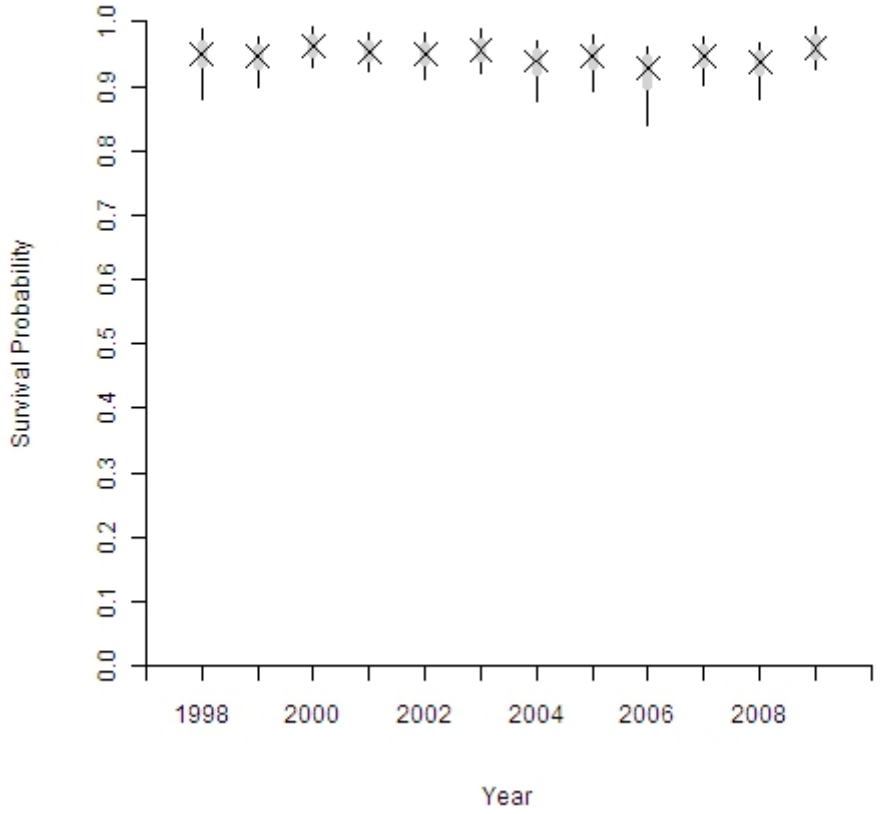
- Tag loss

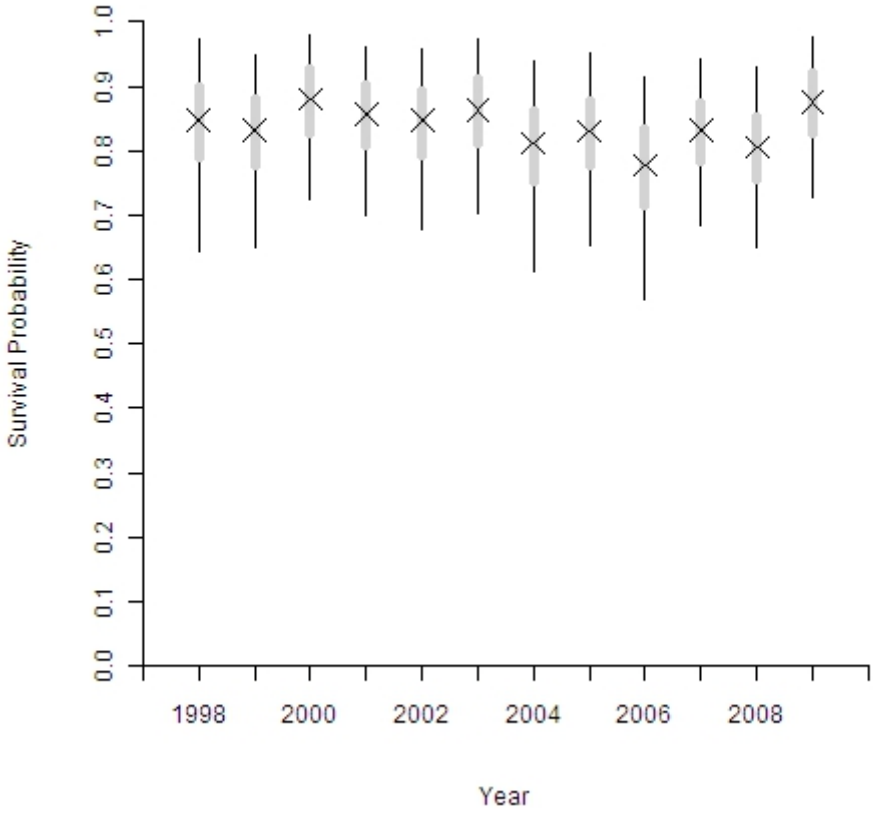
Tags at *t*-1	Tags at *t*	Probability
1	0	0.11 (0.10, 0.13)
	1	0.89 (0.87, 0.90)
2	0	0.04 (0.03, 0.06)
	1	0.14 (0.13, 0.16)
	2	0.81 (0.80, 0.83)

Non-breeder in *t*-1 survival

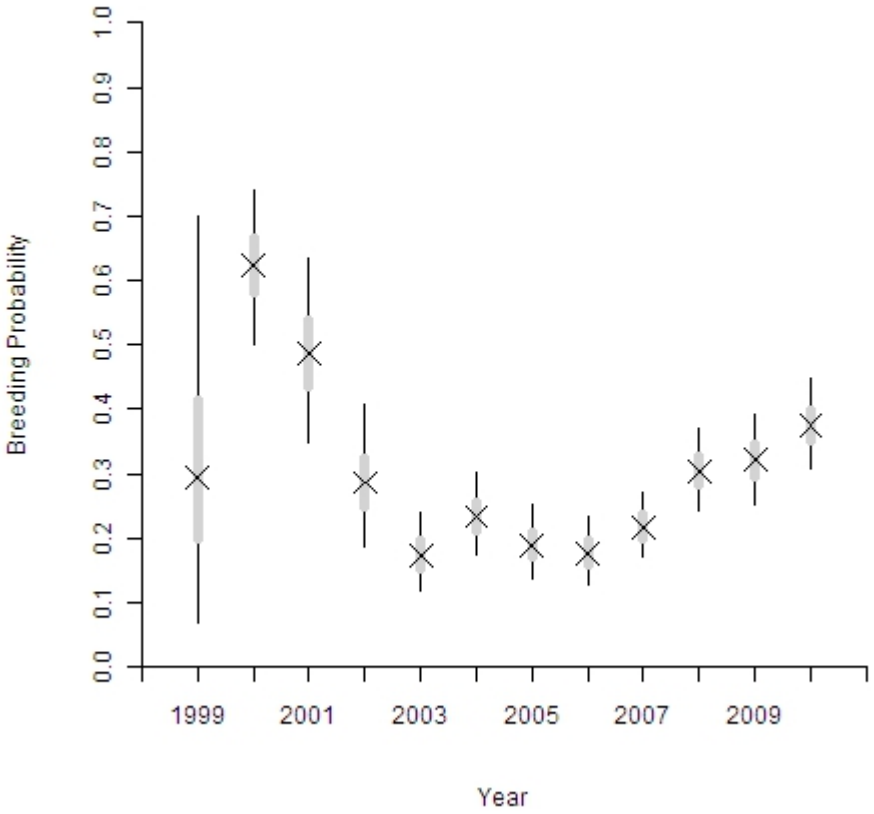


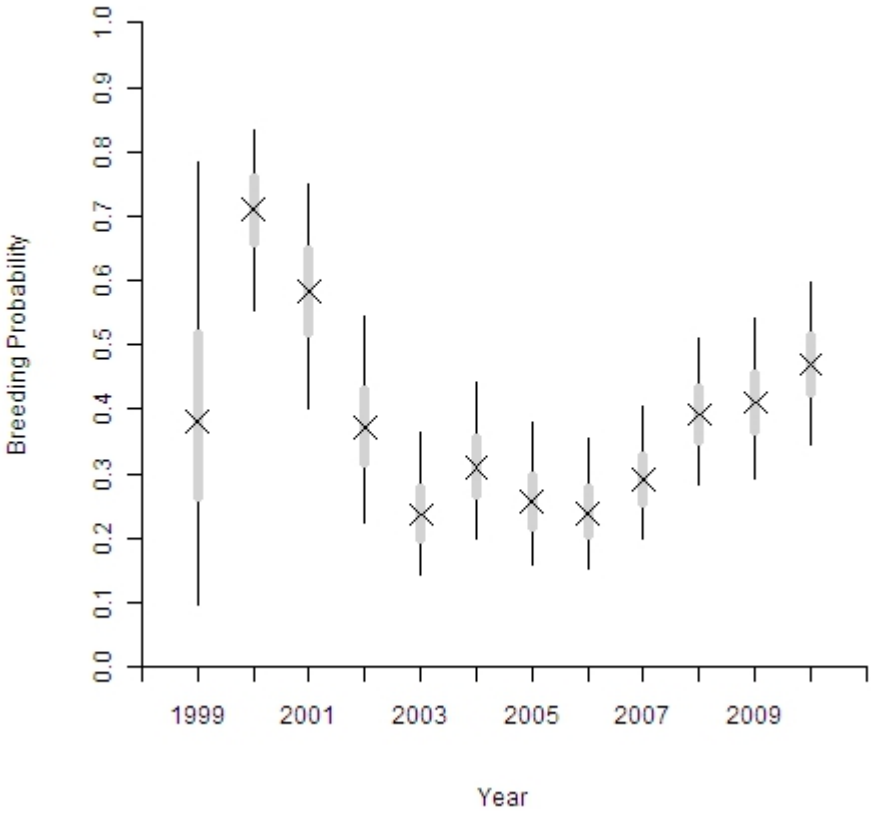
Breeder in *t*-1 survival





Non-breeder in *t*-1 repro.





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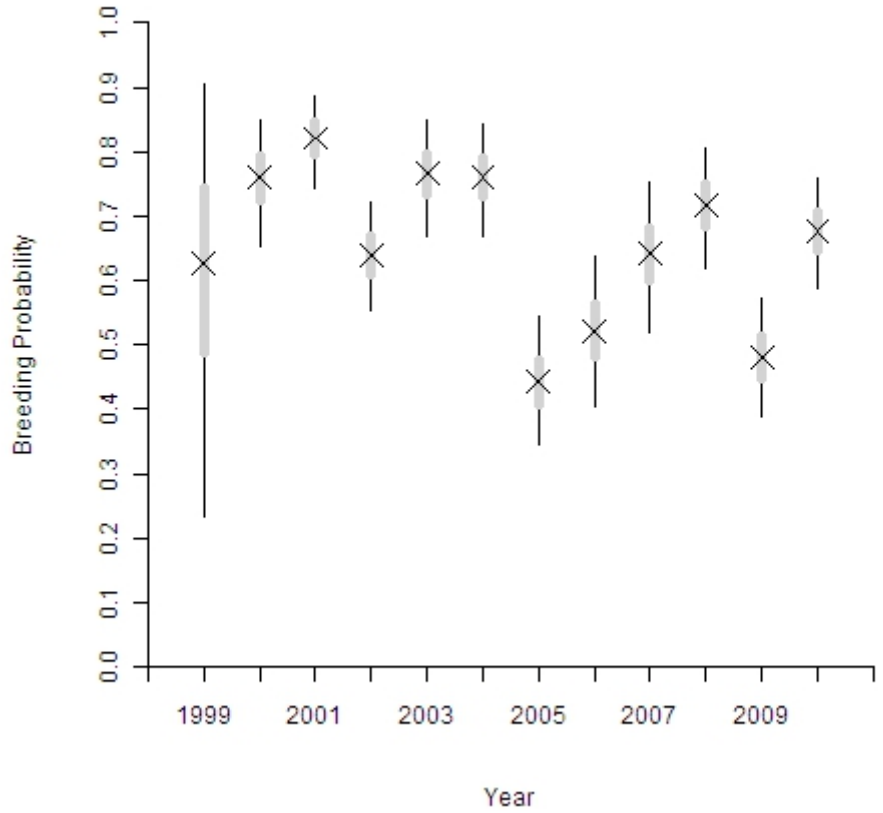

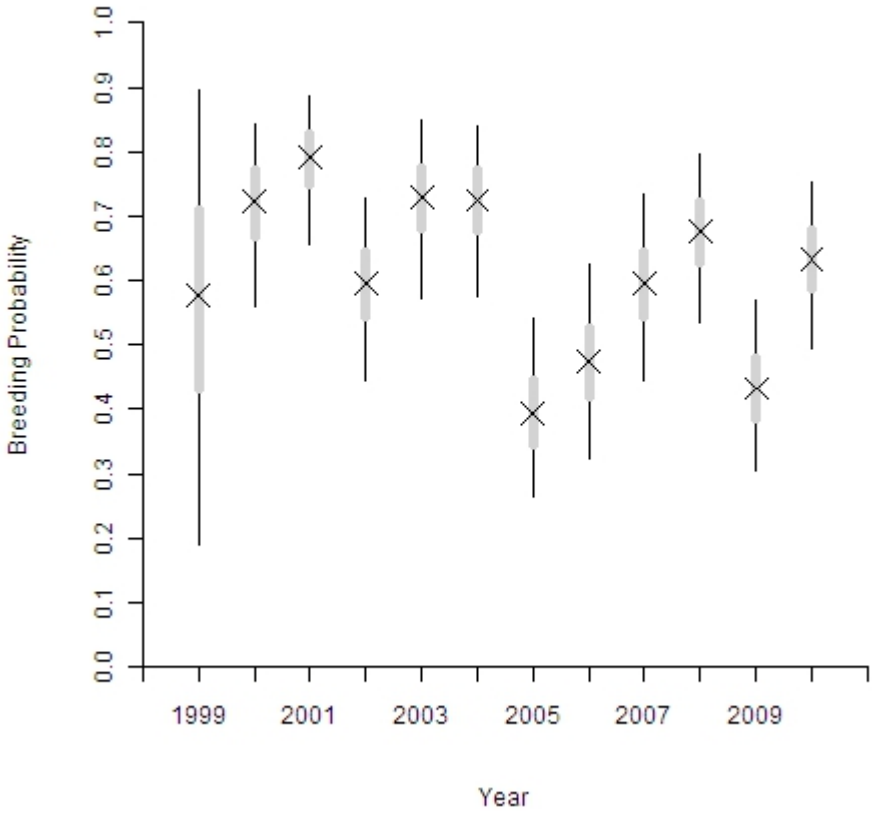

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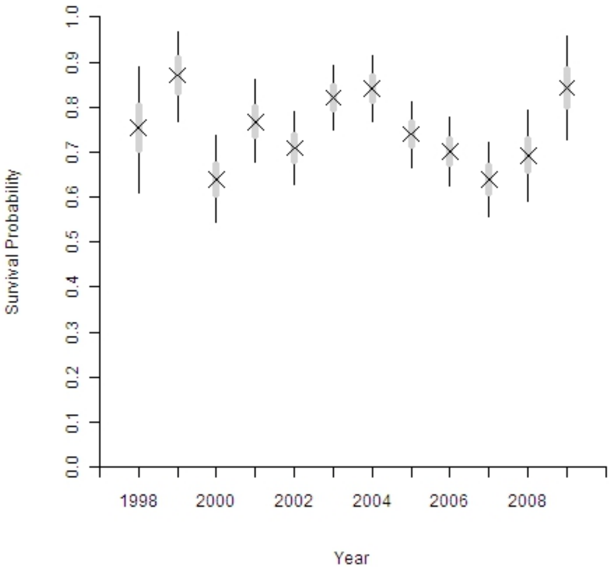

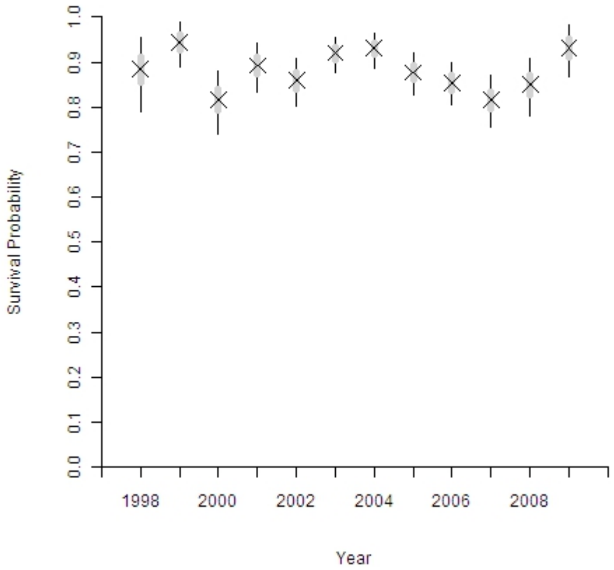

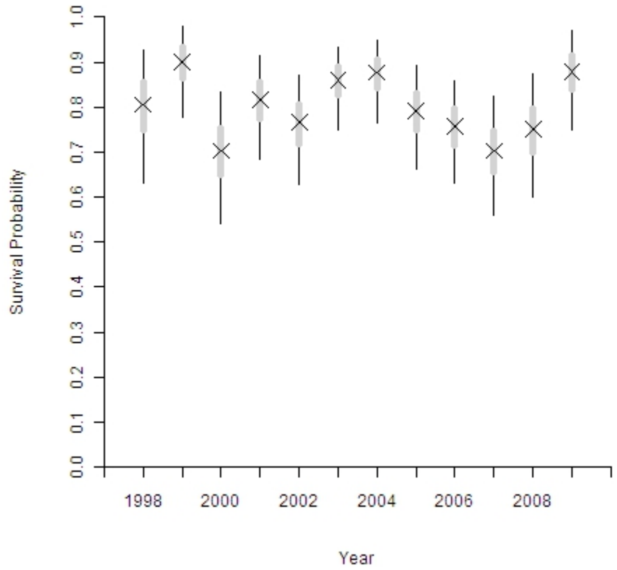

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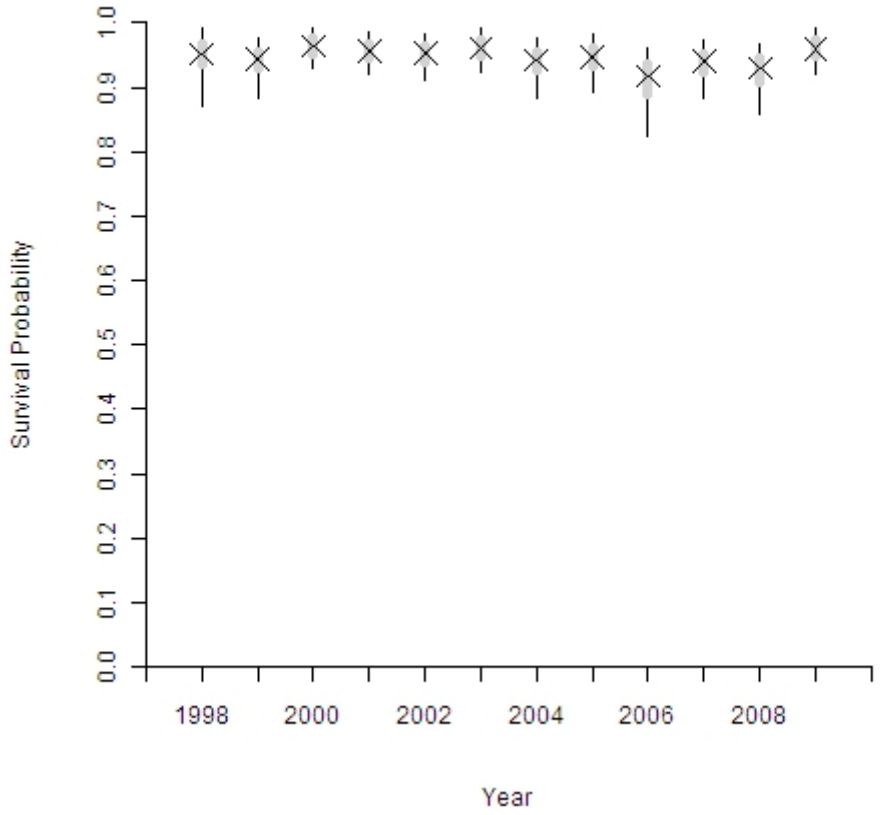
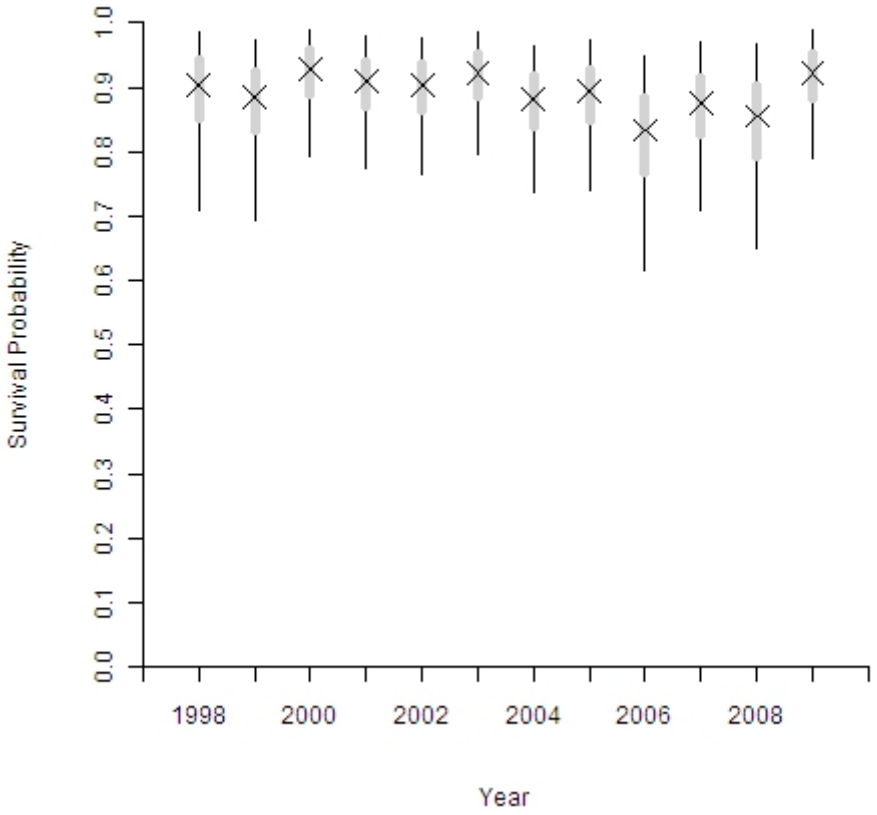
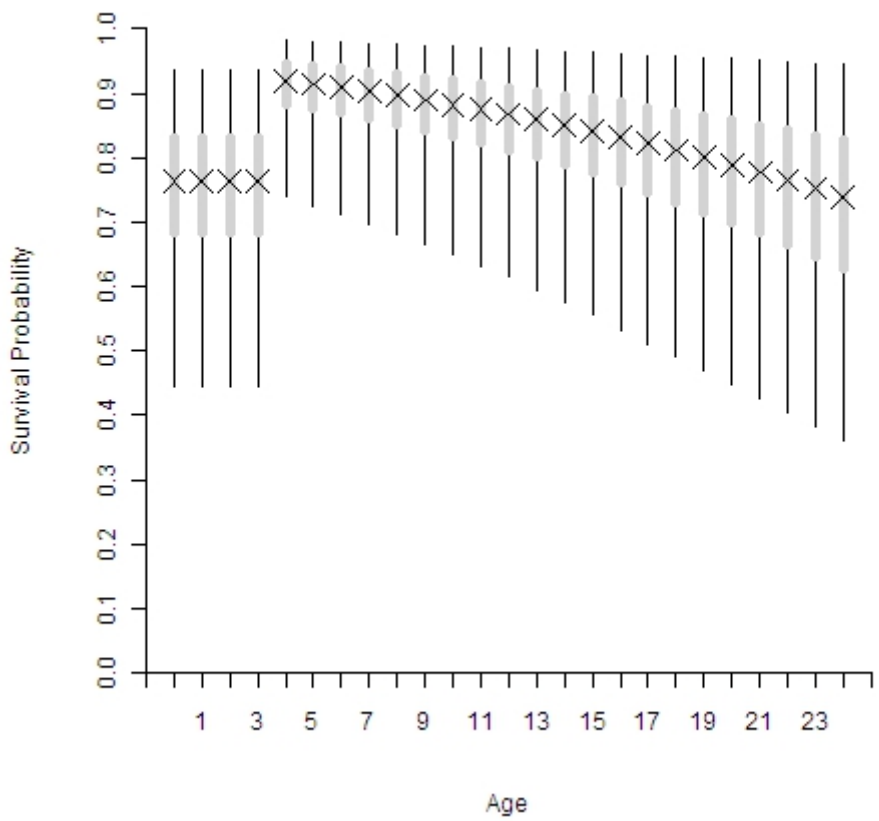
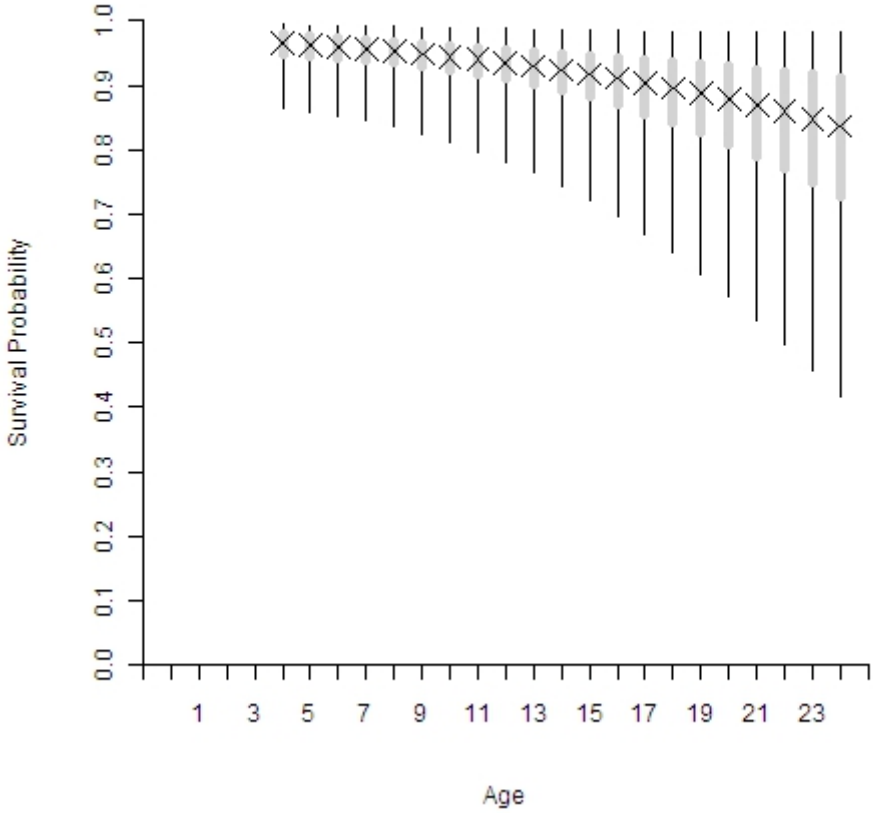




Survival vs Age





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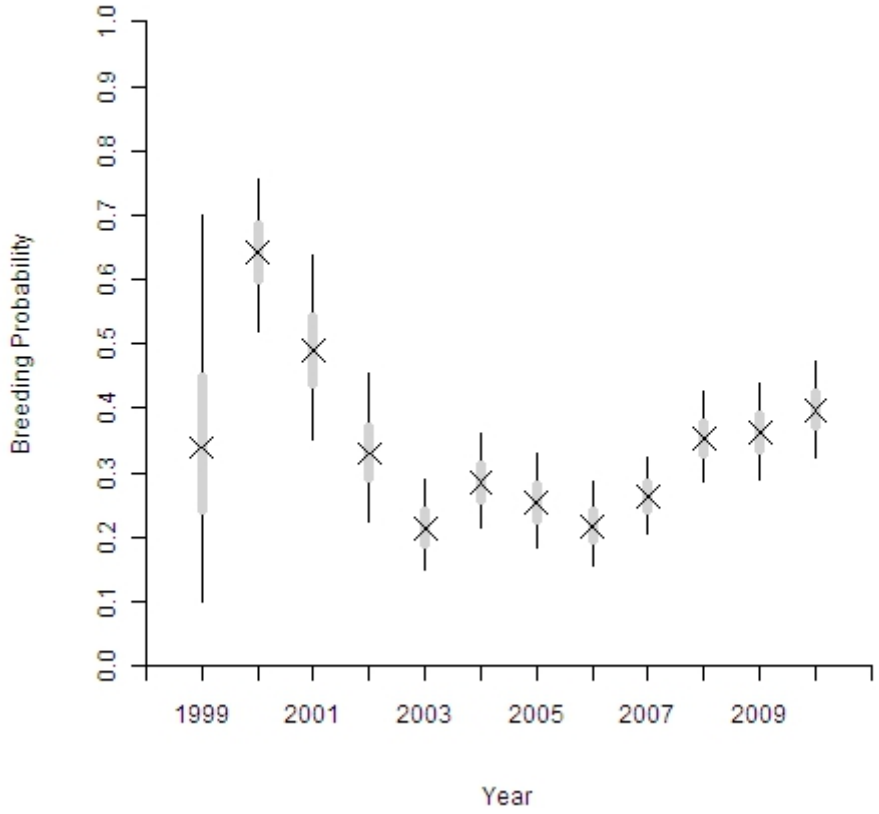

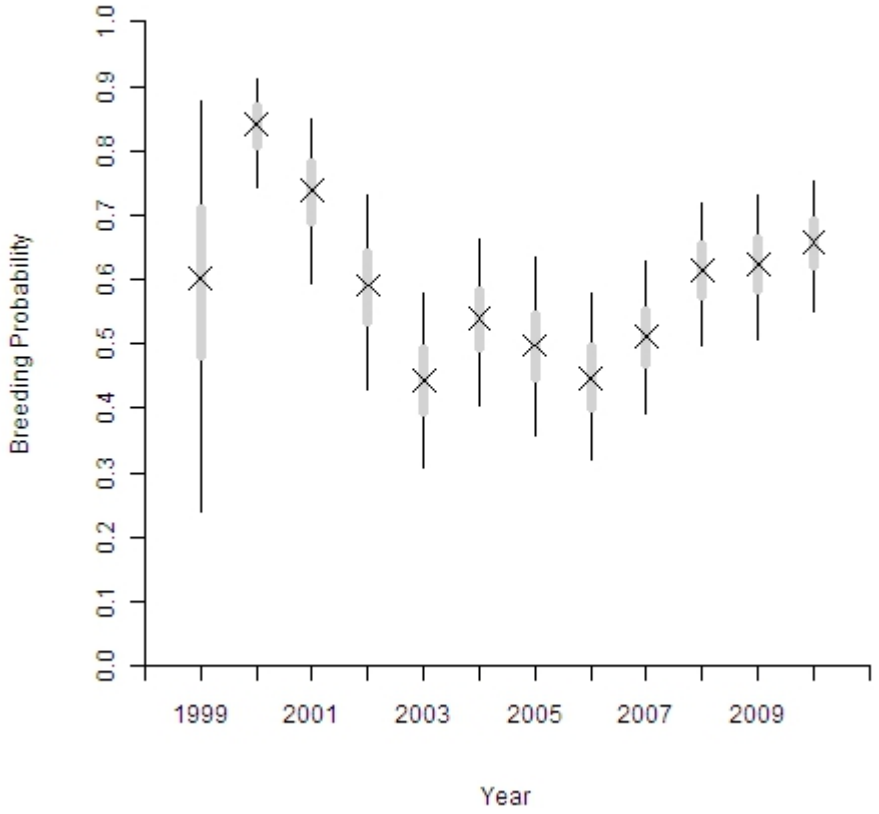

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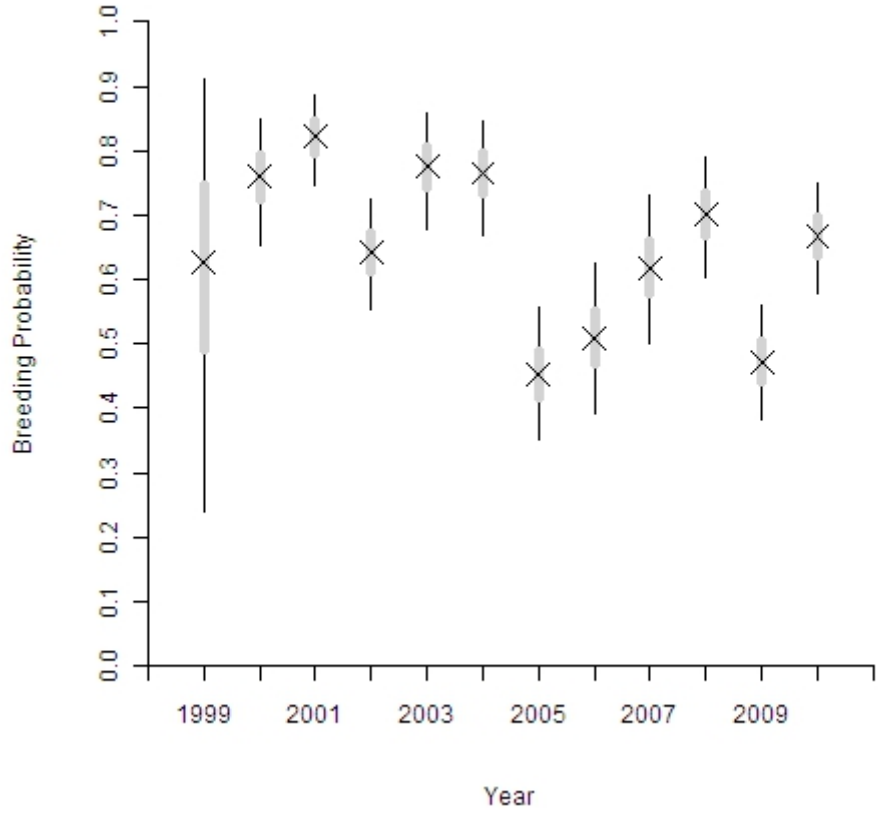

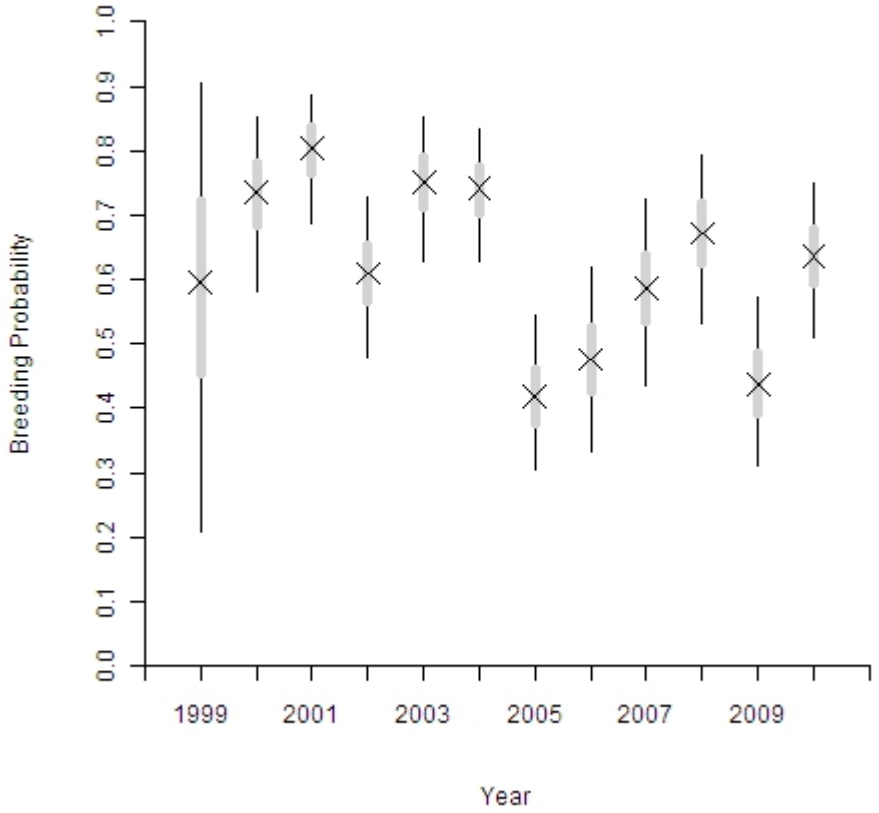

Breeding vs Age