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

POP2007/01 Obj 3

Mach 09 Update

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# 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

- Focus of update to asses relative fit of the models and compare different age-structures

# 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

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

- Analyses conducted with and without accounting for tag-loss to assess it's effect on estimation of demographic parameters

# 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 $S_{age,bred}$

# 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 $B_{age,bred}$

# Survival and Reproduction

- 3 relationships considered between age and survival/reproduction
  - Single age-class
  - 3 age-classes: 0-3, 4-14, 15+
  - 4 age-classes: 0-3, 4-7, 8-14, 15+

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

# 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:
  - Most 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

- Last minute addition: fit fully age-specific model
- Examine for any apparent patterns not accounted for in previous models

- Estimands will have low precision

# Survival and Reproduction: Data

- 1990-2003 tagging cohorts
- Resights from 1998-2008 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)

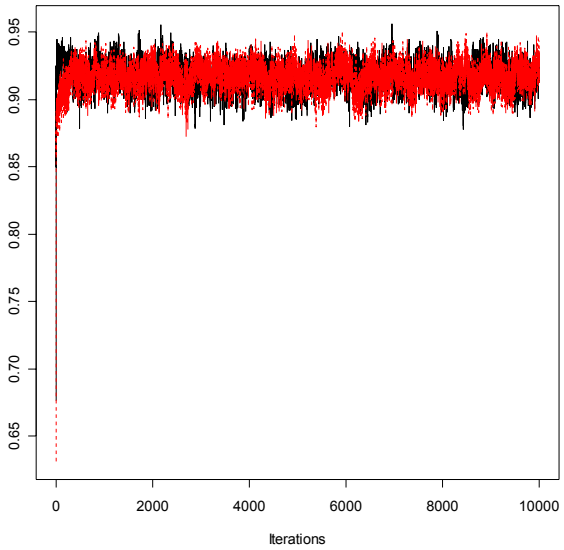
# Survival and Reproduction: Data

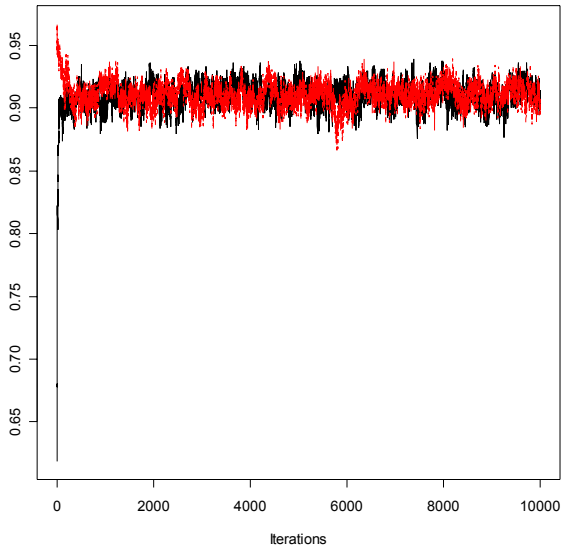
- Retagged females dealt with using the Lazarus approach

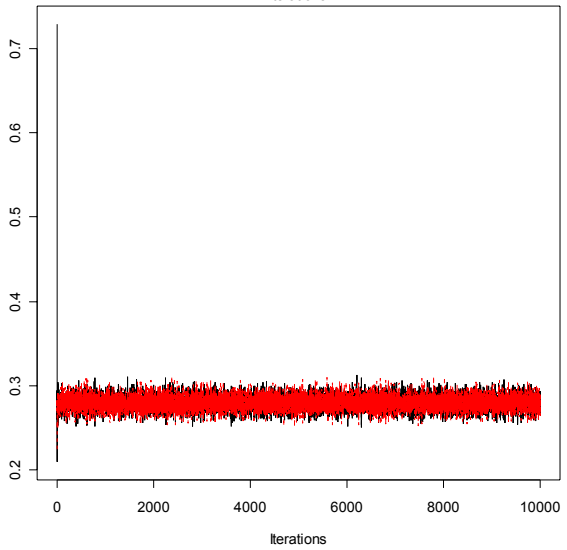
- Almost 1700 tagged females included in analysis

# Results (stricter defn.)

- Traceplots



# Results (stricter defn.)

- Single age-class results appear suspicious, initial rechecks indicate results are incorrect (suspect results should be similar to when using liberal defn.)

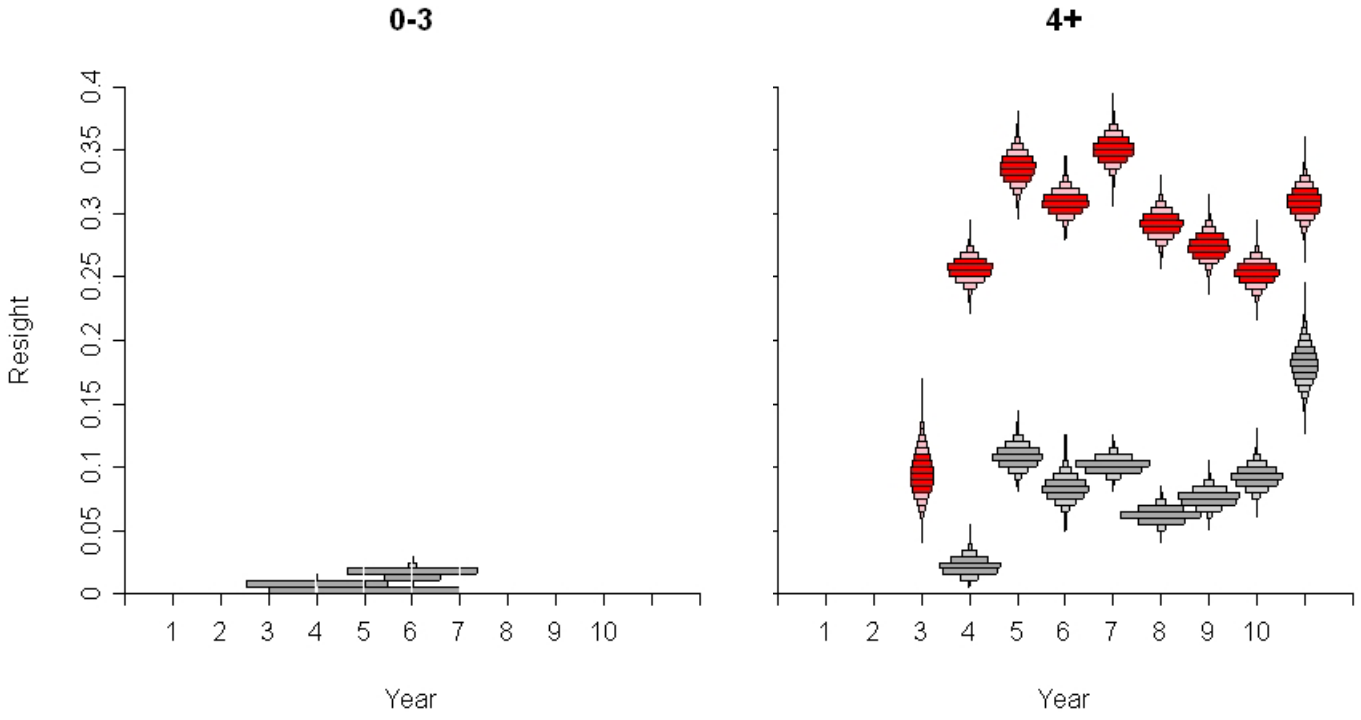
# Results (stricter defn.)

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

| | Age Classes in Model | | |
|---|---|---|---|
| | Single | 3 | 4 |
| Mean | 257719.3 | 258874.7 | 258864.0 |
| 2.5%ile | 257352.9 | 258570.8 | 258561.2 |
| 97.5%ile | 258088.2 | 259163.7 | 259160.9 |
| min | 256971.5 | 258268.0 | 258156.4 |
| max | 258529.4 | 259413.4 | 259463.4 |
| p-value | 0.9999 | 0.2151 | 0.2206 |

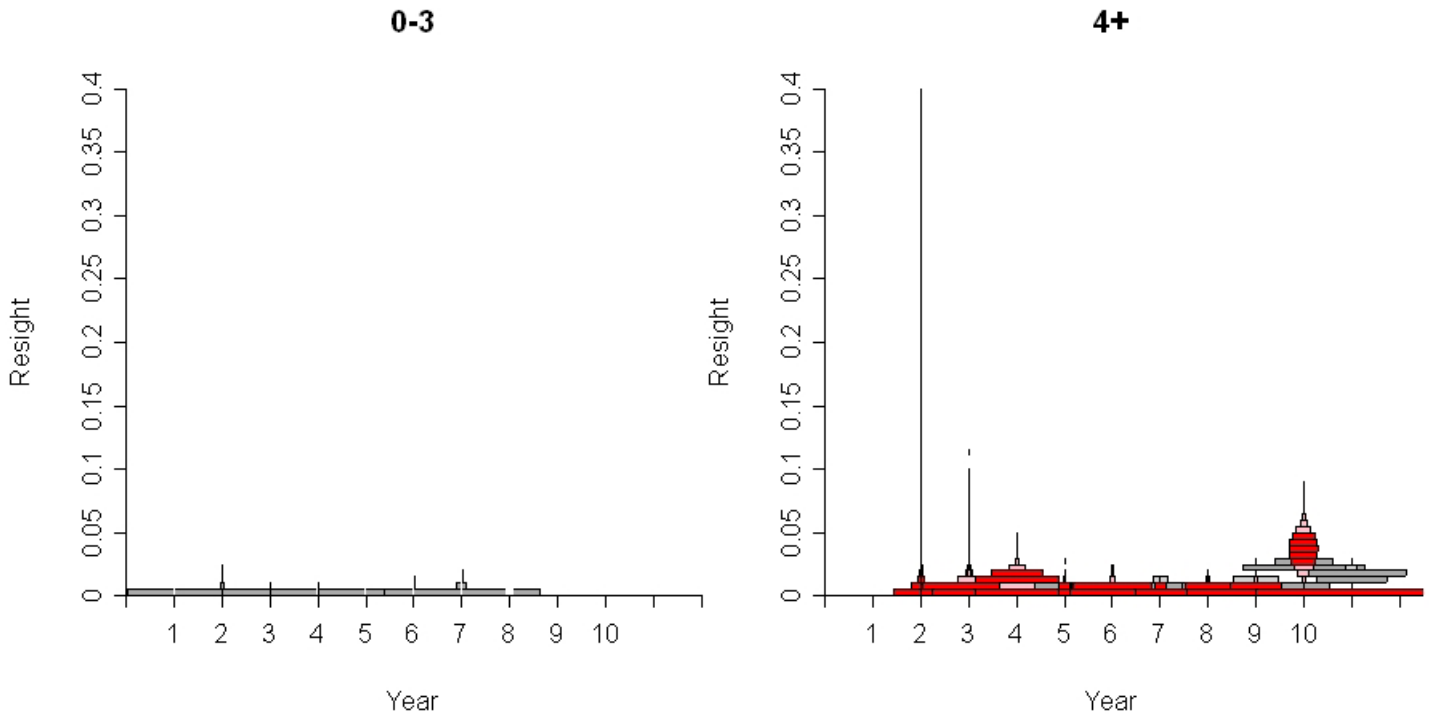
# Results (strict defn.)

- Resight probabilities very similar from different models
- Branded animals



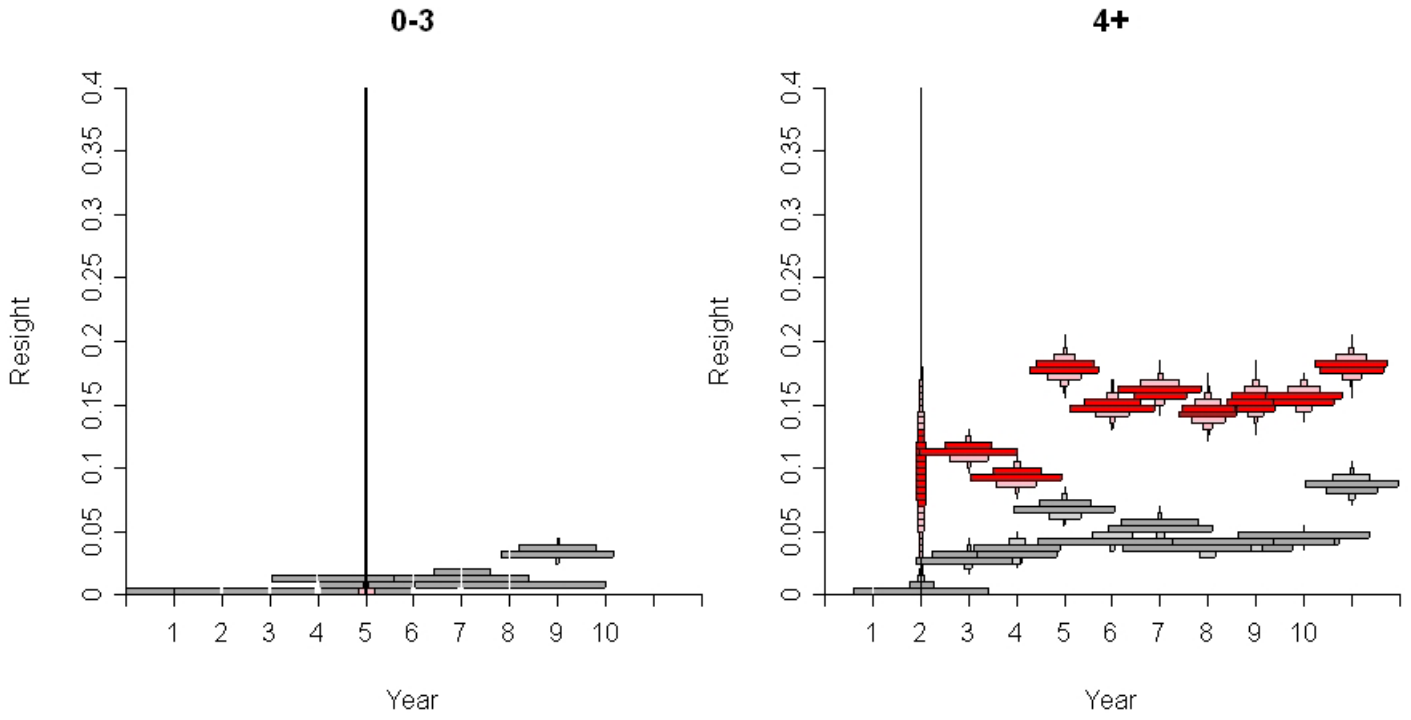
# Results (strict defn.)

- PIT-tagged only animals



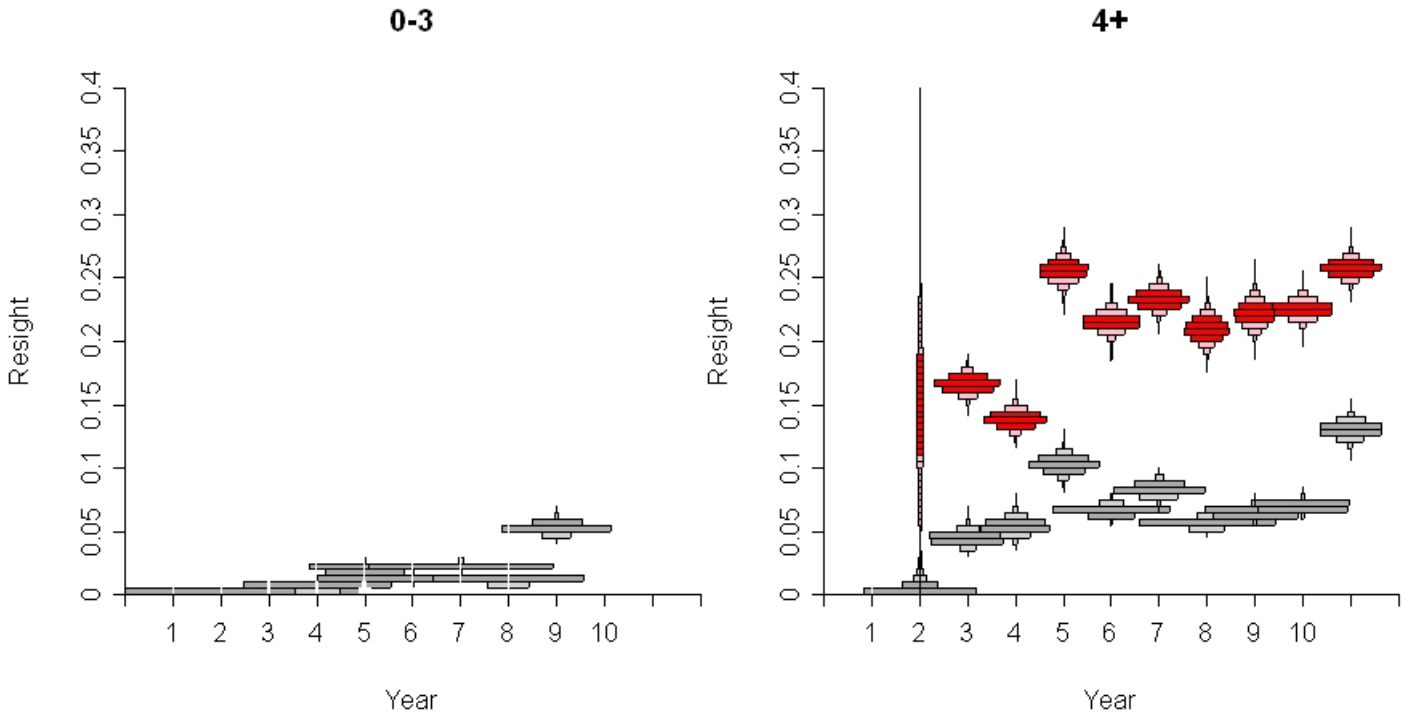
# Results (strict defn.)

- 1 flipper tag



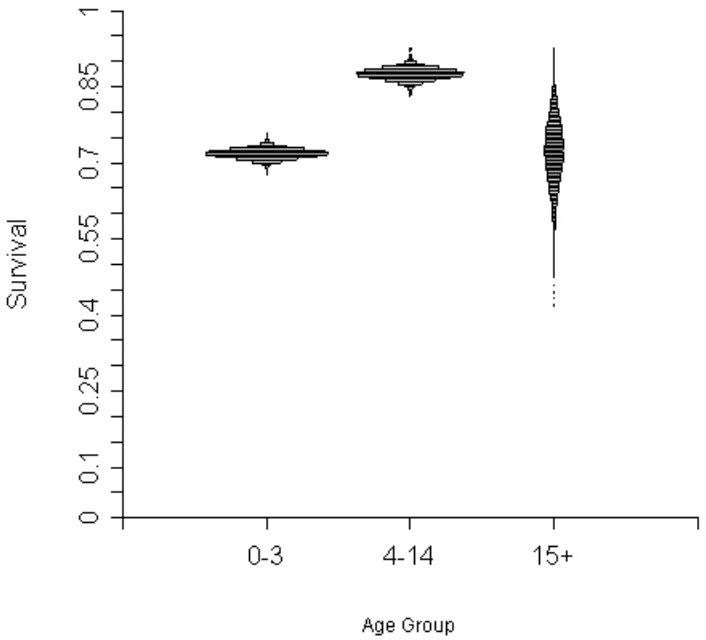
# Results (strict defn.)

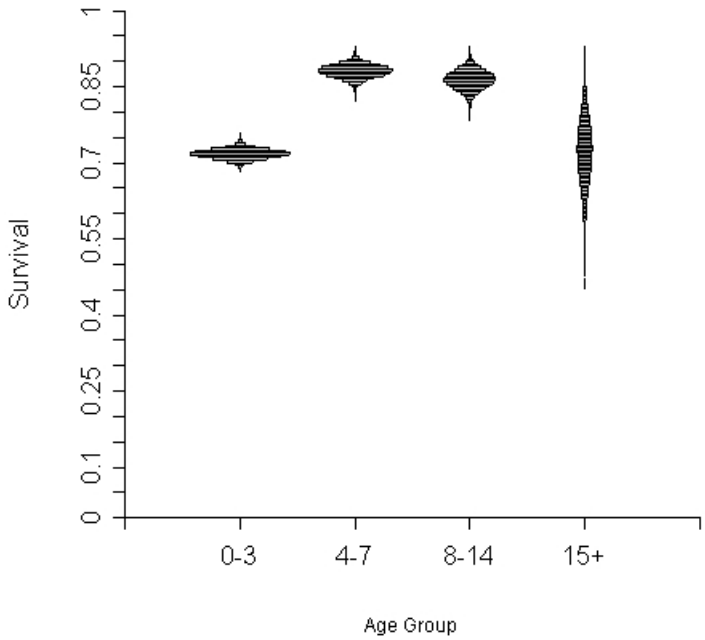
- 2 flipper tags



# Results (strict defn.)

- Non-breeder in *t*-1 survival



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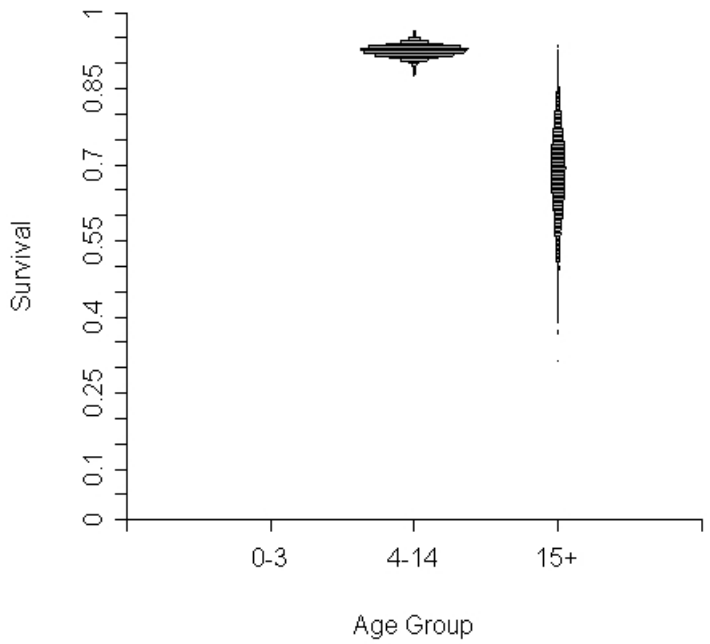
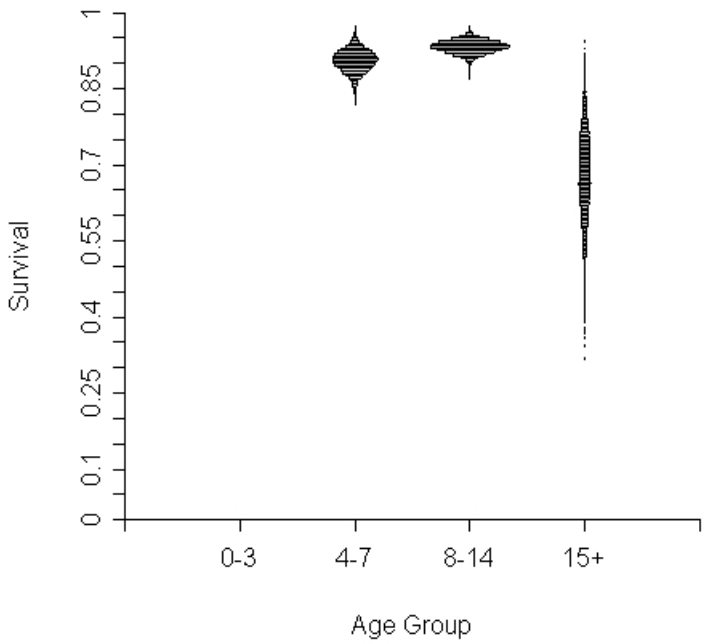
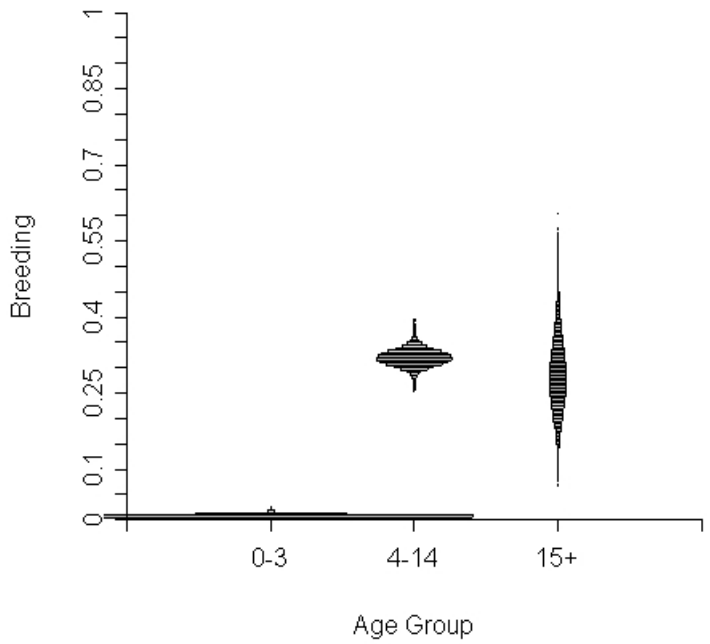
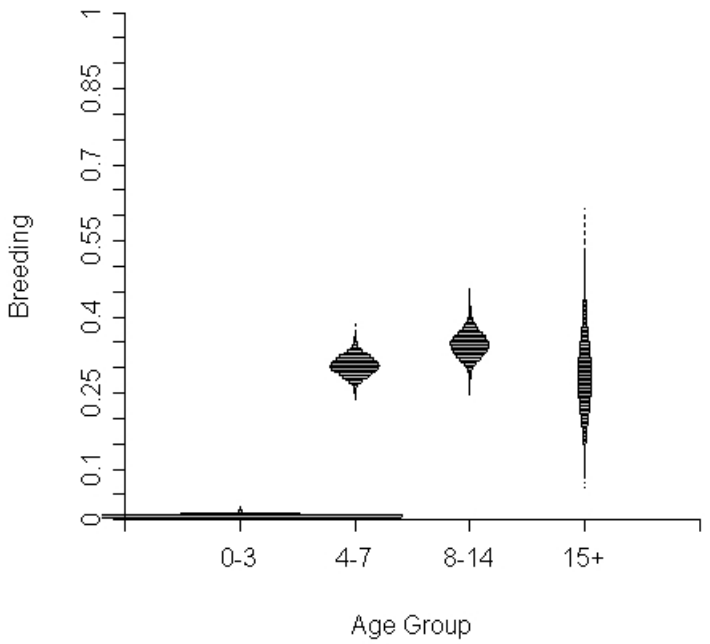


# Results (strict defn.)

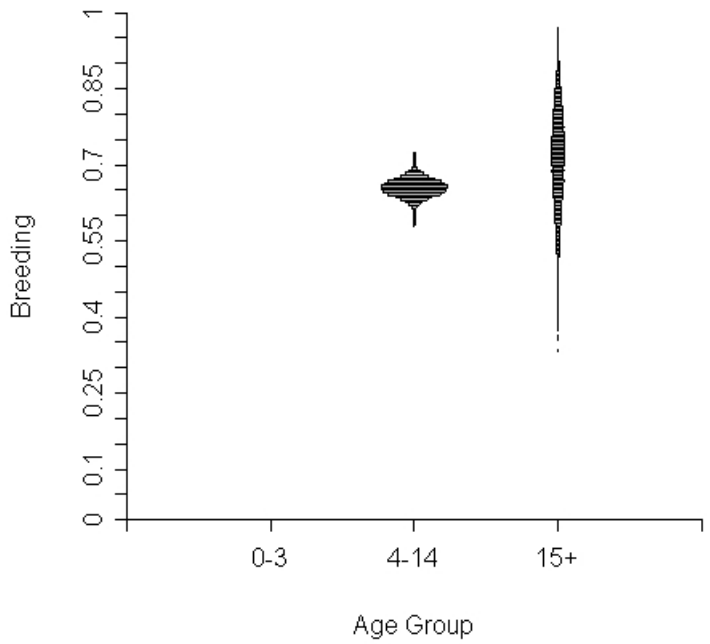
- Non-breeder in *t*-1 reproduction

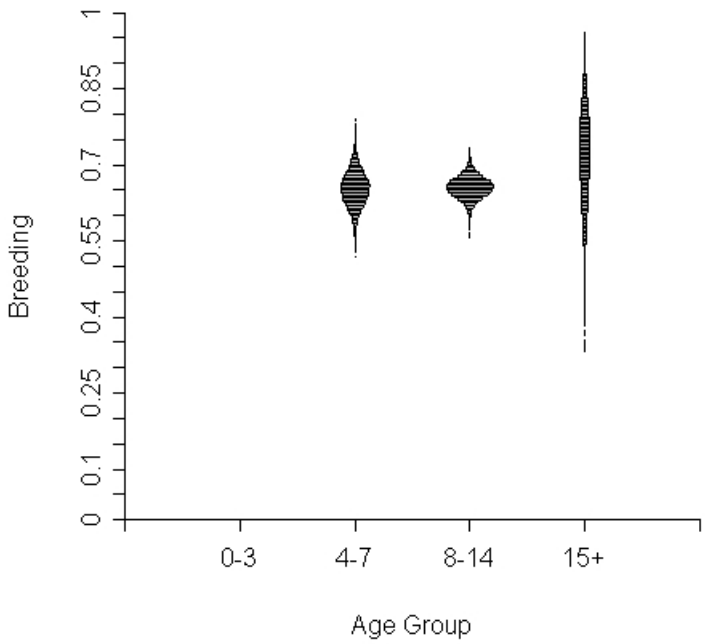


# Results (strict defn.)

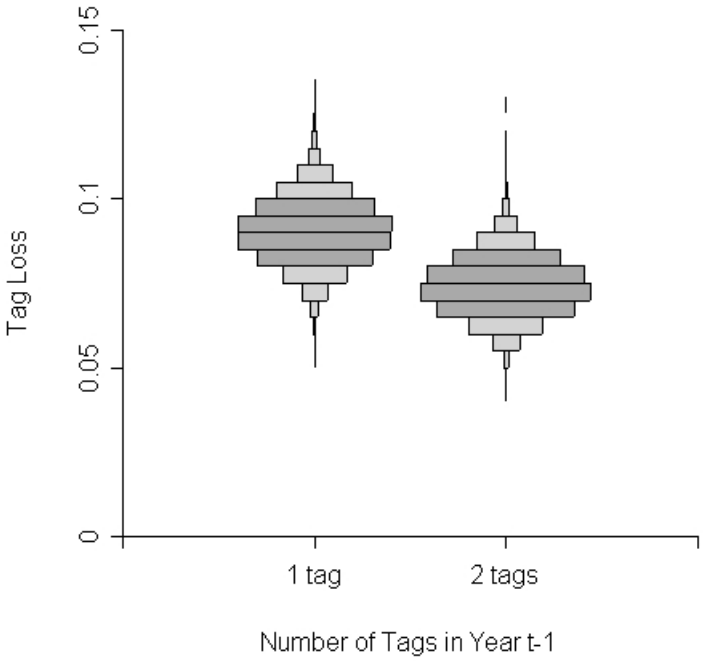
- Breeder in *t*-1 reproduction

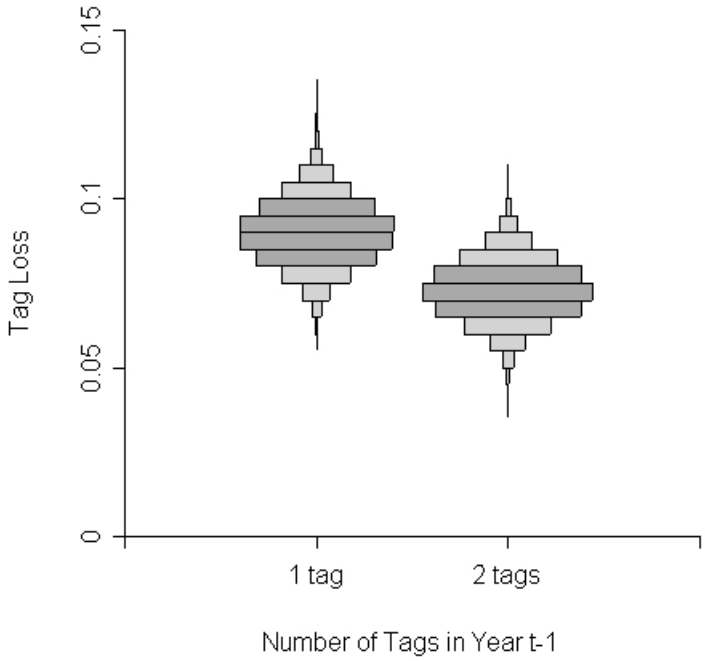


# Results (strict defn.)

- Tag loss



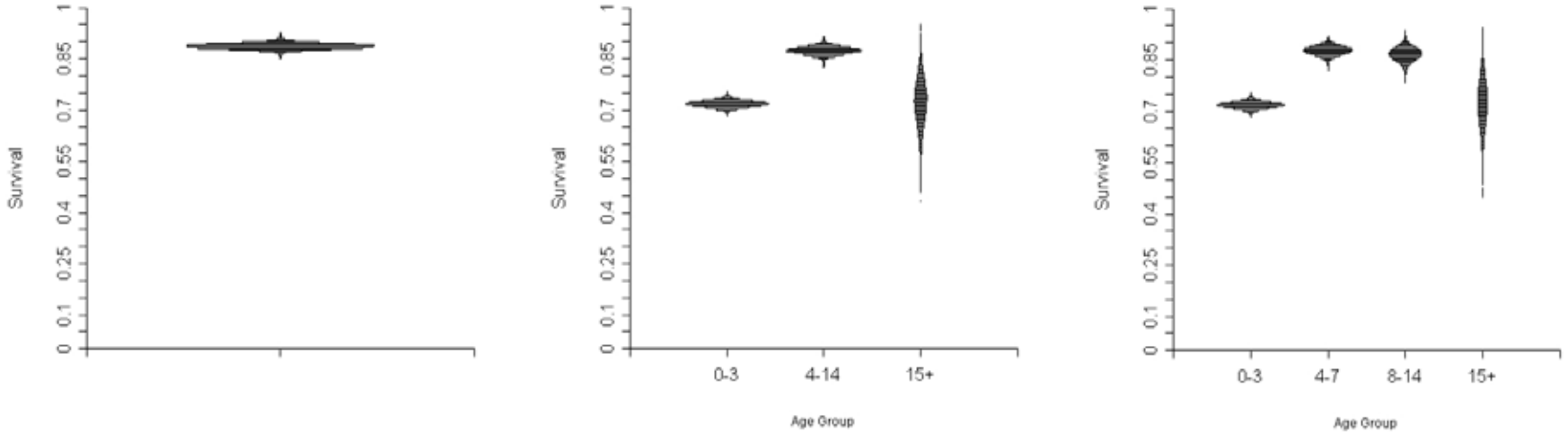
# Results (liberal defn.)

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

| | Age Classes in Model | | |
|---|---|---|---|
| | Single | 3 | 4 |
| Mean | 260086.5 | 259192.2 | 259196.7 |
| 2.5%ile | 259784.9 | 258895.1 | 258898.4 |
| 97.5%ile | 260375.2 | 259485.1 | 259491.5 |
| min | 259444.5 | 258602.1 | 258563.4 |
| max | 260681.8 | 259771.8 | 259840.5 |
| p-value | 0.4274 | 0.2230 | 0.2322 |

# Results (liberal defn.)

- Non-breeder in *t*-1 survival



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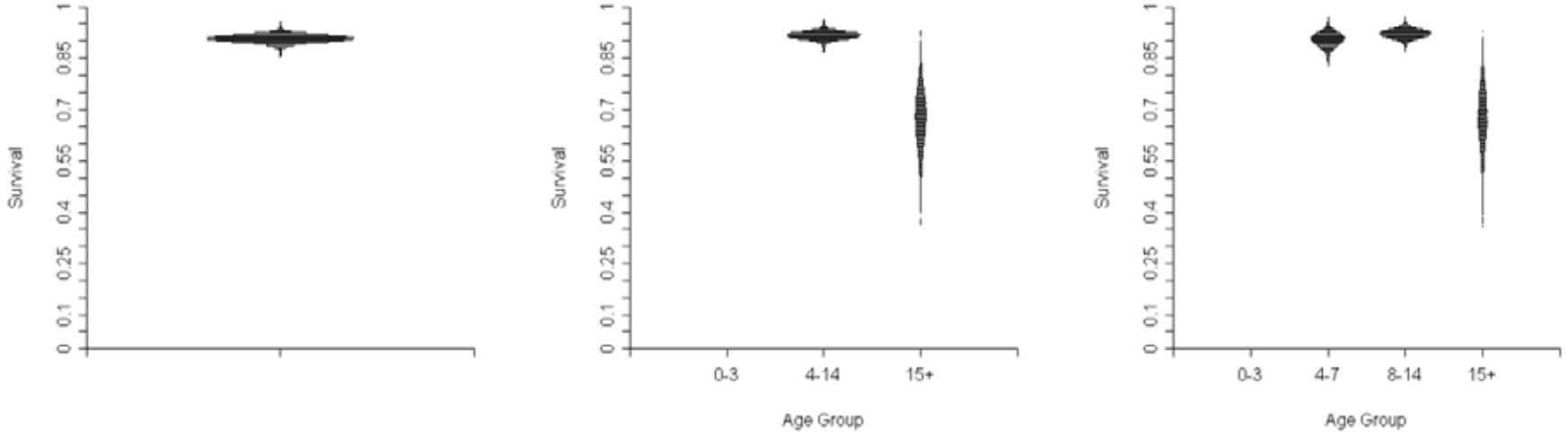
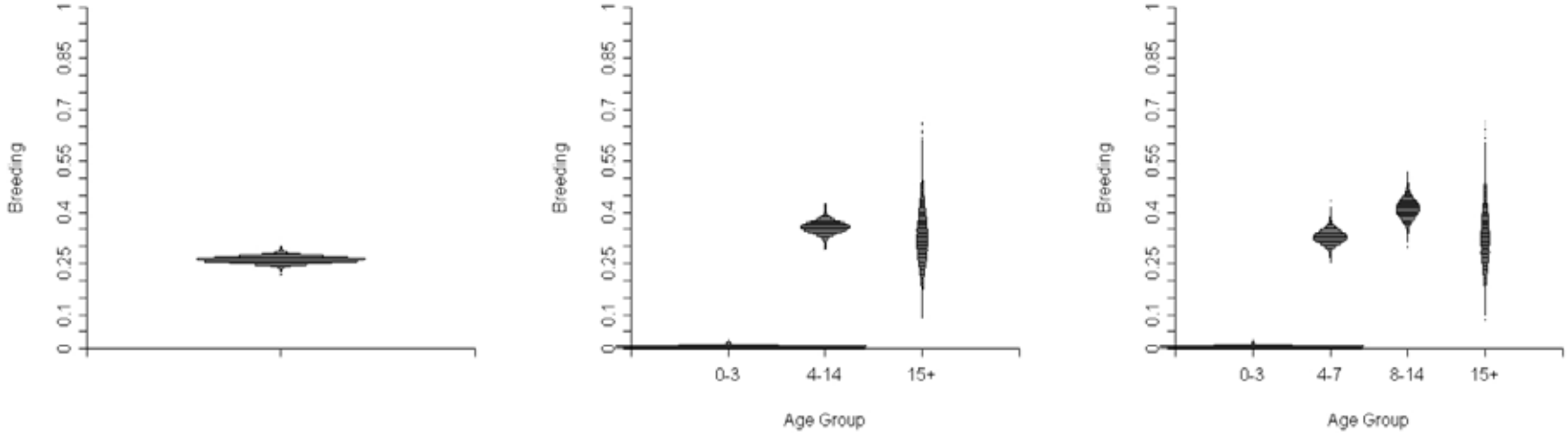


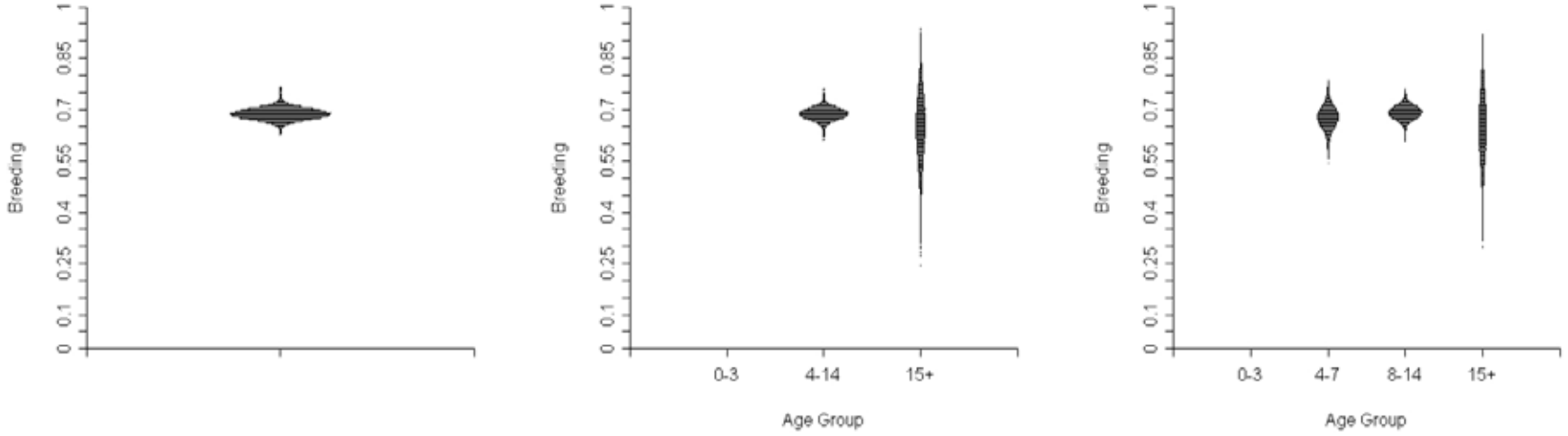
# Results (liberal defn.)

- Non-breeder in *t*-1 reproduction



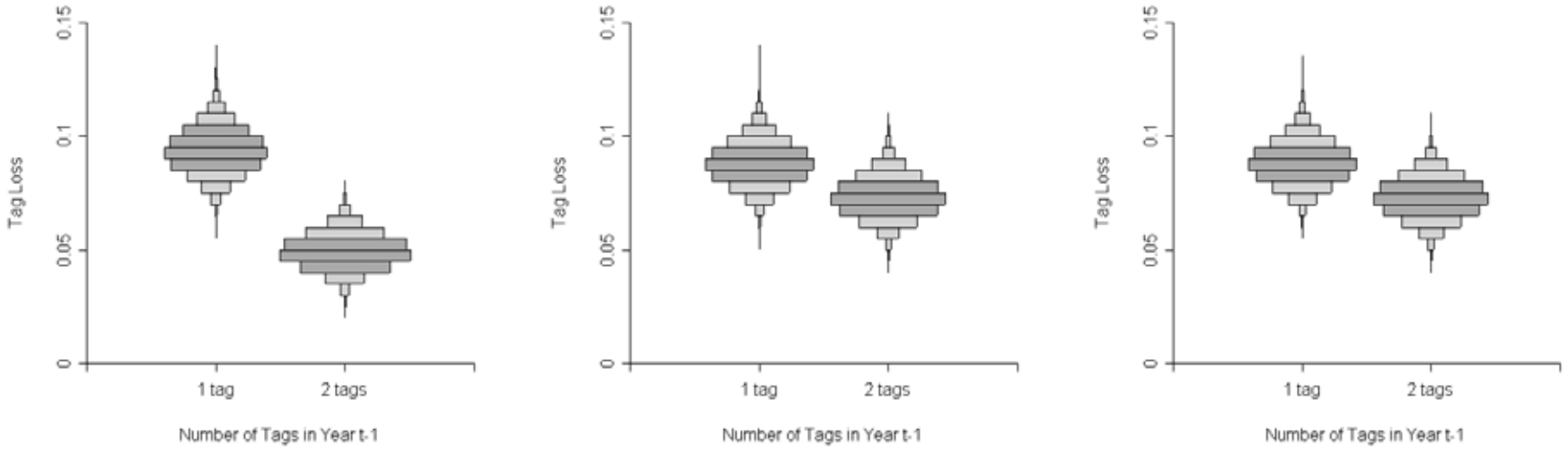
# Results (liberal defn.)

- Breeder in *t*-1 reproduction



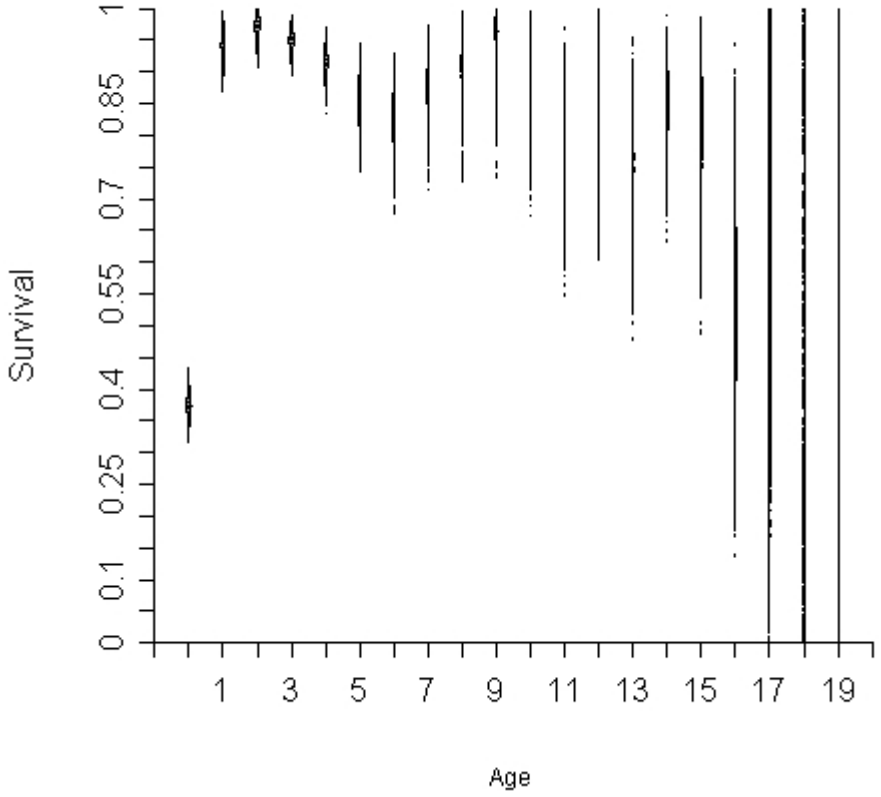
# Results (liberal defn.)

- Tag-loss



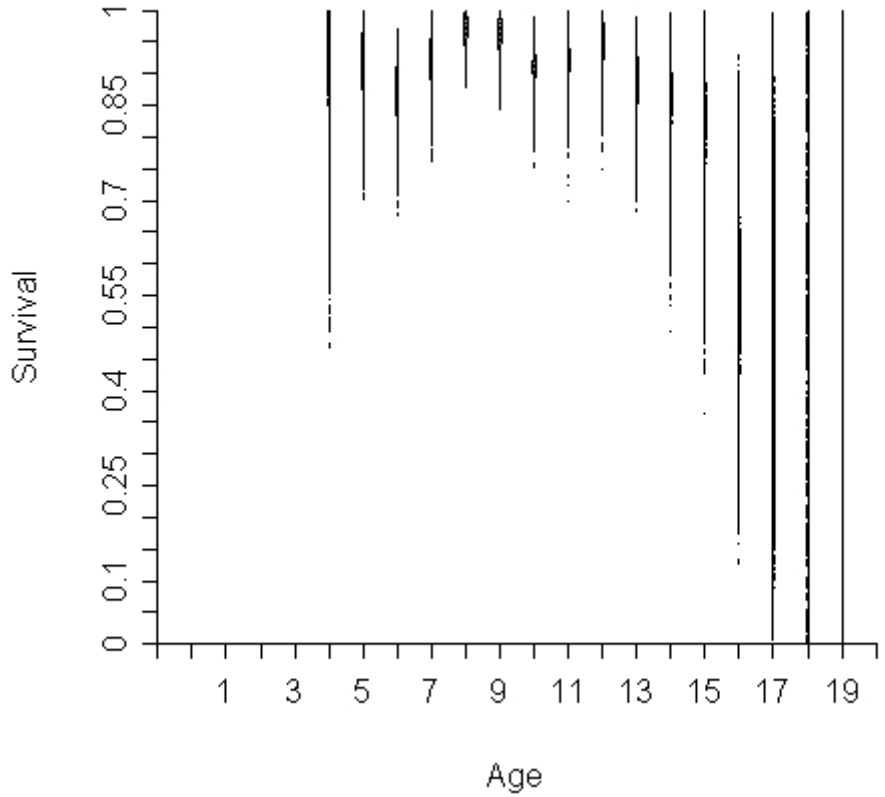
# Results

- Fully age-specific model
- Non breeders in *t*-1 survival



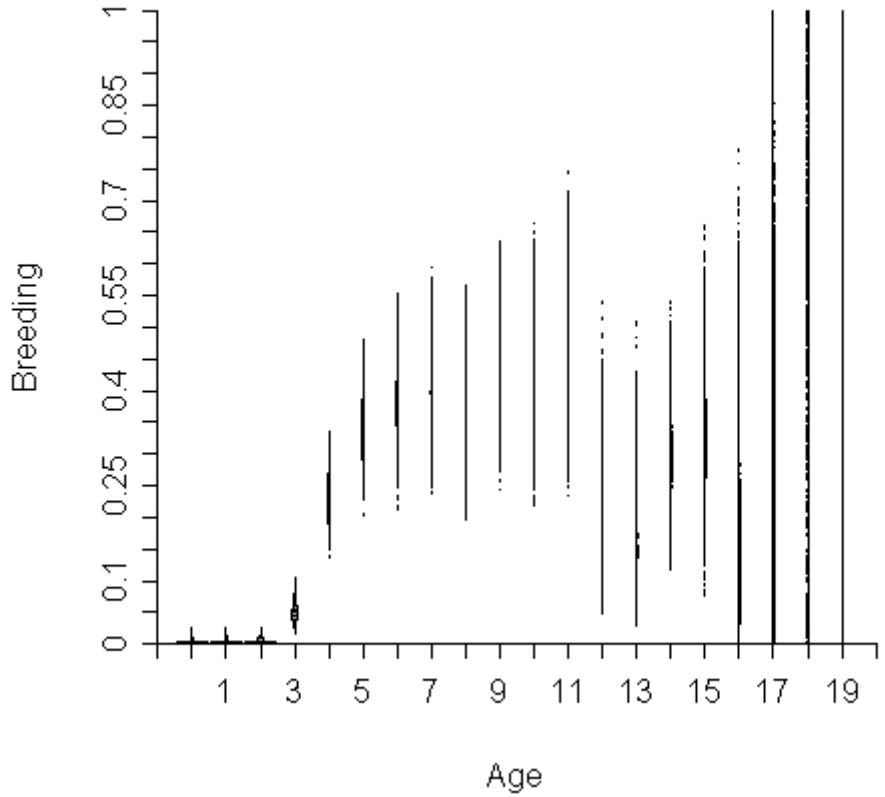
# Results

- Breeders in *t*-1 survival



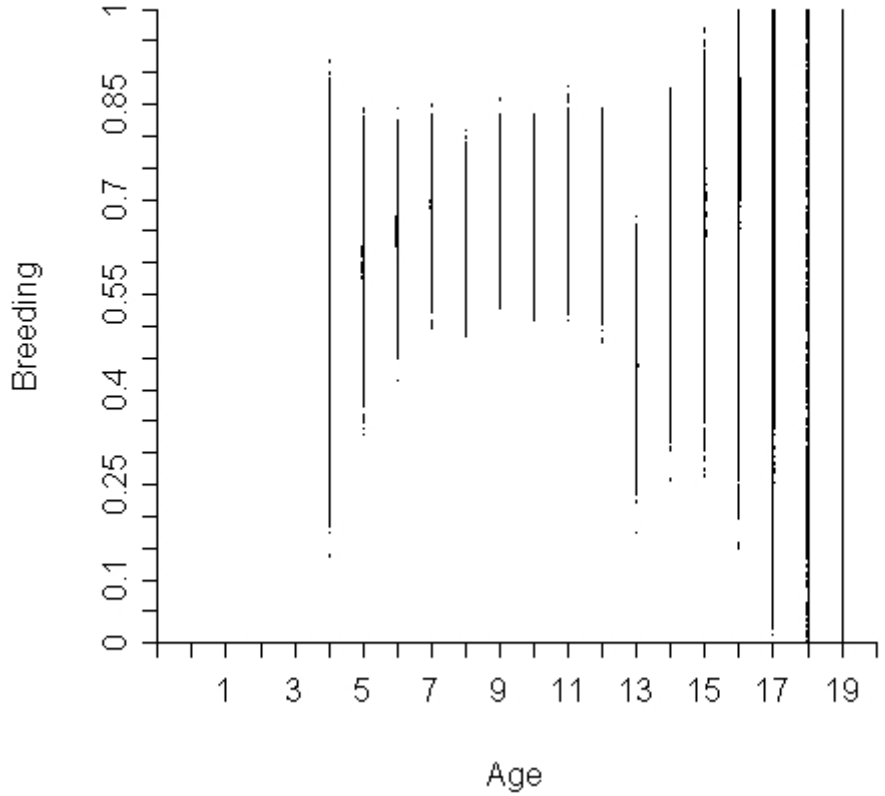
# Results

- Non-breeders in *t*-1 reproduction



# Results

- Breeders in *t*-1 reproduction



# Discussion Points

- 3- or 4-age class models seem reasonable
  - No evidence of poor model fit
  - Capture main features of fully age-specific model
- Liberal definition of “breeder” has little effect on survival, increases breeding probability by 0.02-0.07
- Difficult to determine which might be more correct

# 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