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

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Survival and Reproduction

Estimation methods

The tag-resight data was analysed using mark-recapture methods implemented in the software WinBUGS. This allows the simultaneous estimation of survival and breeding rates with the ability to easily account for tag-loss.

Whether an animal survives between breeding seasons *t* and *t*+1 could be considered as a Bernoulli random variable (i.e., a coin flip) where the probability of survival is S, which may vary by age or breeding status of the animal in year *t* (eqn 1). Similarly, whether an animal breeds in year *t* could also be regarded as a Bernoulli random variable, with probability of breeding equal to B, which may also vary by age or breeding status in the previous year (eqn 2). The number of flipper tags remaining on an animal in year *t*, given the number of tags in the previous year could be represented as a multinomial random variable with only 1 trial (i.e., the outcome from a single roll of a dice), The probability of the number of tags in year t is now a vector, **T** because of the multiple potential outcomes (eqn 3).

$$Survive\ to\ year\ t+1 \mid alive,\ age\ and\ breeding\ status\ in\ year\ t \sim Bernoulli\left(S_{age,bred}\right) \quad (1)$$

$$Breeds\ in\ year\ t \mid alive\ in\ year\ t,\ age\ and\ breeding\ status\ in\ t-1 \sim Bernoulli\left(B_{age,bred}\right) \quad (2)$$

$$Tags\ in\ year\ t \mid alive\ in\ year\ t,\ number\ of\ tags\ in\ t-1 \sim multinomial\left(\mathbf{T}_{tags},1\right) \quad (3)$$

For survival and breeding probabilities 3 relationships with animal age were considered:

1. constant for all ages
2. age groups: 0-3, 4-14, 15+
3. quadratic relationship with age on logit-scale (eqn 4).

$$\mathrm{logit}\left(\theta_{age,bred}\right) = \beta_{0,bred} + \beta_{1,bred} \times age + \beta_{2,bred} \times age^2 \quad (4)$$

Within a breeding season, attempts are made to resight previously tagged individuals. There are a limited number of days of field effort each year, and on any given day individuals may or may not be observed. Therefore, the number of times an individual is seen during a breeding season could be considered as a binomial random variable with a daily sighting probability of p. The sighting probability depends upon whether the animal is currently alive, breeding status, number of flipper tags, presence of a brand and PIT tag. It is assumed that:

1. Animals that have no flipper tags can not be resighted unless they are chipped or branded.
2. Whether an unbranded animal is chipped or not has no effect on the resight probability if the animal has 1 or more flipper tags.
3. Branded animals have the same resight probability regardless of number of flipper tags.
4. There is a consistent odds ratio (δ) between resighting animals with 1 and 2 flipper tags (eqn 5).
5. Resight probabilities are different for breeding and non-breeding animals.
6. Resight probabilities vary annually.

$$\frac{p2_{t,bred}}{1-p2_{t,bred}} = \frac{p1_{t,bred}}{1-p1_{t,bred}} \times \delta \qquad (5)$$

With the exception of the resight probability for animals with 2 tags ($p2$), all other probabilities are estimated independently.

Analyses were conducted with and without accounting for tag loss to illustrate its effect on resulting estimates of demographic parameters. Two definitions of 'breeding' (see below) are used to compare how that may influence results.

Markov chain Monte Carlo methods were used to obtain approximate posterior distributions for all parameters. Two chains of 25,000 iterations were run with the first 5,000 iterations of each chain being discarded as the burn-in period. Chains were checked for convergence and good mixing. Uniform prior distributions were assumed for all probabilities except tag loss when an animal had 2 tags in the previous year, in which case a Dirichlet(1,1,1) prior distribution was used. The natural log of the odds ratio δ was assigned a normal prior distribution with zero mean and SD = 10. A normal prior distribution with zero mean and SD

= 4.47 was assumed for the logistic regression coefficients when survival and age were assumed to have a logistic-quadratic relationship.

Data used

Data was extracted from the Auckland Island sea lion database by Laura Boren (DOC contractor) with additional verification by Darryl MacKenzie (Proteus), for females tagged between 1990 – 2008. As estimation is primarily focused on adult females, only data from the 1990-2003 tagging cohorts were used. Due to the inconsistent field effort prior to 1998, data from 1990-1997 was not considered and all analyses are conditional upon the first encounter of a female in the period 1998-2008. Only encounters inside of the primary field season on Enderby Island were used.

Breeders were defined according to the status allocated to females in the sea lion database. In the primary analysis 'breeders' were defined by those animals given a status of '3' in that year (i.e., 3 = adult female confirmed to have pupped (seen nursing, or giving birth) for that breeding season). A more liberal secondary definition was also used with 'breeders' being defined as those animals given a status of either '3' or '15' in that year (15 = Adult female probably pupped – female seen on three or more occasions including at least one sighting in the presence of a pup, but not seen giving birth, or nursing a pup).

When an animal was retagged during the period 1998-2008, the new tag number was treated as an older animal that had been tagged for the first time, while the old identity was treated as a 'loss on recapture'. This is a standard technique for dealing with retagged animals in mark-recapture analyses.

Results

Constant with respect to age model

Figure 1 presents the posterior distribution for survival for non-breeders and breeders from the models that account and do not for flipper tag loss, with a numerical summary given in Table 1. Survival probability is clearly higher for breeders and non-breeders, and not accounting for flipper tag loss reduces the estimated survival probability, more so for breeders.

Figure 2 presents the posterior distribution for breeding in year t for non-breeders and breeders in year $t-1$ from the models that account and do not for flipper tag loss, with a numerical summary given in Table 2. Individuals that were breeders in the previous year have a higher probability of breeding in the successive year. Accounting for tag loss has a minor effect on estimated breeding probability.

Figure 3 is an illustration of the posterior distribution for the probability of an individual having no tags in year t given either 1 or 2 tags in year $t-1$, with Table 3 presenting a summary of the probabilities for all tag numbers. These results suggest that flipper tags are not lost independently. Furthermore, if tag loss was not accounted for survival would be underestimated by approximately 0.08, although the presence of branded and PIT tagged animals partially mitigates this.

Tables 4 and 5 summarise the posterior distributions for survival and breeding probabilities from models that account for tag loss when a more liberal definition of 'breeder' is used. Survival is relatively unchanged while breeding probability is higher.

Model with 3 age groups

Figure 4 presents the posterior distribution for survival for non-breeders and breeders from the models that account and do not for flipper tag loss, with a numerical summary given in Table 6. Survival probability clearly varies by age group for both breeders and non-breeders. The posterior distribution for breeders in the 0-3 age group indicates that there is no data on such individuals so should be ignored. Survival probability in the older age group is similar for individuals that were breeders or non-breeders in the previous year. Not accounting for flipper tag loss reduces the estimated survival probability.

Figure 5 presents the posterior distribution for breeding in year t by age group for non-breeders and breeders in year $t-1$ from the models that account and do not for flipper tag loss, with a numerical summary given in Table 7. The posterior distribution for breeders in the 0-3 age group indicates that there is no data on such individuals so should be ignored, while for females aged 0-3 that were non-breeders in the previous year the probability of breeding in the current year is essentially 0. Breeding probabilities for both older age groups are similar, but do vary given breeding status in the previous year with individuals that bred in the previous year having a higher probability of breeding in the current year. Not accounting for tag loss reduces the estimated breeding probability for females aged 4-14 that did not breed in the previous year.

Figure 6 illustrates the posterior distribution for the probability of an individual having no tags in year t given either 1 or 2 tags in year $t-1$, with Table 8 presenting a summary of the probabilities for all tag numbers. These results suggest that flipper tags are not lost independently. Furthermore, if tag loss was not accounted for survival would be underestimated by approximately 0.09, although the presence of branded and PIT tagged animals partially mitigates this.

Tables 9 and 10 summarise the posterior distributions for survival and breeding probabilities from models that account for tag loss when a more liberal definition of 'breeder' is used. Survival is relatively unchanged while breeding probability is higher.

Model with logistic-quadratic relationship with age

Figure 7 presents the posterior distribution for survival by age for non-breeders and breeders from the models that account and do not for flipper tag loss. A summary of the posterior distribution for the logistic regression coefficients are given in Table 11. Survival probability clearly varies by age group for both breeders and non-breeders, although distributions have a large degree of uncertainty for young and old breeders, likely due to scarcity of data. Not accounting for flipper tag loss reduces the estimated survival probabilities.

Figure 8 presents the posterior distribution for breeding in year t by age for non-breeders and breeders in year $t-1$ from the models that account and do not for flipper tag loss. A summary of the posterior distribution for the logistic regression coefficients are given in Table 12. For females that were non-breeders in the previous year, the probability of breeding in the current year is zero for young and old individuals, peaking at approximately 0.55 for 9-year olds. The precision of estimates for females that were breeders in the previous year is again poor for young and old animals, but the posterior distributions centred around 0.7. Not accounting for tag loss reduces the estimated breeding probability for females that did not breed in the previous year.

Figure 9 illustrates the posterior distribution for the probability of an individual having no tags in year t given either 1 or 2 tags in year $t-1$, with Table 13 presenting a summary of the probabilities for all tag numbers. These results suggest that loss of flipper tags are not independent. Furthermore, if tag loss was not accounted for survival would be underestimated by approximately 0.07-0.13, although the presence of branded and PIT tagged animals partially mitigates this.

Tables 14 and 15 summarise the posterior distributions for the logistic regression coefficient for survival and breeding probabilities from models that account for tag loss when a more liberal definition of 'breeder' is used. Survival is relatively unchanged while breeding probability is higher.

All models

For all models the estimated sighting probabilities are extremely similar hence only the ones from the model with the 3 age groups are present here in Figures 10-13. Breeders are indicated with the red-based shading and non-breeders with the grey-based shading.

Discussion

Not accounting for tag loss clearly results in underestimates of demographic parameters, in particular survival probabilities. The result of this is that if the biased estimates are used in population models to approximate population growth rates, the growth rates will be underestimated (best guess: by approximately 0.02-0.04 without a more formal comparison). It is therefore important that any subsequent analysis explicitly accounts for tag loss. Furthermore, it does not appear that flipper tags are lost independently, therefore we should not assume that the probability of the number of tags on an animal changing from 2→1 is the same as the probability of changing from 1→0. It has only been possible to recognise this here by having some animals that can still be identified even if they have no flipper tags (branded animals and those with PIT tags). Were we unable to do this we would be forced to assume that tags are lost independently, which while not correct, would still be better than ignoring the issue entirely.

It has been assumed that PIT tags are not lost. This is unlikely to be true in practice, and by not addressing this issue survival probabilities are possibly still underestimated.

No formal comparison of the different models has been made here due to the difficulties to do so using this particularly implementation of these models using Markov chain Monte Carlo methods. However, clearly the simple model that assumed all females had the same breeding and survival probabilities regardless of age is overly simplistic, while the model that assumed a logistic-quadratic relationship with age had some undesirable properties with poor precision for young and older individuals that were breeders in the previous year. A simpler model was also fitted where a logistic-quadratic relationship was assumed for non-breeders, but a logistic-linear relationship was assumed for breeders. While this improved precision to some degree, the precision was still relatively poor for older animals. This is likely a consequence of small sample sizes and point estimates that tend to middling values (absolute levels of uncertainty reduce as posterior distributions tend to 0 or 1). The model with 3 age groups seems to be a useful compromise as no restrictive parametric relationships are imposed, but with sufficient flexibility to capture the main features of any relationship between the demographic parameters and sea lion age.

Population Size

It was originally suggested that the Gales-Fletcher method be revisited for estimating population size, but using values for demographic parameters that have been estimated directly from New Zealand sea lion data. This now seems to be an unproductive way forward given some of the key assumptions used by the Gales-Fletcher method, in particular the assumption of a stable age distribution. As indicated in MacKenzie (2008), using the Gales-Fletcher method essentially results in multiplying the annual pup counts by a constant amount each year (approximately 4.73). Any alteration to the demographic parameter values used within this method, will simply result in a modification of the scaling factor and not necessarily yield more reliable annual estimates.

More traditional mark-recapture methods can not be used either from the existing data given that tagging is primarily of pups. However, from the tag-resight data it is possible to estimate the number of animals alive in each year from each tagging cohort ($\hat{n}_{cohort,t}$; e.g., Figure 14), achieved simply within the estimation described above. Dividing this number by the fraction of the pups produced in that year that were included in that tagged cohort (r_{cohort}), would therefore provide an estimate of the number of individuals that were born in that cohort year that are still currently alive (eqn 6). An estimate of the number of individuals alive in year *t* from all years in which pup tagging occurred is achieved by eqn 7 (e.g., Figure 15). Note that if only a specific portion of the population was of interest (e.g., females aged 4+), that could be easily accounted for by only summing over those specific cohorts of interest in eqn 7.

$$\hat{N}_{cohort,t} = \frac{\hat{n}_{cohort,t}}{r_{cohort}} \qquad (6)$$

$$\hat{N}_t = \sum_{cohort} \hat{N}_{cohort,t} \qquad (7)$$

An obvious disadvantage of this approach is that $\hat{N}_t$ is only applicable to the portion of the overall population that have been born in years that tagging occurred. As such, assuming annual tagging of pups, it may not be a good indicator of total population size until the earliest tagged cohort represents some of the oldest animals in the population (e.g., approximately 15+ years).

Figures

Figure 1: Illustration of posterior distribution for probability of survival from year *t* to *t*+1 for individuals that were non-breeders and breeders in year *t*, from models and account and do not account for flipper tag loss.

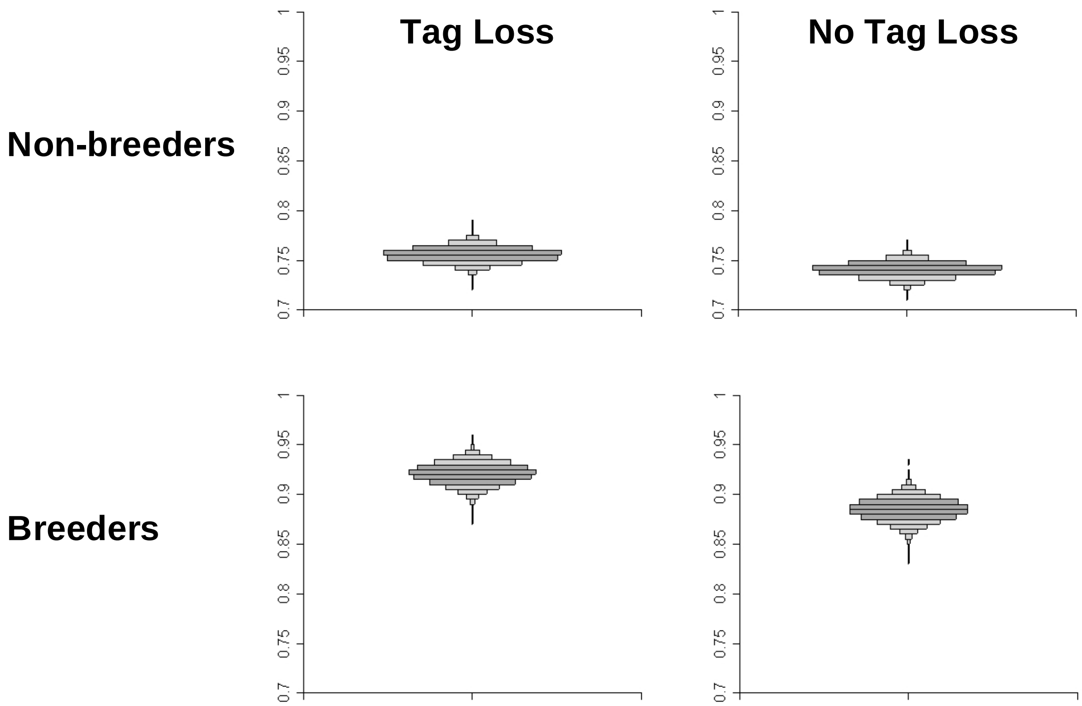


Figure 2: Illustration of posterior distribution for probability of breeding in year t for individuals that were non-breeders and breeders in year $t-1$, from models and account and do not account for flipper tag loss.

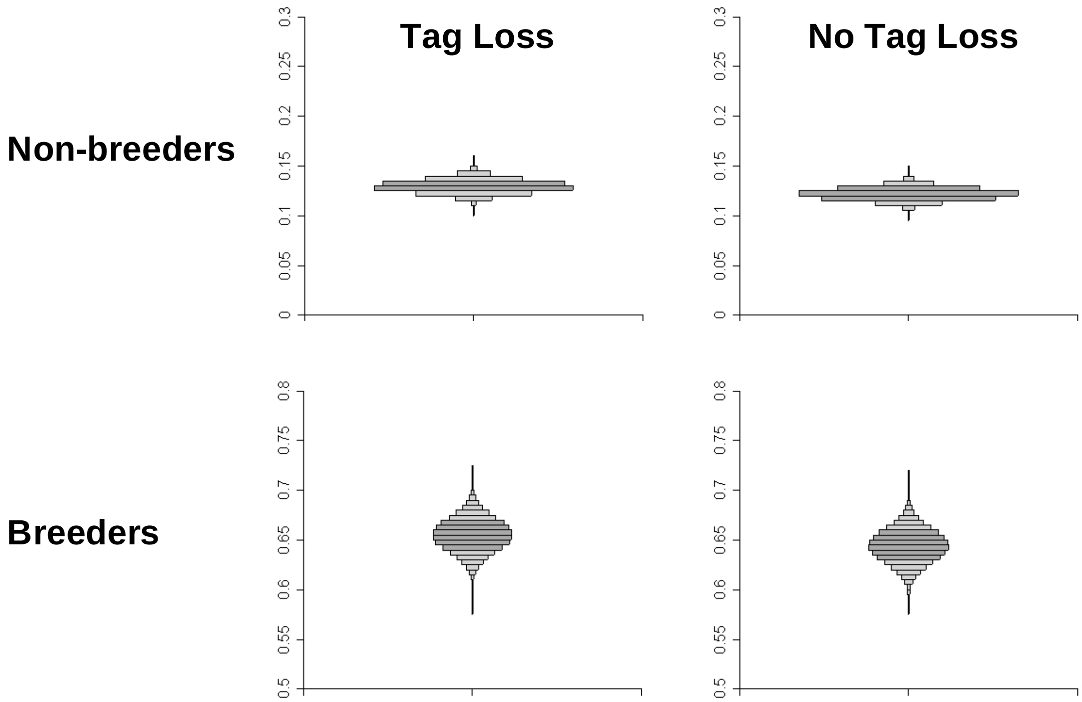


Figure 3: Posterior distribution for the probability of having no tags in year t given the number of tags in year $t-1$, from the model where survival and breeding probabilities are constant with respect to age.

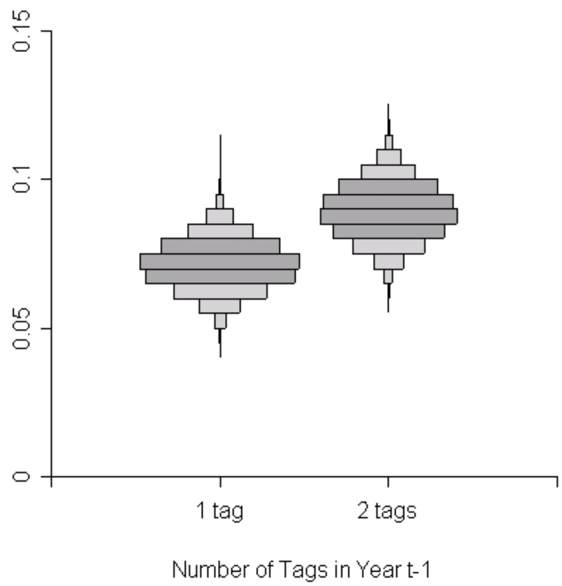


Figure 4: Illustration of posterior distribution for probability of survival from year *t* to *t*+1 by age group for individuals that were non-breeders and breeders in year *t*, from models and account and do not account for flipper tag loss.

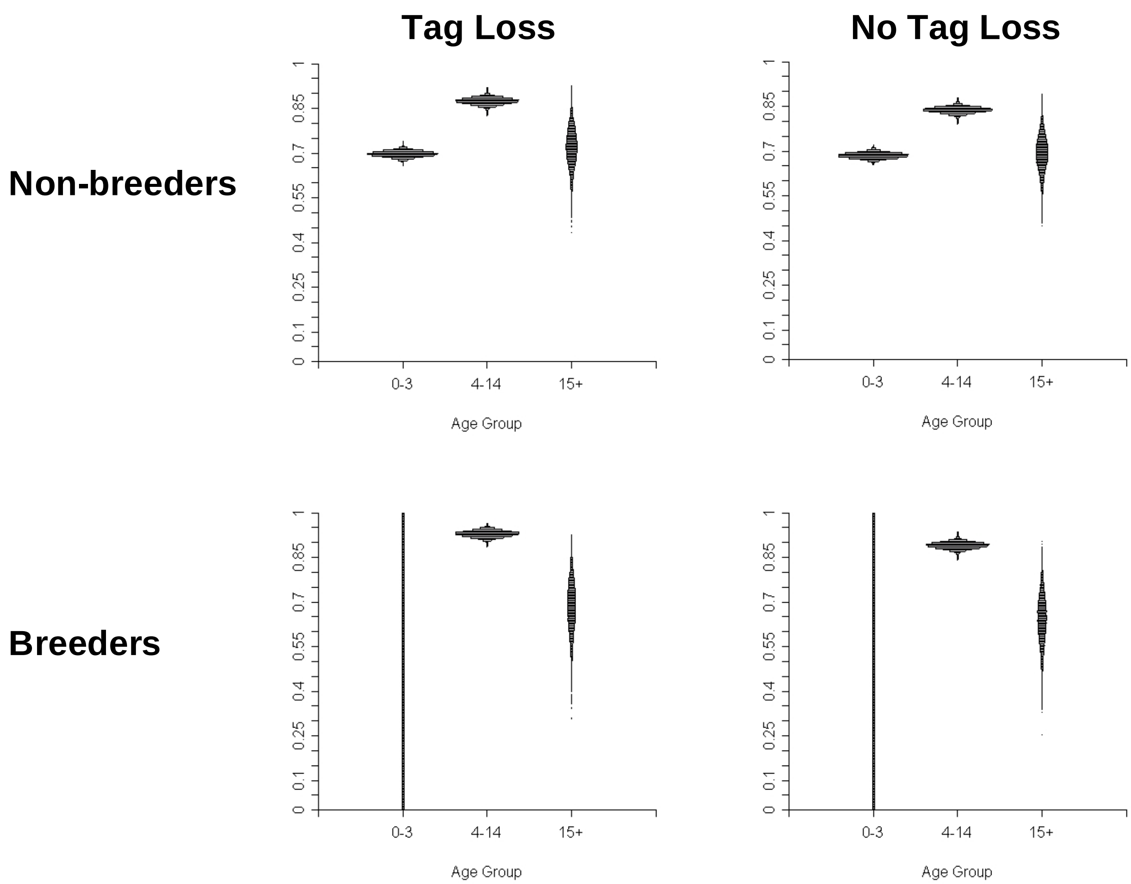


Figure 5: Illustration of posterior distribution for probability of breeding in year t by age group for individuals that were non-breeders and breeders in year $t-1$, from models and account and do not account for flipper tag loss.

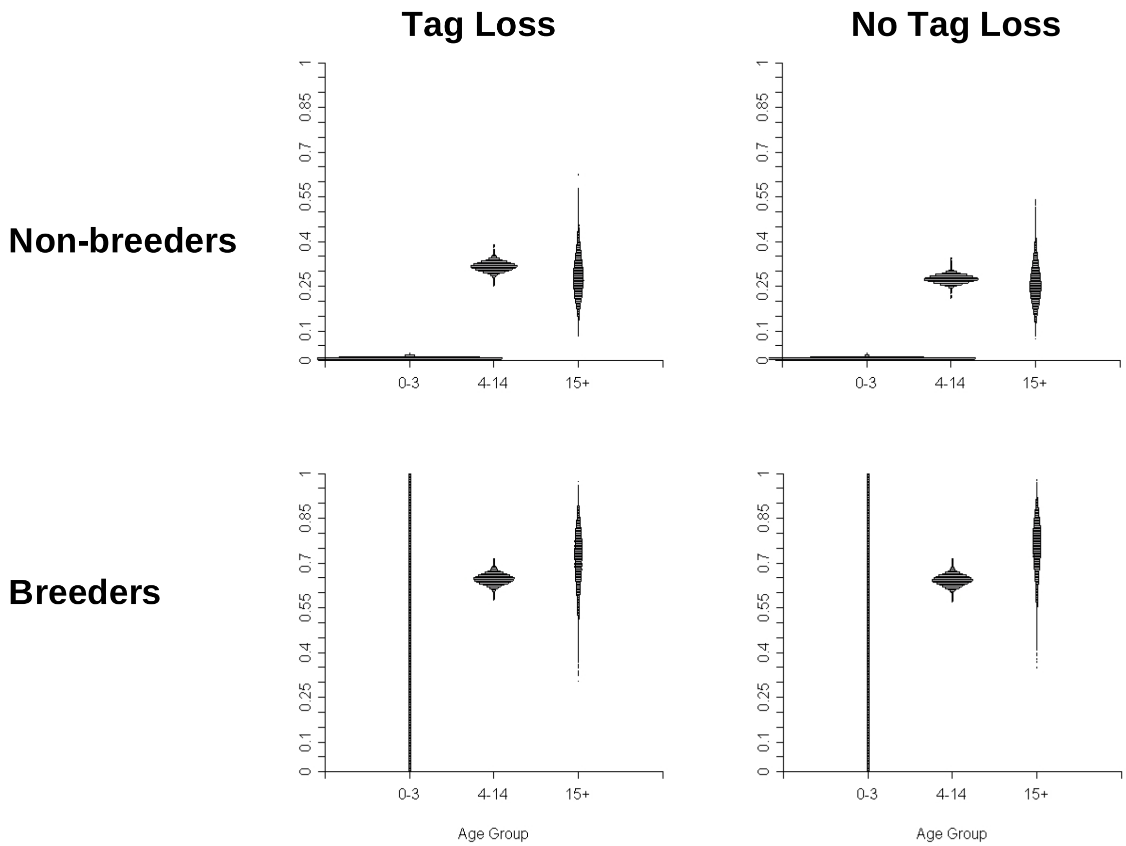


Figure 6: Posterior distribution for the probability of having no tags in year t given the number of tags in year $t-1$, from the model with 3 age groups for survival and breeding probabilities.

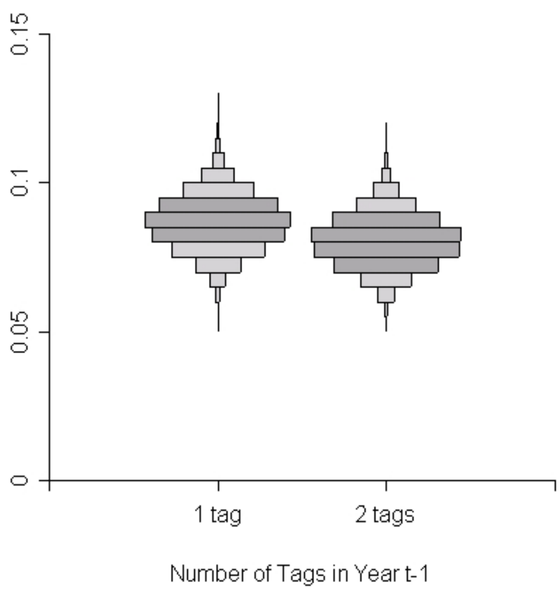


Figure 7: Illustration of posterior distribution for probability of survival from year t to t+1 by age for individuals that were non-breeders and breeders in year t, from models and account and do not account for flipper tag loss. Model assumes logistic-quadratic relationship with age.

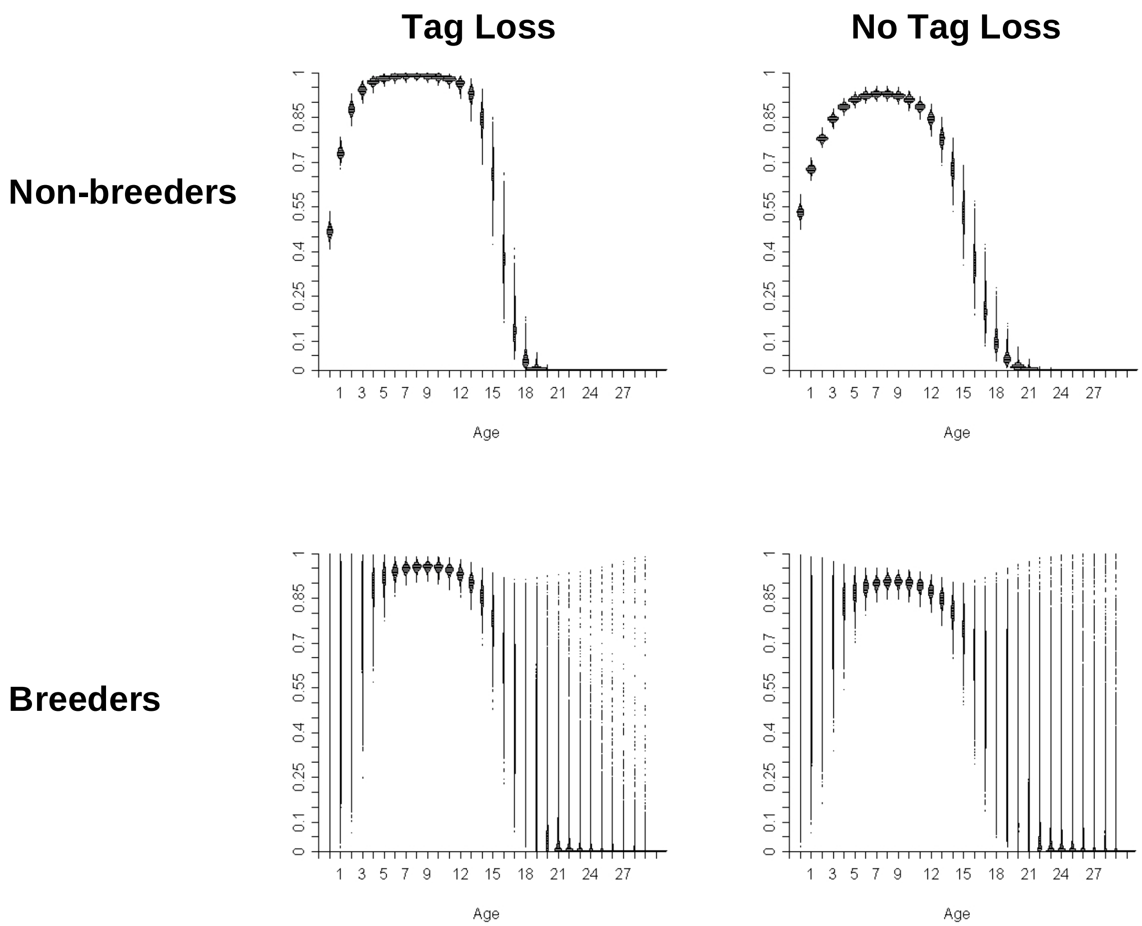


Figure 8: Illustration of posterior distribution for probability of breeding in year t by age for individuals that were non-breeders and breeders in year $t-1$, from models and account and do not account for flipper tag loss. Model assumes logistic-quadratic relationship with age.

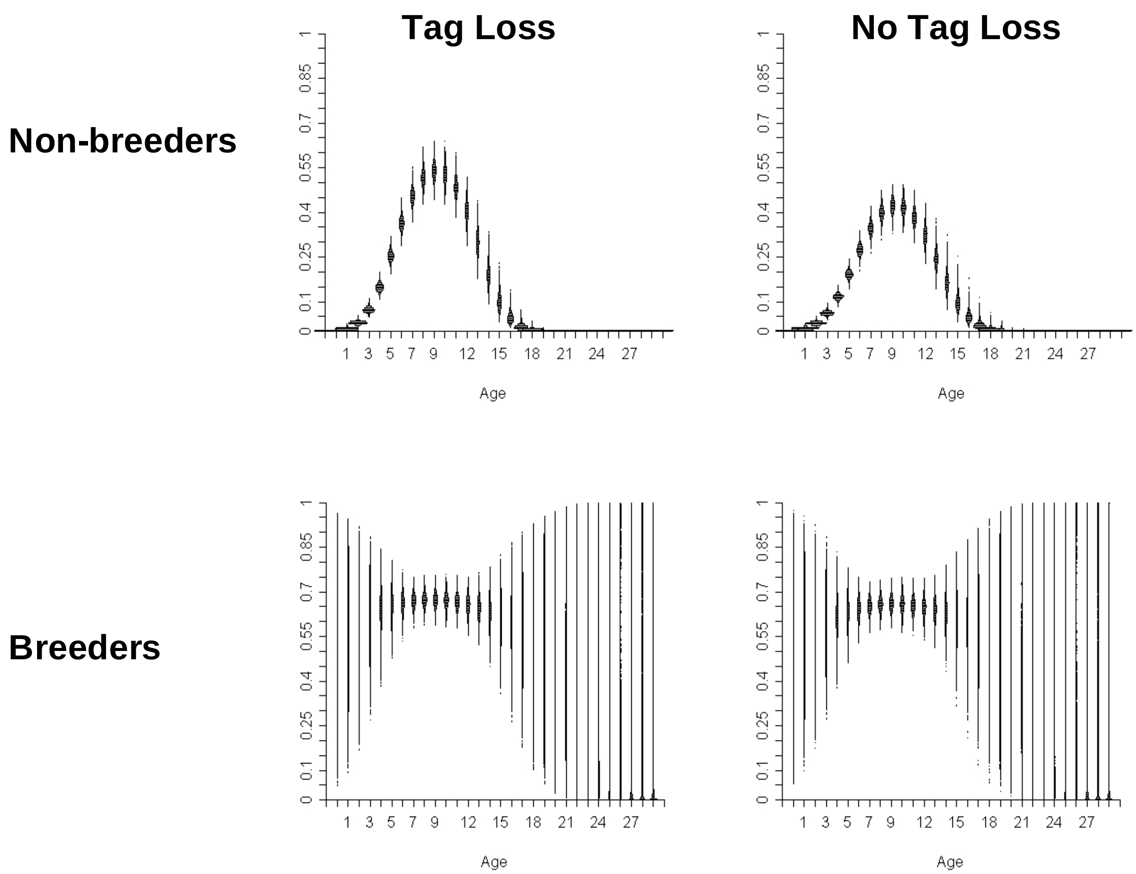


Figure 9: Posterior distribution for the probability of having no tags in year t given the number of tags in year $t-1$, from the model where survival and breeding probabilities have logistic-quadratic relationship with age.

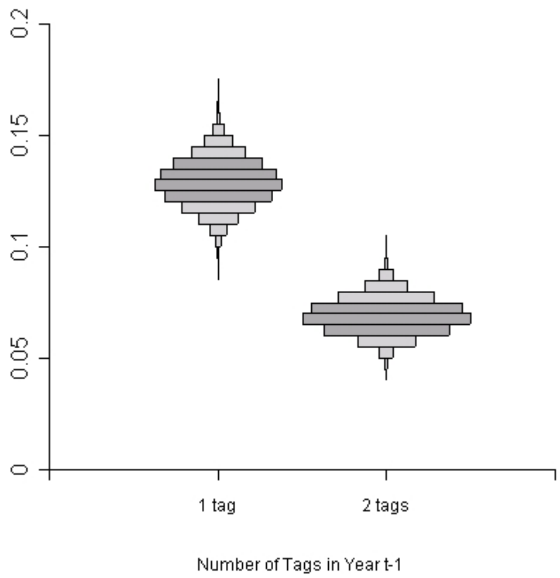


Figure 10: Posterior distribution for the daily probability of sighting a branded individual in each year.

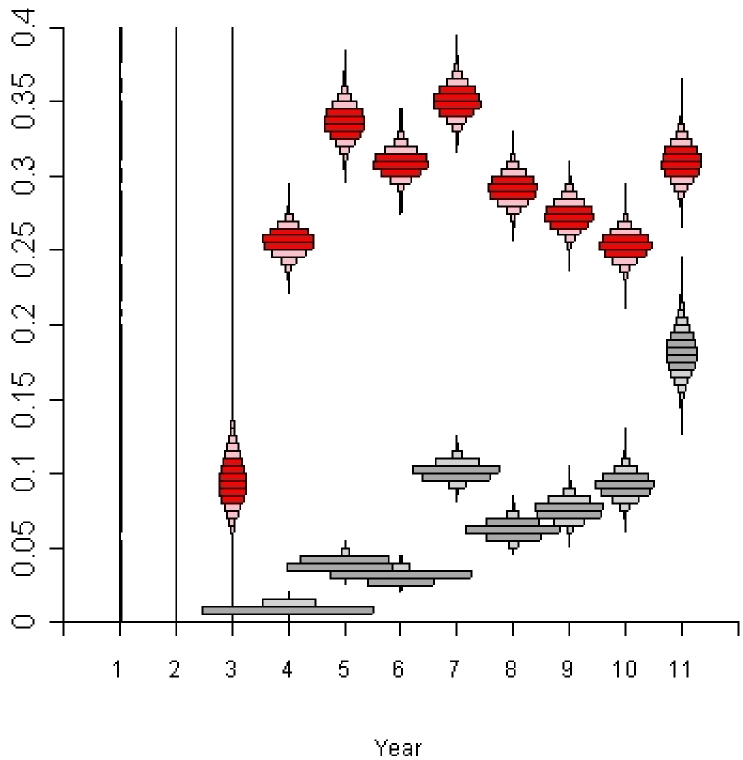


Figure 11: Posterior distribution for the daily probability of sighting a PIT tagged individual with no flipper tags in each year.

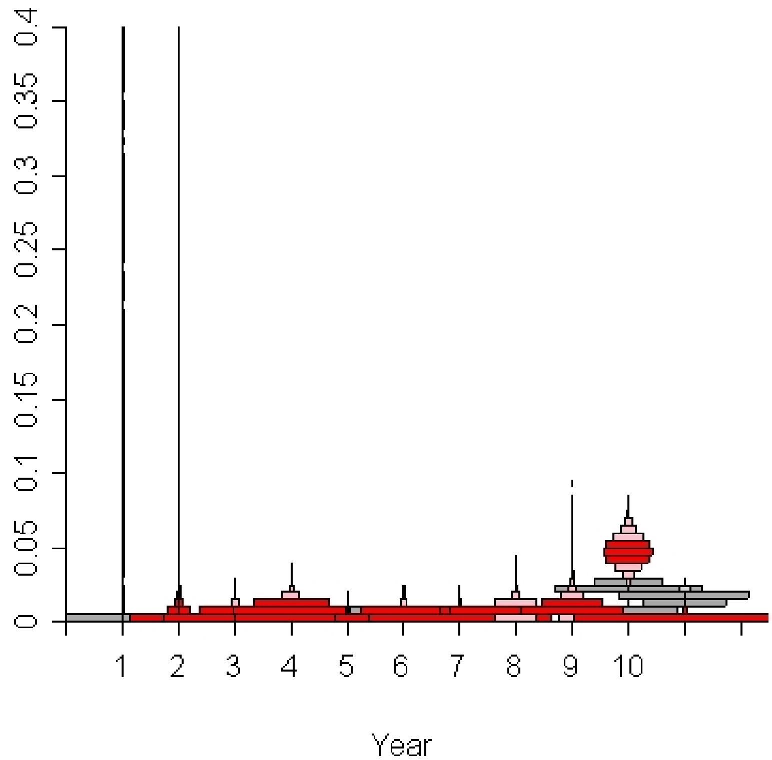


Figure 12: Posterior distribution for the daily probability of sighting an individual with 1 flipper tag in each year.

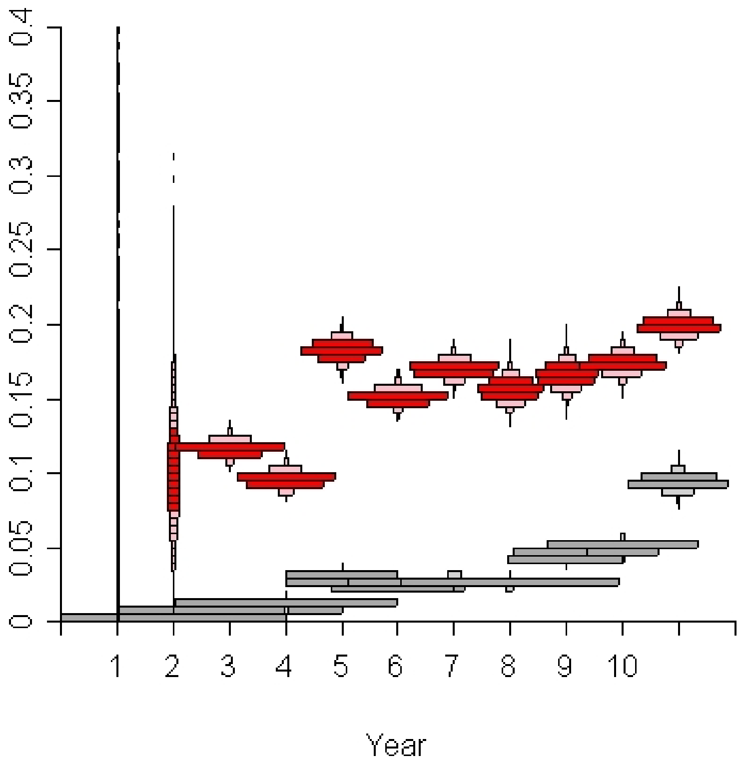


Figure 13: Posterior distribution for the daily probability of sighting an individual with 2 flipper tags in each year.

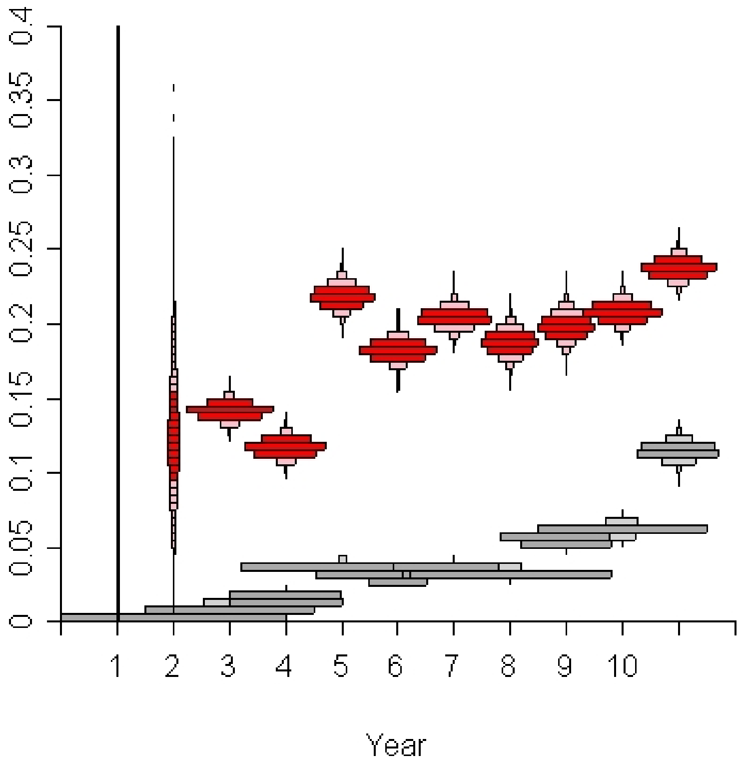


Figure 14: Number of female sea lions estimated to be alive that were first released in year 1 (1998) on Enderby Island.

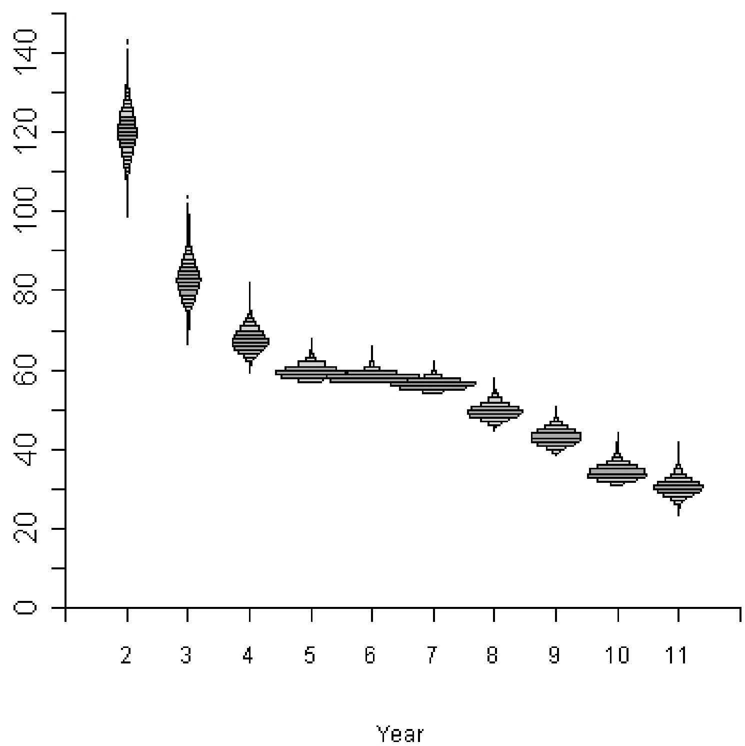
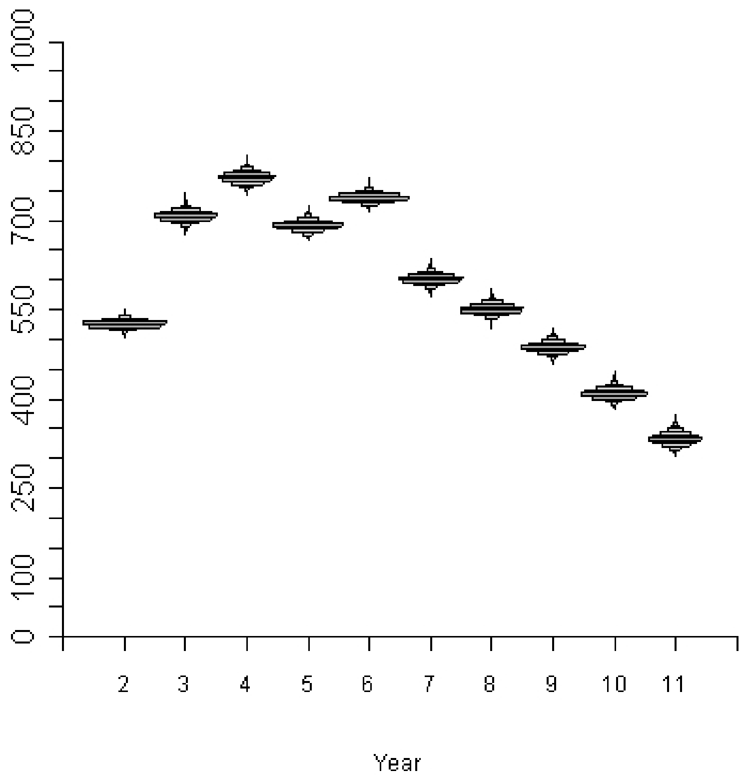


Figure 15: Number of female sea lions estimated to be alive that where first released between years 1 and 6 (1998-2003) from Enderby Island.



Tables

Table 1: Summary of posterior distributions for the probability of survival from year t to t+1 for individuals that were non-breeders and breeders in year t, from models that account and do not account for flipper tag loss.

		Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	0.756	0.007	0.742	0.756	0.770
	Breeders	0.921	0.010	0.900	0.921	0.941
No Tag Loss	Non-breeders	0.741	0.007	0.727	0.741	0.754
	Breeders	0.885	0.011	0.862	0.885	0.906

Table 2: Summary of posterior distributions for the probability of breeding in year t for individuals that were non-breeders and breeders in year $t-1$, from models and account and do not account for flipper tag loss.

		Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	0.130	0.006	0.117	0.130	0.143
	Breeders	0.655	0.017	0.622	0.655	0.687
No Tag Loss	Non-breeders	0.122	0.006	0.111	0.122	0.134
	Breeders	0.644	0.017	0.611	0.644	0.677

Table 3: Summary of posterior distribution for the number of tags in in year t given the number of tags in year $t-1$, from the model where survival and breeding probabilities are constant with respect to age.

Tags in t-1	Tags in t	Mean	SD	2.5%ile	Median	97.5%ile
1	0	0.071	0.008	0.056	0.071	0.088
1	1	0.929	0.008	0.912	0.929	0.944
2	0	0.089	0.009	0.072	0.089	0.108
2	1	0.161	0.009	0.145	0.161	0.180
2	2	0.749	0.011	0.727	0.749	0.771

Table 4: Summary of posterior distributions for the probability of survival from year t to t+1 for individuals that were non-breeders and breeders in year t, accounting for tag loss and data using the more liberal definition of 'breeders'.

	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	0.755	0.007	0.741	0.755	0.769
Breeders	0.912	0.010	0.891	0.912	0.932

Table 5: Summary of posterior distributions for the probability of breeding in year t for individuals that were non-breeders and breeders in year $t-1$, accounting for tag loss and data using the more liberal definition of 'breeders'.

	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	0.142	0.007	0.129	0.142	0.155
Breeders	0.682	0.015	0.652	0.682	0.713

Table 6: Summary of posterior distributions for the probability of survival from year *t* to *t*+1 by age group for individuals that were non-breeders and breeders in year *t*, from models and account and do not account for flipper tag loss.

		Age Group	Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	0-3	0.697	0.009	0.678	0.697	0.716
		4-14	0.874	0.010	0.854	0.875	0.894
		15+	0.719	0.062	0.591	0.720	0.835
	Breeders	0-3	-	-	-	-	-
		4-14	0.929	0.010	0.908	0.929	0.948
		15+	0.682	0.081	0.515	0.685	0.832
No Tag Loss	Non-breeders	0-3	0.686	0.009	0.668	0.686	0.703
		4-14	0.839	0.009	0.820	0.839	0.857
		15+	0.691	0.057	0.575	0.693	0.797
	Breeders	0-3	-	-	-	-	-
		4-14	0.890	0.011	0.868	0.891	0.911
		15+	0.640	0.079	0.479	0.643	0.787

Table 7: Summary of posterior distributions for the probability of breeding in year t by age group for individuals that were non-breeders and breeders in year $t-1$, from models and account and do not account for flipper tag loss.

		Age Group	Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	0-3	0.010	0.002	0.006	0.010	0.015
		4-14	0.316	0.015	0.289	0.316	0.346
		15+	0.285	0.069	0.162	0.281	0.431
	Breeders	0-3	-	-	-	-	-
		4-14	0.647	0.017	0.613	0.647	0.679
		15+	0.714	0.091	0.521	0.719	0.874
No Tag Loss	Non-breeders	0-3	0.009	0.002	0.005	0.009	0.014
		4-14	0.274	0.012	0.251	0.274	0.300
		15+	0.259	0.063	0.146	0.256	0.392
	Breeders	0-3	-	-	-	-	-
		4-14	0.643	0.017	0.609	0.643	0.676
		15+	0.749	0.087	0.562	0.756	0.898

Table 8: Summary of posterior distribution for the number of tags in in year t given the number of tags in year $t-1$, from the model with 3 age groups for survival and breeding probabilities.

Tags in t-1	Tags in t	Mean	SD	2.5%ile	Median	97.5%ile
1	0	0.087	0.009	0.069	0.087	0.105
1	1	0.913	0.009	0.895	0.913	0.931
2	0	0.081	0.009	0.064	0.081	0.098
2	1	0.164	0.009	0.147	0.164	0.183
2	2	0.755	0.011	0.733	0.755	0.776

Table 9: Summary of posterior distributions for the probability of survival from year *t* to *t*+1 by age group for individuals that were non-breeders and breeders in year *t*, accounting for tag loss and data using the more liberal definition of 'breeders'.

	Age Group	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	0-3	0.700	0.009	0.682	0.700	0.719
	4-14	0.873	0.010	0.852	0.873	0.893
	15+	0.720	0.066	0.585	0.722	0.842
Breeders	0-3	-	-	-	-	-
	4-14	0.919	0.011	0.898	0.919	0.939
	15+	0.673	0.077	0.516	0.676	0.817

Table 10: Summary of posterior distributions for the probability of breeding in year *t* by age group for individuals that were non-breeders and breeders in year *t*−1, accounting for tag loss and data using the more liberal definition of 'breeders'.

	Age Group	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	0-3	0.010	0.002	0.006	0.009	0.015
	4-14	0.353	0.015	0.323	0.353	0.383
	15+	0.329	0.074	0.193	0.326	0.482
Breeders	0-3	-	-	-	-	-
	4-14	0.678	0.016	0.646	0.678	0.708
	15+	0.649	0.090	0.465	0.652	0.813

Table 11: Summary of posterior distributions for the logistic regression coefficients for model that assumes logistic-quadratic relationship between survival and age. Coefficients are different for individuals that were non-breeders and breeders in year *t*, from models that account and do not account for flipper tag loss.

		Term	Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	Intercept	4.533	0.344	3.920	4.516	5.290
		Age	0.130	0.019	0.095	0.130	0.169
		Age^2	-0.077	0.006	-0.090	-0.076	-0.065
	Breeders	Intercept	2.954	0.248	2.529	2.934	3.503
		Age	0.153	0.103	-0.057	0.156	0.347
		Age^2	-0.046	0.014	-0.073	-0.046	-0.019
No Tag Loss	Non-breeders	Intercept	2.566	0.093	2.387	2.565	2.752
		Age	0.044	0.010	0.024	0.044	0.064
		Age^2	-0.044	0.002	-0.048	-0.044	-0.039
	Breeders	Intercept	2.192	0.140	1.924	2.189	2.474
		Age	0.094	0.070	-0.047	0.095	0.229
		Age^2	-0.029	0.010	-0.049	-0.029	-0.009

Table 12: Summary of posterior distributions for the logistic regression coefficients for model that assumes logistic-quadratic relationship between breeding and age. Coefficients are different for individuals that were non-breeders and breeders in year $t-1$, from models that account and do not account for flipper tag loss.

		Term	Mean	SD	2.5%ile	Median	97.5%ile
Tag Loss	Non-breeders	Intercept	-0.183	0.089	-0.358	-0.183	-0.008
		Age	0.311	0.020	0.273	0.311	0.351
		Age^2	-0.071	0.005	-0.081	-0.071	-0.061
	Breeders	Intercept	0.705	0.097	0.516	0.704	0.899
		Age	0.020	0.053	-0.083	0.020	0.125
		Age^2	-0.006	0.009	-0.024	-0.006	0.011
No Tag Loss	Non-breeders	Intercept	-0.637	0.080	-0.793	-0.637	-0.482
		Age	0.281	0.019	0.245	0.281	0.319
		Age^2	-0.061	0.005	-0.070	-0.061	-0.052
	Breeders	Intercept	0.627	0.096	0.439	0.626	0.817
		Age	0.028	0.053	-0.078	0.028	0.133
		Age^2	-0.006	0.009	-0.024	-0.006	0.011

Table 13: Summary of posterior distribution for the number of tags in in year *t* given the number of tags in year $t-1$, from the model where survival and breeding probabilities have logistic-quadratic relationship with age.

Tags in *t*-1	Tags in *t*	Mean	SD	2.5%ile	Median	97.5%ile
1	0	0.129	0.011	0.109	0.129	0.150
1	1	0.871	0.011	0.850	0.871	0.891
2	0	0.069	0.008	0.055	0.069	0.085
2	1	0.166	0.009	0.148	0.166	0.185
2	2	0.764	0.011	0.743	0.765	0.785

Table 14: Summary of posterior distributions for the logistic regression coefficients for probability of survival from year *t* to *t*+1 by age for individuals that were non-breeders and breeders in year *t*, accounting for tag loss and data using the more liberal definition of 'breeders'. Model assumes logistic-quadratic relationship with age.

	Term	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	Intercept	3.825	0.229	3.406	3.814	4.305
	Age	0.105	0.016	0.075	0.105	0.136
	Age^2	-0.064	0.005	-0.073	-0.064	-0.055
Breeders	Intercept	2.658	0.189	2.306	2.651	3.049
	Age	0.133	0.088	-0.044	0.135	0.300
	Age^2	-0.040	0.012	-0.063	-0.040	-0.016

Table 15: Summary of posterior distributions for the logistic regression coefficients for the probability of breeding in year *t* by age for individuals that were non-breeders and breeders in year *t*−1, accounting for tag loss and data using the more liberal definition of 'breeders'. Model assumes logistic-quadratic relationship with age.

	Term	Mean	SD	2.5%ile	Median	97.5%ile
Non-breeders	Intercept	-0.055	0.100	-0.249	-0.057	0.144
	Age	0.340	0.021	0.299	0.339	0.381
	Age^2	-0.072	0.005	-0.082	-0.072	-0.062
Breeders	Intercept	0.767	0.094	0.582	0.767	0.956
	Age	0.066	0.052	-0.036	0.066	0.168
	Age^2	-0.014	0.008	-0.030	-0.014	0.003