Department of Conservation Final Report

Title of Report:	Assessment of mark-recapture sample size on survival estimates of female NZ sea lions at the Auckland Islands
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1 Executive summary

- A study was undertaken to assess the effect of flipper tagging sample size on the estimation of survival of female NZ sea lions at Sandy Bay
- The SeaBird demographic modelling software was used to determine variability in the estimates of survival and pupping rate using the recapture observations of bootstrap samples of individuals tagged as pups (*n* = 50, 100 and 150)
- Decreasing the tagged sample size from 150 to 100 individuals led to a small reduction in the precision of survival estimates (i.e. an increase in CV of 0.03, 0.01 and 0.01 for survival to age 2, age 2-5 and age 6-14, respectively)
- A much larger reduction in the precision of survival estimates was obtained when decreasing the tagged sample size from 150 to 50 individuals (i.e. an increase in CV of 0.13, 0.03 and 0.04 for survival to age 2, age 2-5 and age 6-14, respectively)
- The increase in CV of estimates of probability of pupping were greater than those of survival estimates
- A second exploratory study was undertaken to assess the effects of variable resighting effort on annual resighting probability and survival at Dundas
- Tag resighting effort at Dundas has varied through time though has consistently been much lower than that at Sandy Bay, though the CVs of survival estimates for Dundas were similar to those obtained for the Sandy Bay population (CV = 0.18 and 0.08 for survival at age 0-2 and 6-14 respectively, compared with 0.16 and 0.05 for Sandy Bay).
- At Dundas, annual resighting probability estimates ranging from 0.35-0.63 were obtained in years with 2 days of resighting with a minimum of 50 individuals observed each day; and 0.54-0.71 for years with 3 days of resighting.
- We estimate that 3 days of intensive resighting effort at Dundas would lead to the resighting of more than half of the breeding-age population each year and an even greater proportion of those nursing a pup.

2 Contents

3 Introduction

A mark recapture program has been conducted on NZ sea lions at the Auckland Islands since the early 1980s, with continuous tagging effort at the largest rookeries at Sandy Bay and Dundas since the late 1990s. These mark-recapture observations have been used in demographic assessments aimed at identifying patterns in demographic rates (e.g. survival-at-age) that might explain observed variation in population size through time. Currently all pups born at the Sandy Bay are flipper tagged each year and resighting effort is relatively high (>30 days). At Dundas, a fraction of pups are flipper tagged and resighting effort is low (typically <10 days).

An assessment of the effects of sampling effort on the estimation of survival was conducted. There were two separate components to this analysis:

1. An assessment of the effects of reducing the number of pups tagged each year on model estimates of survival for females tagged as pups and resighted at Sandy Bay;
2. A brief assessment of the effects of extending the tag resighting period on survival estimates obtained for females tagged and resighted at Dundas, i.e. the magnitude of resighting effort required to get reasonable survival estimates.

4 Methods

NZ sea lion mark recapture data were extracted from the Dragonfly New Zealand sea lion demographics mark recapture database (Dragonfly, 2012).

4.1 Sandy Bay tag sample size assessment

For each of three different sample sizes (150, 100 and 50 females flipper-tagged as pups):

- A random sample with replacement (bootstrap sample) was taken of females flipper-tagged as pups at Sandy Bay along with their attributed annual resighting histories. The SeaBird demographic modelling software (model configuration as run 7a of Roberts *et al.*, 2013) was then used to generate point estimates for survival-at-age and pupping probability parameters. This step was repeated 200 times;

- The coefficient of variation (CV) was calculated for each parameter by year (Figure 1) as: the standard deviation of the 200 bootstrap point estimates divided by the mean of these bootstrap point estimates.
- The mean CV for each parameter across all years in the time series was calculated (Table 1).

4.2 Dundas tag resighting assessment

- SeaBird was used to generate MCMC estimates (*n* = 250) of annual resighting probability and survival at age from observations of NZ sea lions flipper-tagged (1990-1992 and 1998-2011) and resighted at Dundas (1999-2012). The basic model configuration was similar to that of model run 7a (Roberts et al., 2013), with some differences:
    - There were no separate partitions for different breeding statuses (pupping rate not estimated)
    - Resighting effort at ages 6 and 7 was year-invariant
- Model estimates of annual resighting probability were then related to actual resighting effort in each year
- Variability in model estimates of survival was compared with that of estimates for the Sandy Bay population (model run 7a, Roberts et al., 2013)

5 Results

5.1 Sandy Bay tag sample size assessment

The CVs associated with the parameter estimate for each year in the time series are listed in Table A.1. For each estimated parameter, the bootstrapped mean of the point estimate for each year in the time series did not vary appreciably with tagged sample size (Table A.2).

For all survival and pupping rate parameter estimates the CV increased as the tagging sample size was reduced (Figure 1). Decreasing the tagged sample size from 150 to 100 individuals led to a small increase in CV of survival estimates at age (0.03, 0.01 and 0.01 for survival to age 2, age 2-5 and age 6-14, respectively). A much larger increase in CV of survival estimates was obtained when decreasing the tagged sample size from 150 to 50 individuals (0.13, 0.03 and 0.04 for survival to age 2, age 2-5 and age 6-14, respectively). The increase in CV of probability of pupping with decreasing tagged sample size was greater than for survival estimates (Table 1).

Table 1: Mean coefficient of variation of demographic rate estimates for decreasing tag bootstrap sample sizes (150, 100 and 50 females tagged as pups); reported as mean calculated across all years in the time series.

Demographic rate	Mean CV		
	n = 150	*n* = 100	*n* = 50
Survival cohort to age 2	0.18	0.21	0.31
Survival age 2-5	0.05	0.06	0.08
Survival age 6-14	0.06	0.07	0.10
Prob. non-puppers (yr-1) pupping	0.23	0.29	0.41
Prob. puppers (yr-1) pupping	0.10	0.12	0.17

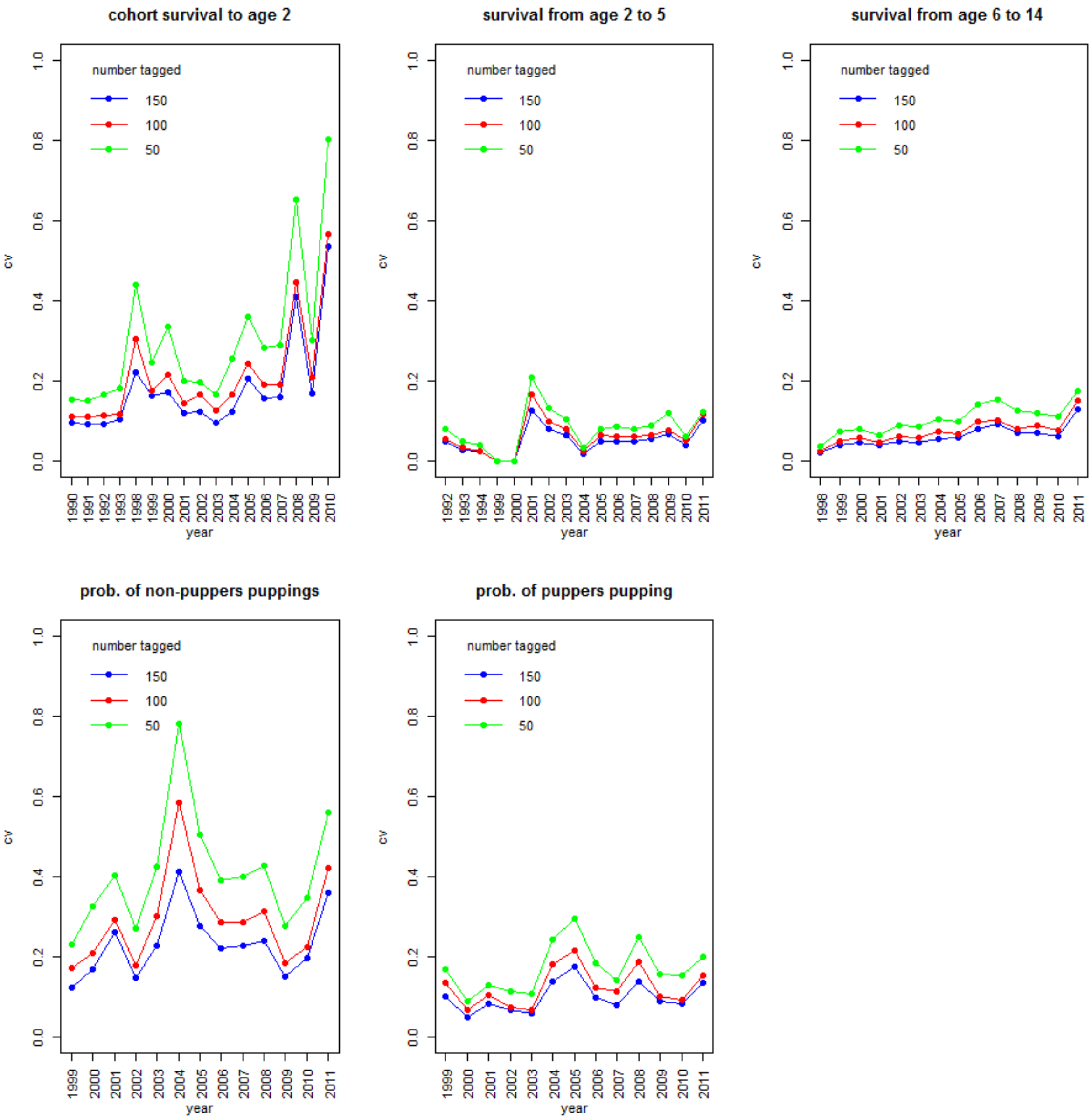

Figure 1: Plots of CV by year for survival-at-age estimates (top) and pupping probability estimates (bottom) for decreasing tag bootstrap sample sizes: 150 (blue), 100 (red) and 50 (green)

5.2 Dundas tag resighting assessment

A total of 123 days with resighting effort were recorded at Dundas from 1998 to 2012. Numbers of females resighted in a day ranged from 1 to 333, with fewer than 50 females observed in 80% of days with resighting effort (Figure 2). A subset of days with a minimum of 50 individuals resighted comprised 67% of the total resightings. Median estimates of annual resighting probability ranged from 0.11 to 0.71 for age 8+ individuals with a mean annual CV of 0.17 (Figure 3).

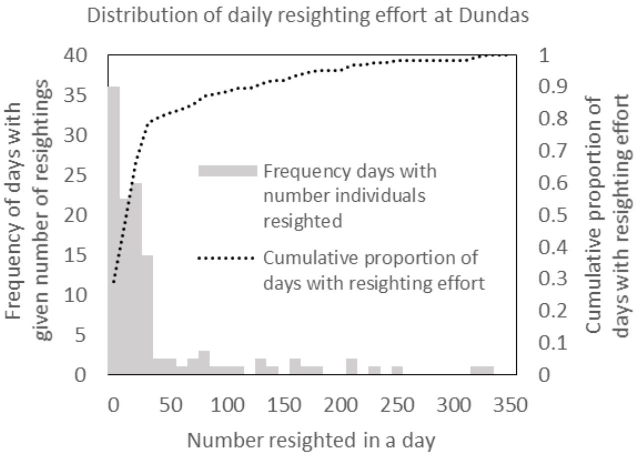

Figure 2: Distribution of tag resighting effort at Dundas 1998-2012

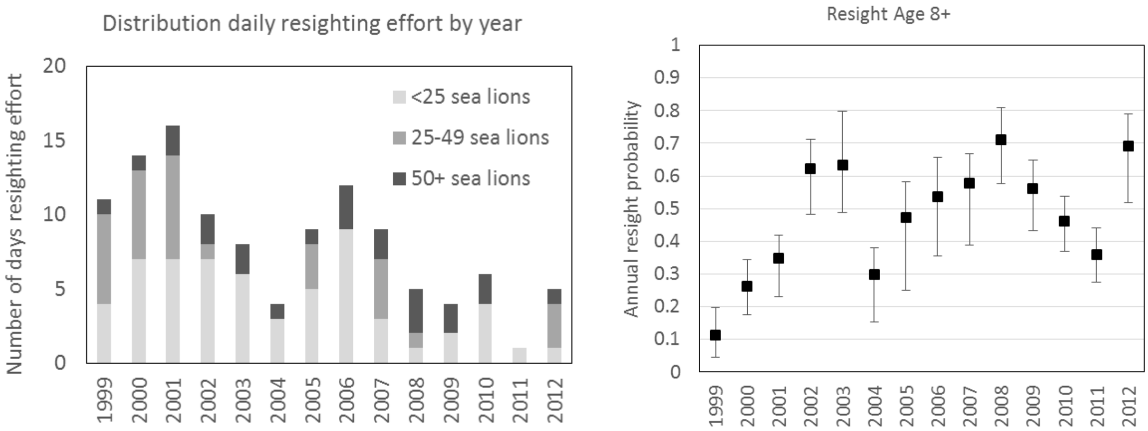

Figure 3: Distribution of daily resighting effort by year (1999-2012) and numbers observed each day (left); and MCMC estimates of resighting probability of females tagged as pups and resighted at Dundas at age 8+ (right); bars are 95% confidence intervals.

A poor relationship was obtained between the annual number of individual resightings and annual estimate of resighting probability (Figure 4). A much better relationship was observed when comparing with the number of days with high resighting effort (at least 50 individuals seen) (Figure 4). Annual resighting probability estimates ranged from: 0.11-0.47 for years with 1 day of resighting with at least 50 individuals; 0.35-0.63 for years with 2 days of resighting effort; and 0.54-0.71 for years with 3 days of resighting effort. This compares with annual resighting probabilities typically >0.8 with a 3-week long resighting period at Sandy Bay (MacKenzie, 2012).

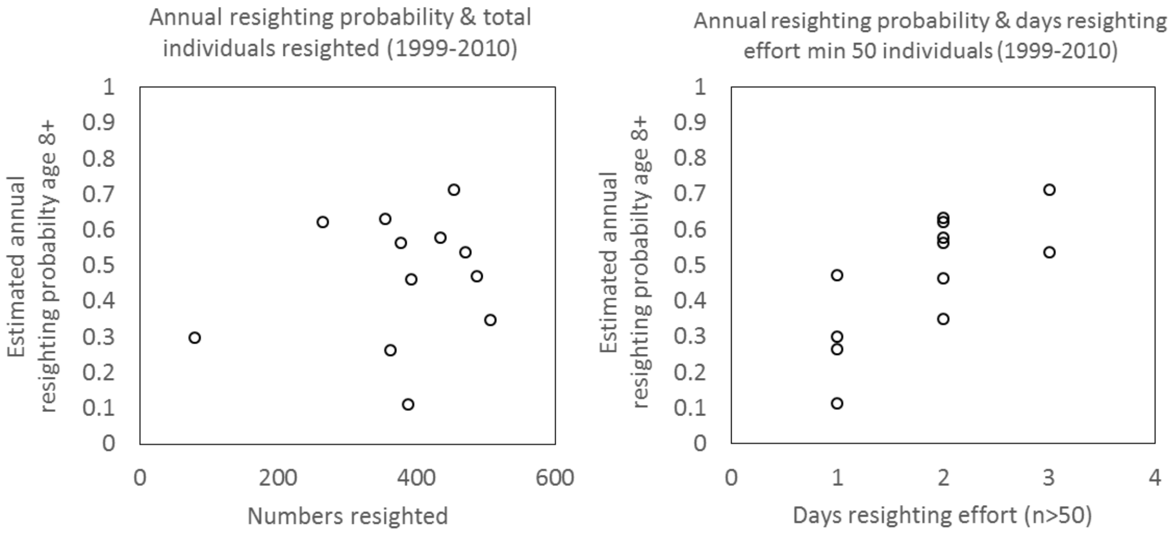

Figure 4: Magnitude of resighting effort at Dundas and annual estimate of resighting probability.

Variability in model estimates of survival for Dundas (Figure 5) was not much greater than that of an analogous model using mark recapture observations from Sandy Bay (CV = 0.18 and 0.08 for survival at age 0-2 and 6-14 respectively, compared with 0.16 and 0.05 for the Sandy Bay population) (Roberts et al., 2013).

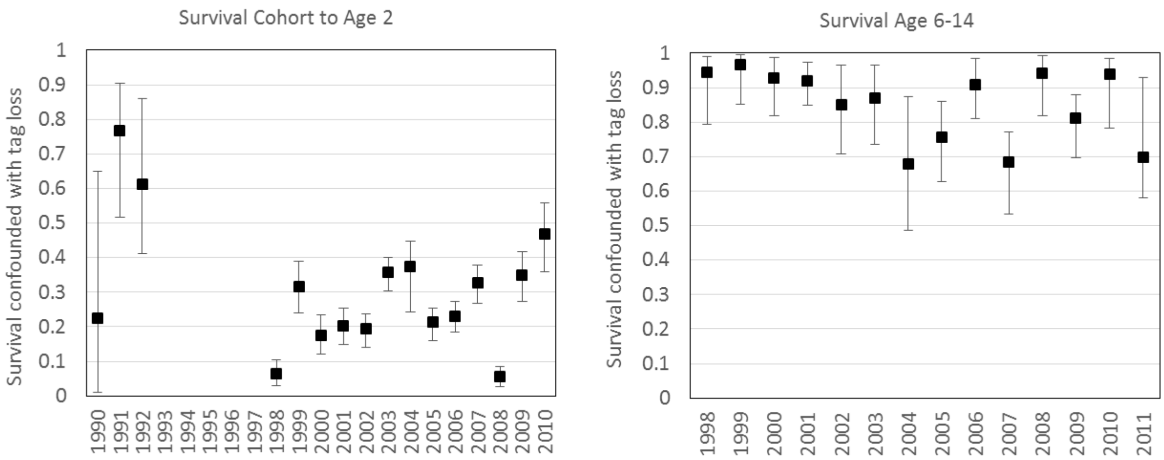

Figure 5: MCMC estimates of selected survival at age parameters for females tagged and resighted at Dundas; bars are 95% confidence intervals.

6 References

Dragonfly 2012. New Zealand sea lion demographics database version "NZSL sightings v20121218". Available from <http://data.dragonfly.co.nz/nzsl-demographics/>. [December 2012]

MacKenzie DI 2012. Review of female New Zealand sea lion tag-resight data collected on Enderby Island. Unpublished report held by the Department of Conservations, Wellington.

Roberts J, Fu D, Doonan I, Francis RICC, 2013. New Zealand sea lion – demographic assessment of the causes of decline at the Auckland Islands – Milestone 2 Report, Model options developed. POP2012-02.

7 Appendix A

Table A.1: CV by year for survival-at-age and pupping probability estimates with decreasing tagged sample sizes: 150, 100 and 50.

cohort survival to age 2

number tagged	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
150	0.0948	0.0913	0.0927	0.1058	0.2211	0.1621	0.1716	0.1196	0.1216	0.0961	0.1226	0.2065	0.1565	0.1614	0.4085	0.1695	0.5360
100	0.1121	0.1112	0.1125	0.1170	0.3033	0.1764	0.2159	0.1456	0.1670	0.1245	0.1672	0.2425	0.1897	0.1914	0.4458	0.2084	0.5666
50	0.1525	0.1510	0.1663	0.1801	0.4392	0.2473	0.3354	0.2004	0.1963	0.1667	0.2559	0.3605	0.2836	0.2893	0.6531	0.3029	0.8046

survival from age 2 to 5

number tagged	1990	1993	1994	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.0475	0.0274	0.0231	0.0005	0.0002	0.1264	0.0813	0.0635	0.0192	0.0504	0.0498	0.0497	0.0538	0.0668	0.0395	0.1011
100	0.0565	0.0330	0.0248	0.0007	0.0002	0.1654	0.0972	0.0796	0.0229	0.0645	0.0616	0.0615	0.0655	0.0777	0.0519	0.1159
50	0.0785	0.0495	0.0406	0.0009	0.0003	0.2101	0.1313	0.1058	0.0342	0.0809	0.0865	0.0810	0.0881	0.1203	0.0605	0.1218

survival from age 6 to 14

number tagged	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.0214	0.0410	0.0466	0.0408	0.0478	0.0469	0.0544	0.0580	0.0797	0.0911	0.0717	0.0695	0.0615	0.1282
100	0.0232	0.0487	0.0594	0.0449	0.0615	0.0595	0.0741	0.0686	0.0971	0.1027	0.0792	0.0902	0.0760	0.1494
50	0.0372	0.0741	0.0792	0.0640	0.0895	0.0857	0.1039	0.0979	0.1423	0.1532	0.1246	0.1207	0.1109	0.1752

probability of non-puppers pupping

number tagged	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.1229	0.1684	0.2603	0.1469	0.2264	0.4133	0.2760	0.2218	0.2279	0.2399	0.1519	0.1967	0.3594
100	0.1732	0.2097	0.2922	0.1772	0.3024	0.5854	0.3670	0.2869	0.2848	0.3141	0.1859	0.2237	0.4204
50	0.2295	0.3267	0.4033	0.2717	0.4241	0.7814	0.5053	0.3900	0.3989	0.4269	0.2770	0.3490	0.5615

probability of puppers pupping

number tagged	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.1005	0.0491	0.0833	0.0678	0.0588	0.1399	0.1760	0.0968	0.0802	0.1382	0.0902	0.0814	0.1359
100	0.1367	0.0686	0.1054	0.0728	0.0686	0.1801	0.2156	0.1222	0.1151	0.1867	0.1019	0.0927	0.1535
50	0.1704	0.0879	0.1288	0.1141	0.1062	0.2435	0.2953	0.1843	0.1412	0.2488	0.1566	0.1537	0.1988

Table A.2 Bootstrap point estimate means (rounded to two decimal places), by year for survival-at-age and pupping probability parameters for decreasing tagged sample sizes: 150, 100 and 50.

cohort survival to age 2

number tagged	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
150	0.55	0.61	0.55	0.42	0.13	0.44	0.25	0.46	0.37	0.56	0.42	0.19	0.29	0.28	0.05	0.28	0.21
100	0.55	0.61	0.55	0.43	0.13	0.43	0.25	0.46	0.37	0.56	0.42	0.19	0.29	0.28	0.05	0.28	0.19
50	0.54	0.61	0.55	0.43	0.14	0.43	0.26	0.44	0.38	0.56	0.42	0.19	0.29	0.29	0.05	0.27	0.18

survival from age 2 to 5

number tagged	1990	1993	1994	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.74	0.78	0.82	1.00	1.00	0.73	0.89	0.82	0.99	0.92	0.84	0.92	0.88	0.83	0.96	0.88
100	0.74	0.79	0.82	1.00	1.00	0.75	0.89	0.83	0.99	0.92	0.85	0.92	0.88	0.83	0.95	0.89
50	0.74	0.78	0.82	1.00	1.00	0.78	0.86	0.84	0.98	0.92	0.85	0.92	0.89	0.83	0.95	0.92

survival from age 6 to 14

number tagged	1990	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.90	0.92	0.81	0.90	0.81	0.86	0.82	0.89	0.77	0.69	0.82	0.77	0.86	0.90
100	0.90	0.92	0.80	0.89	0.81	0.85	0.82	0.90	0.77	0.70	0.82	0.78	0.87	0.89
50	0.90	0.91	0.81	0.89	0.80	0.86	0.81	0.89	0.79	0.68	0.85	0.79	0.86	0.88

probability of non-puppers pupping

number tagged	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.45	0.47	0.36	0.57	0.48	0.27	0.24	0.30	0.46	0.47	0.51	0.56	0.37
100	0.45	0.46	0.37	0.56	0.48	0.26	0.23	0.29	0.47	0.47	0.52	0.56	0.36
50	0.46	0.48	0.37	0.57	0.47	0.28	0.24	0.30	0.46	0.47	0.52	0.53	0.38

probability of puppers pupping

number tagged	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
150	0.62	0.83	0.68	0.83	0.83	0.45	0.41	0.79	0.74	0.45	0.76	0.71	0.66
100	0.63	0.83	0.67	0.83	0.84	0.45	0.41	0.80	0.75	0.44	0.76	0.72	0.66
50	0.62	0.83	0.67	0.82	0.82	0.45	0.42	0.80	0.75	0.44	0.76	0.71	0.68