POP2012-02

New Zealand sea lion – demographic assessment of the causes of decline at the Auckland Islands

7a model results

CSP Technical Working Group

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Optimal model configuration

- Annual **survival** estimates for age groupings 0, 1, 2-5, 6-14, 15+
  - Survival at Age 15+ is time-invariant
  - All others have separate estimate for years where data informative

- Annual **breeding probability** for Age 4+ individuals
  - Separate estimates for breeders and non-breeders
  - All time-varying (1998-2011)

- Annual **resighting probability** of age groupings 1-2, 3, 4I-5I, 6I, 7I, B, N
  - Separate estimates for breeders and non-breeders
  - All time varying 1999-2011
  - Decline in resighting probability estimated of breeders after mid-2000s suggests a problem as nearly all breeders should be resighted in every year since 1999. This can be fixed to 1 – all resighted.

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Fits to tagging observations - optimal model

Model run	Survival estimates Age	Survival Yr groups	Breeding Prob estimates Age	Breeding Prob Yr groups	Resighting prob estimates Age	Resighting prob Yr groups	Maturation	LL	params	AIC
7a	0, 1, 2-5, 6-14, 15+	15+ time invariant	4+ (P), 4+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant	Time varying	-7976.2	178	16,308
6b	0, 1, 2-5, 6-14, 15+	15+ time invariant	4+ (P), 4+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8023.6	152	16,351
6d	0, 1, 2-5, 6-14, 15+	15+ time invariant	functional form	a4 & b4 time invariant	1-2,3,4-5,6,7,N	1-2 time invariant		-8022.8	154	16,354
6a	0, 1, 2-5, 6-14, 15+	15+ time invariant	4+ (P), 4-14 (N), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8020.5	159	16,359
5j	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8017.1	166	16,366
4m	0, 1, 2-5, 6-14, 15+	0 & 15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7999.6	185	16,369
5m	0, 1, 2-5, 6-14, 15+	6+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8032.2	153	16,370
6c	0, 1, 2-5, 6-14, 15+	15+ time invariant	functional form	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8019.3	166	16,371
5l	0, 1, 2-5, 6-14, 15+	0 & 15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	1-2 time invariant		-8036.4	149	16,371
5d	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	Separate estimates all yrs		-8008.5	179	16,375
5b	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4-5,6,7,N	Separate estimates all yrs		-7999.3	192	16,383
5h	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	4-5 time invariant		-8023.8	169	16,386
4i	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7992.4	202	16,389
4k	0, 1, 2-5, 6-14, 15+	2-5 & 15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8008	187	16,390
5f	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	7 time invariant		-8025.2	170	16,390
5i	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	3 time invariant		-8027.5	168	16,391
3	0, 1, 2-5, 6-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7987.6	208	16,391
4j	0, 1, 2-5, 6-14, 15+	6+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8007.2	189	16,392
5g	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	6 time invariant		-8026.4	170	16,393
4h	0, 1, 2-5, 6+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8001.7	201	16,405
4e	0, 1, 2-4, 5-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7995.1	208	16,406
4d	0, 1, 2, 3-5, 6-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7981.1	222	16,406
5e	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	N time invariant		-8038.7	166	16,409
4g	0, 1, 2-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8010.7	194	16,409
5k	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1-2,3,4-5,6,7,N	0-7 time invariant		-8087.6	127	16,429
4c	0, 1, 2, 3, 4, 5, 6-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-7977	243	16,440
5a	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4-7,N	Separate estimates all yrs		-8053.7	175	16,457
4a	u1, u3, u4, max (u3) at age3	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8140	145	16,570
4b	u1, u3, u4, max (u3) at age2	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8141.1	144	16,570
5c	0, 1, 2-5, 6-14, 15+	15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4-6,7,N	Separate estimates all yrs		-8411.4	182	17,187
4f	0-1, 2-5, 6-14, 15+	Separate estimates all yrs	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8476.6	191	17,335
4l	0, 1, 2-5, 6-14, 15+	1 & 15+ time invariant	4-14 (P), 4-14 (N), 15+ (P), 15+ (N)	Separate estimates all yrs	1,2,3,4,5,6,7,N	Separate estimates all yrs		-8483.1	186	17,338

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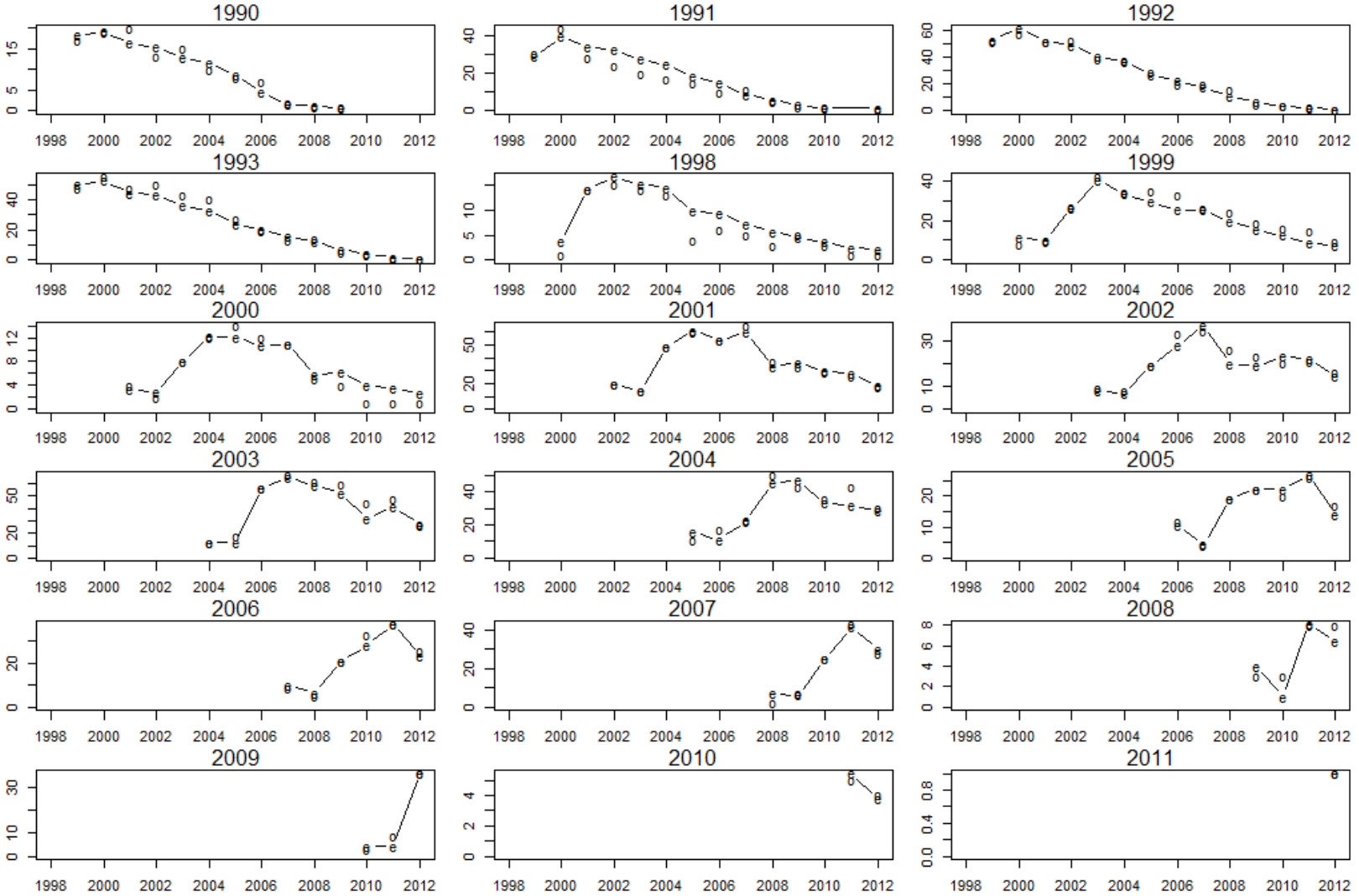
Fits to tagging obs - optimal model



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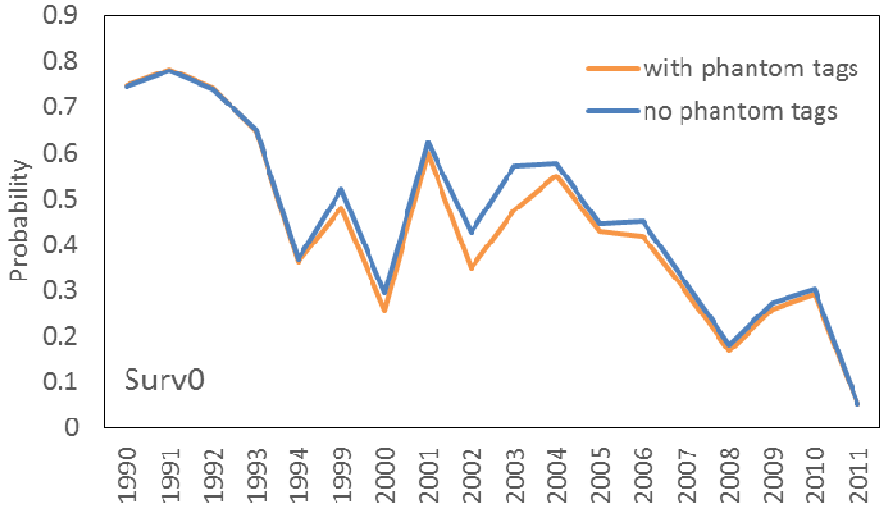
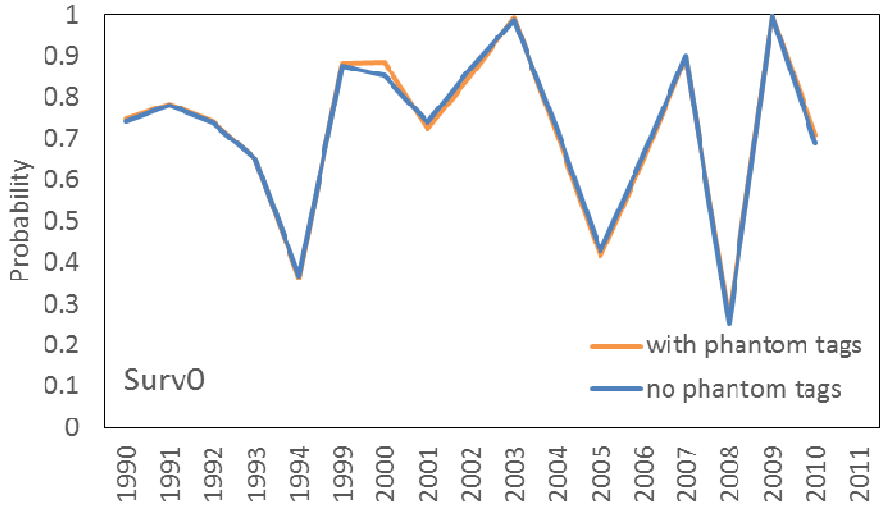
Pups dead at tagging

- Some pups recorded as dead at the time of tagging, e.g. disease mortalities in 2002 & 2003 – we are overestimating Surv0 if these are not accounted for
- We included additional “phantom tag” observations in SeaBird input files – animals that are tagged and then not observed again
- SeaBird decreases Surv0 (and not resighting probability - prob. resight ages 1&2 = 0.104 with phantom tags & 0.105 without). Minor effect on Surv1 in 2009





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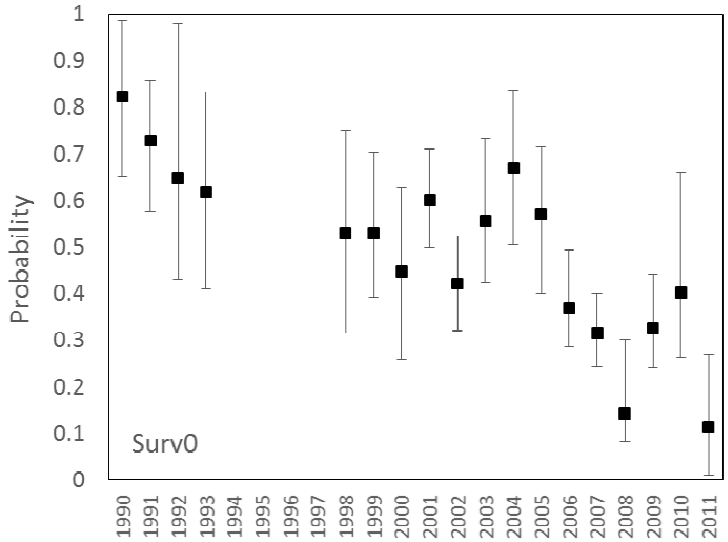
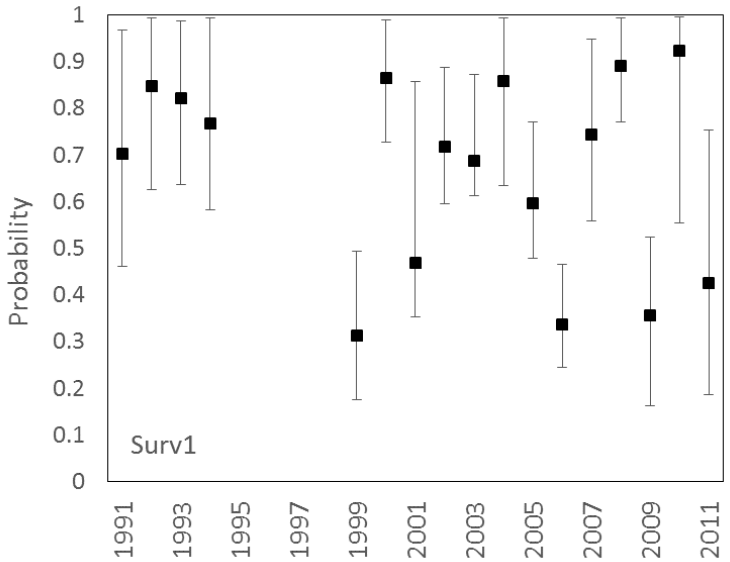
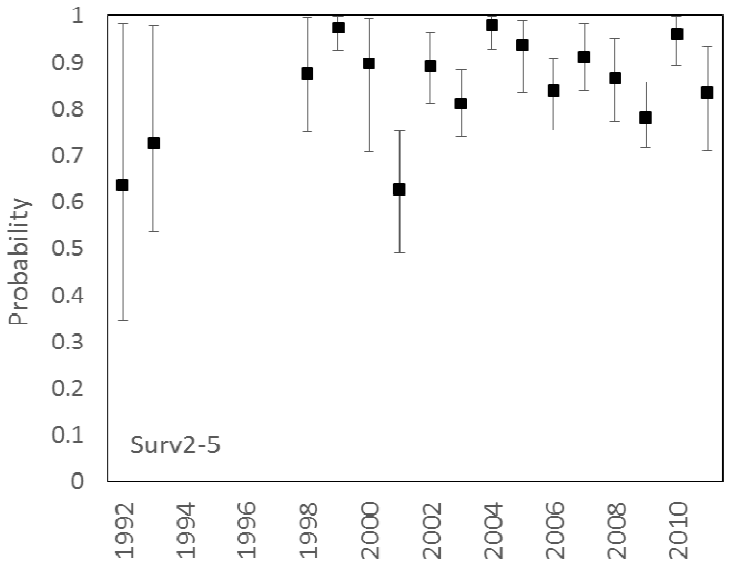
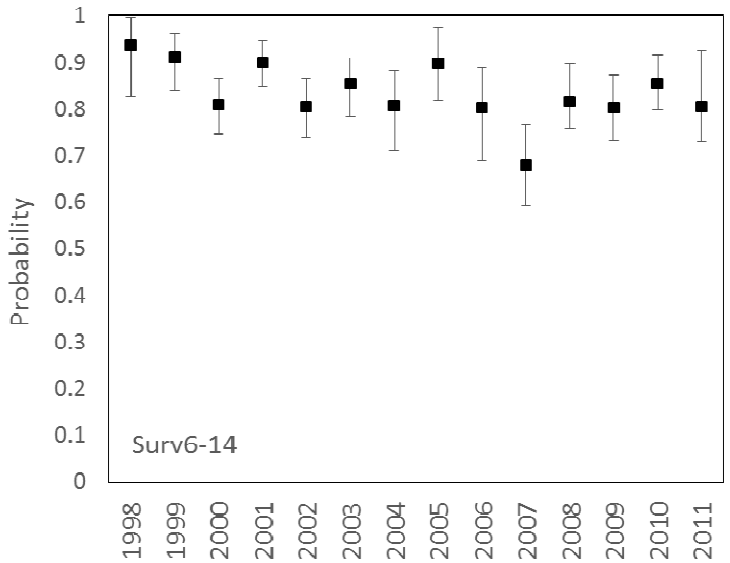
MCMC runs 400,000 length; 400 samples – survival

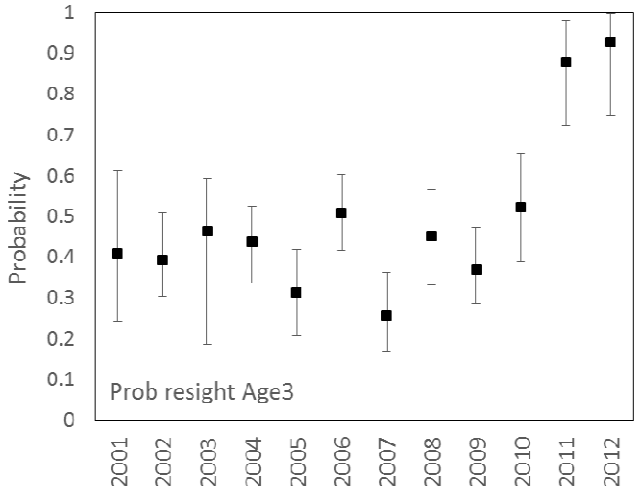


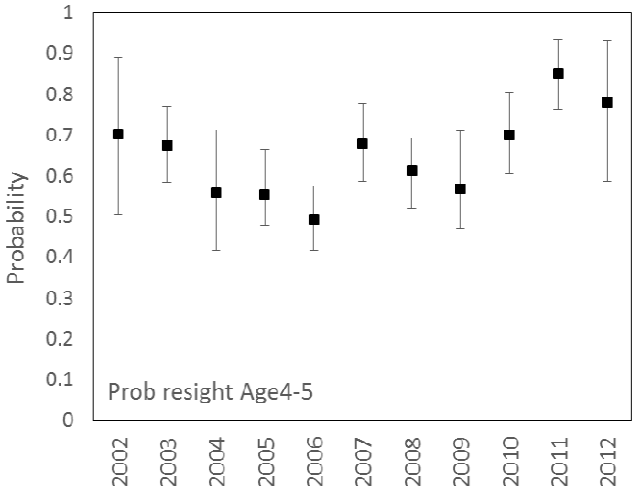


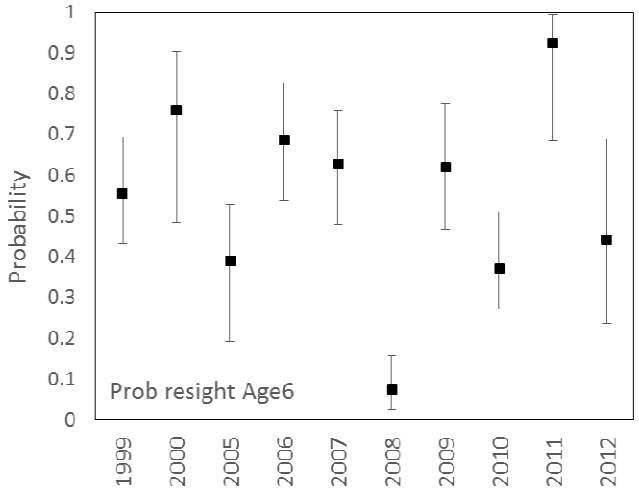


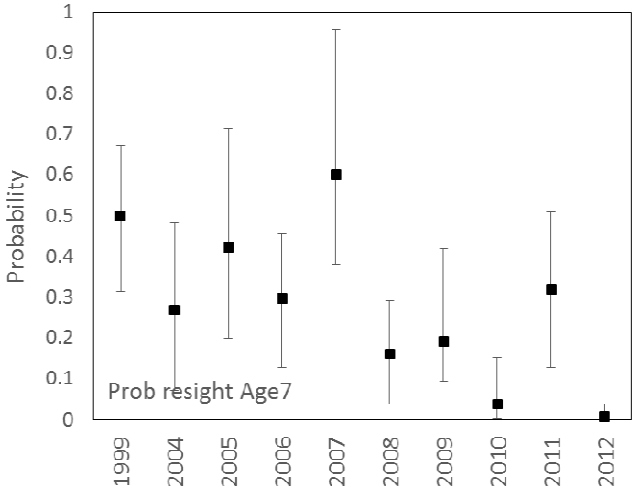


MCMC runs – resighting probability









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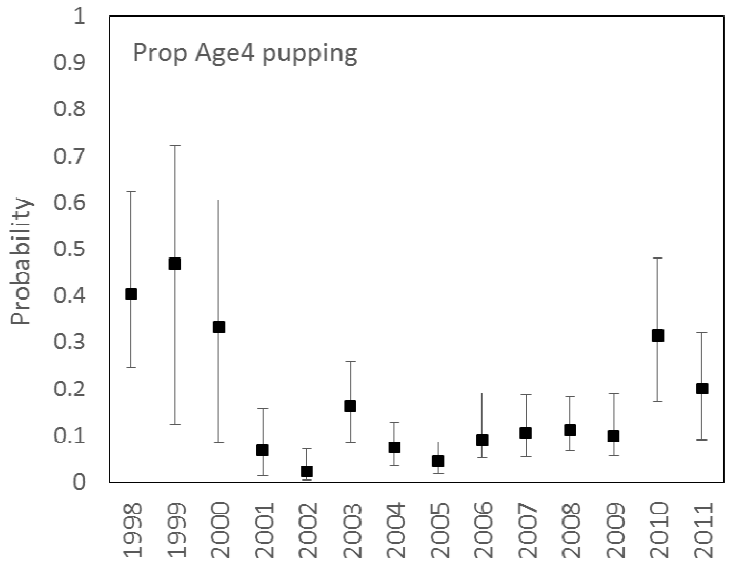
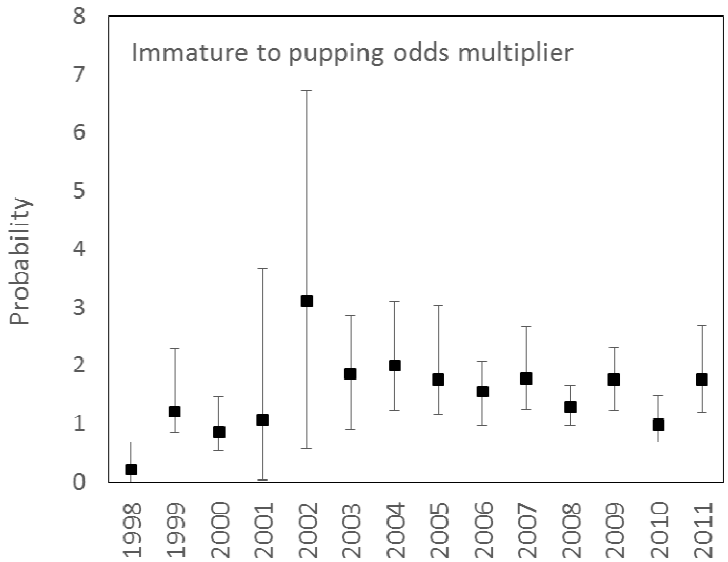
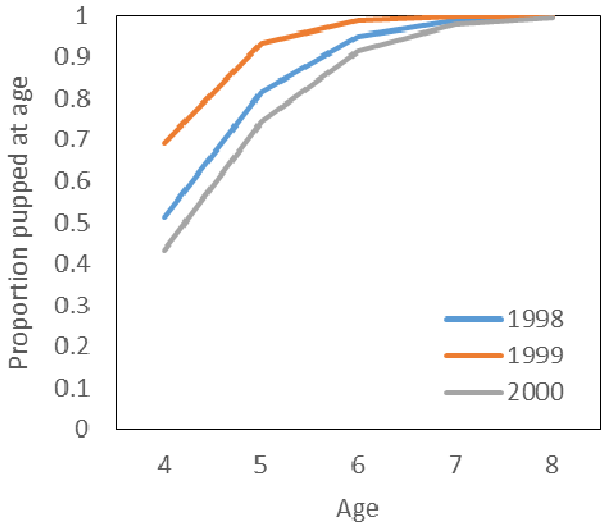
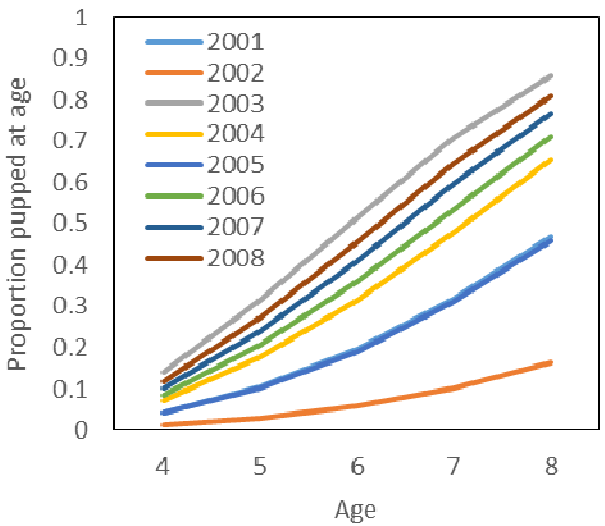
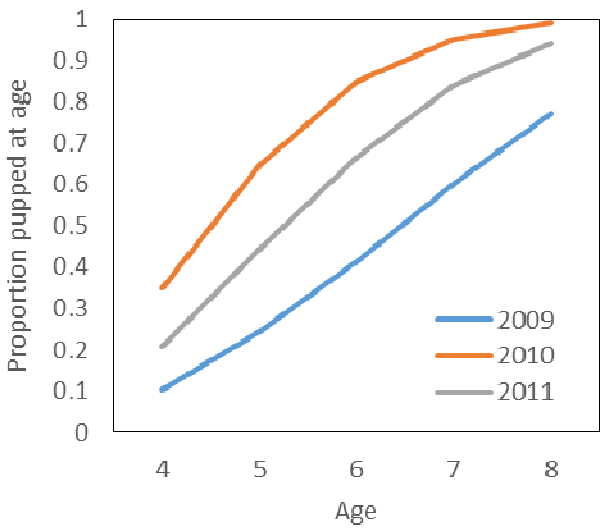
MCMC runs – maturation



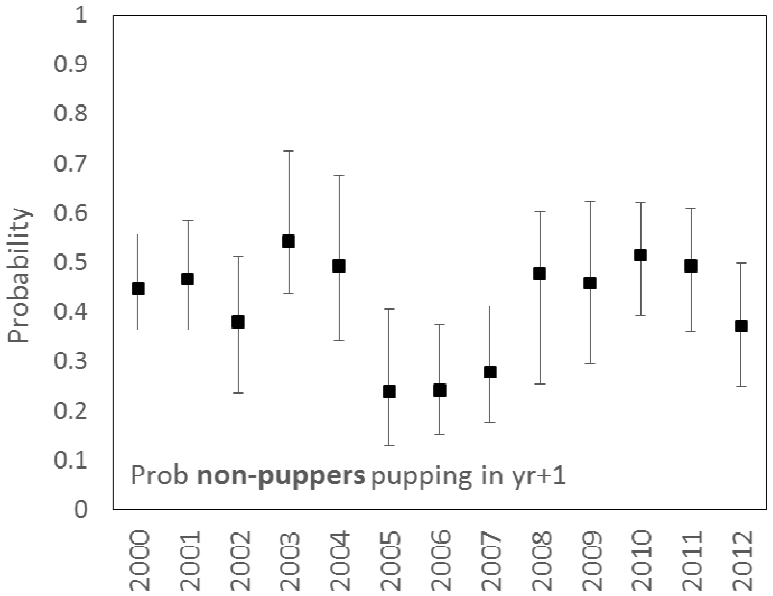


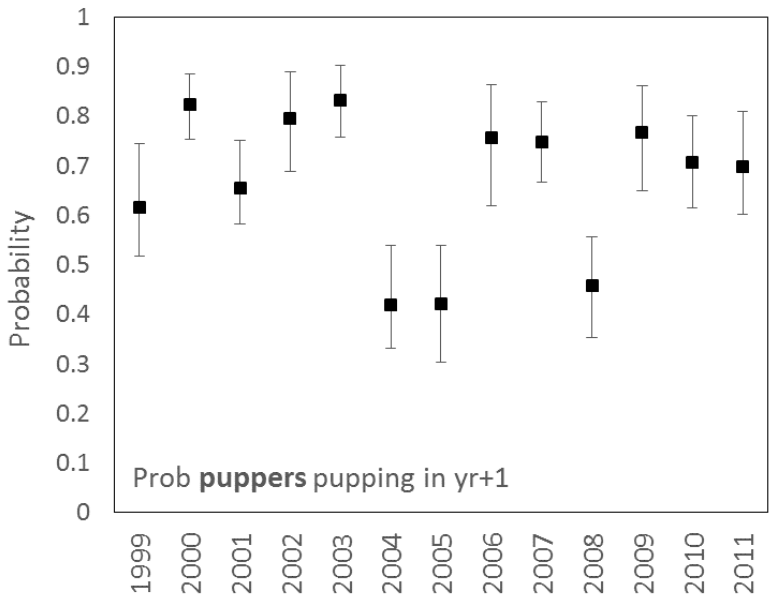






MCMC runs – breeding probability





- Probable cohort effects on breeding probability (1998 & 2000 cohort)
- Also year effects e.g. 2008 (low survivorship too)

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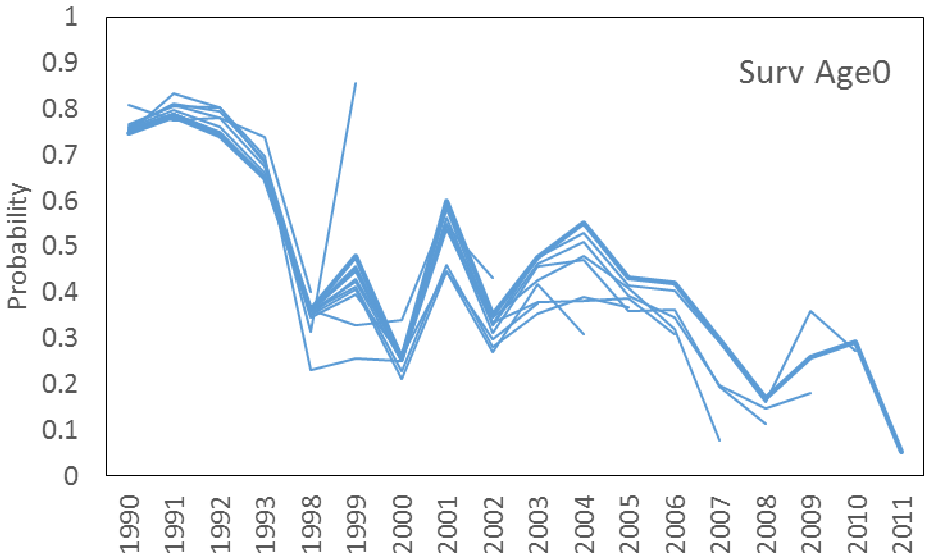
Retrospective analysis



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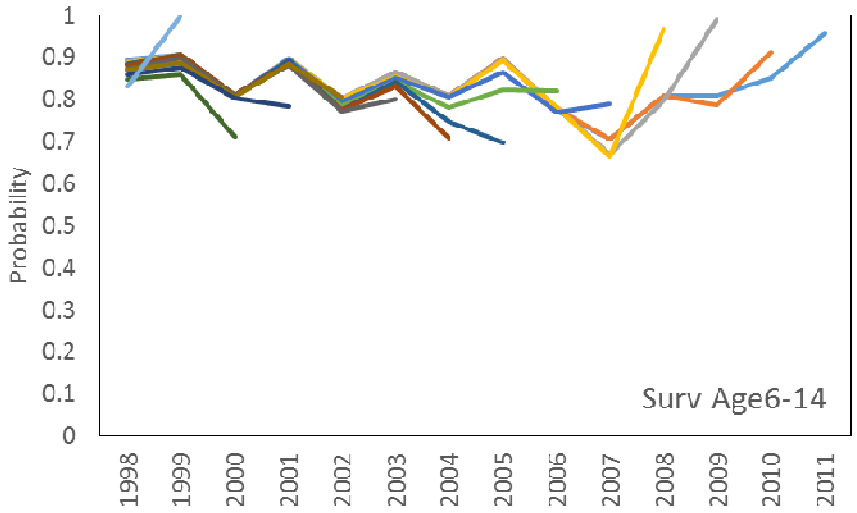
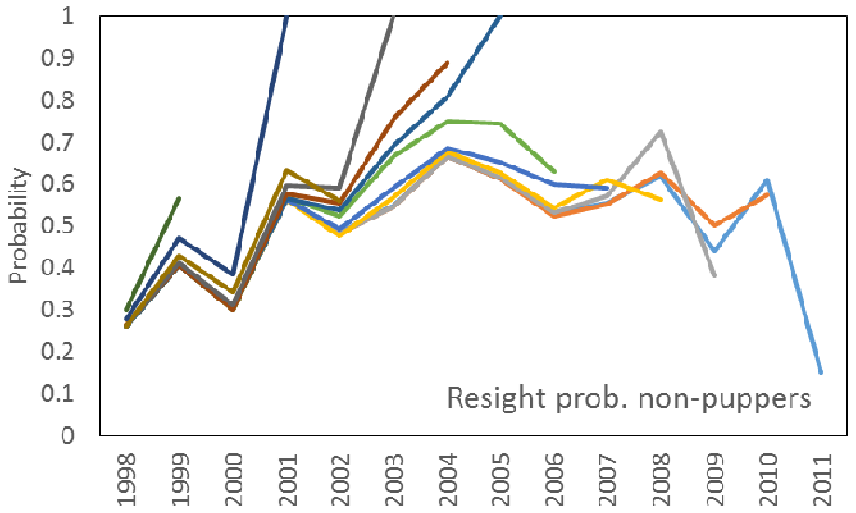
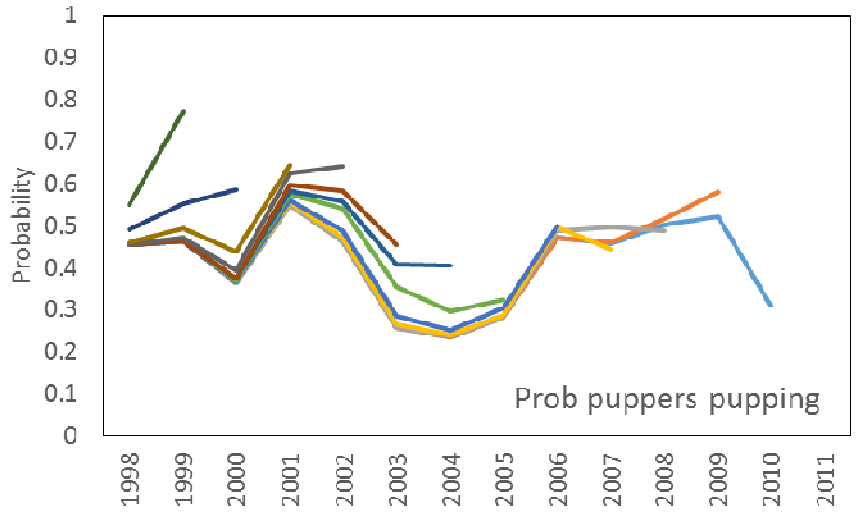
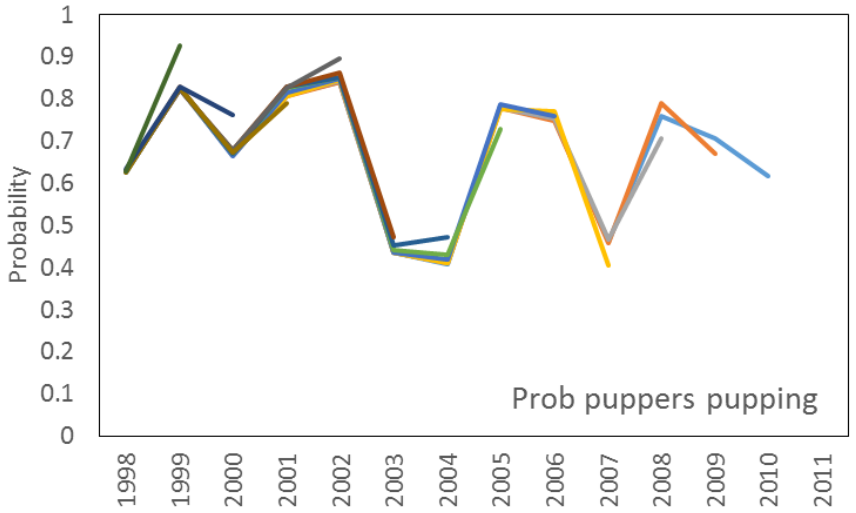
Retrospective analysis









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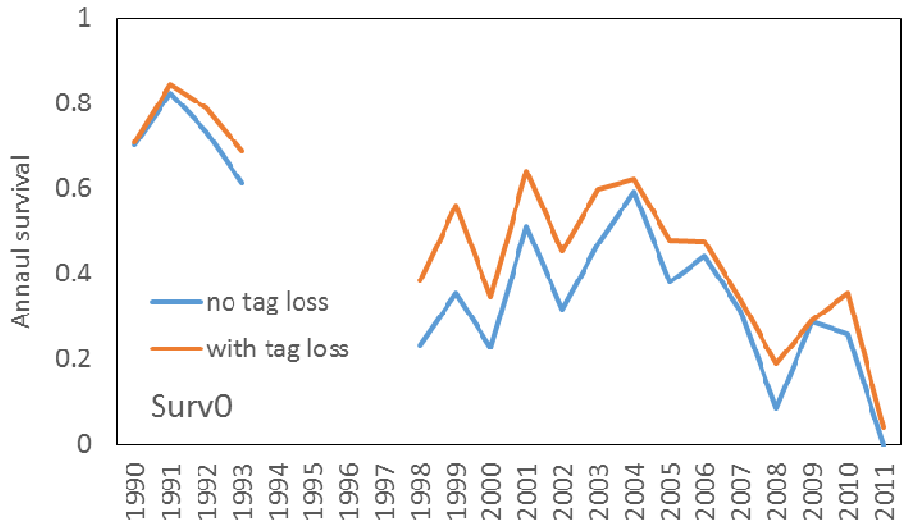
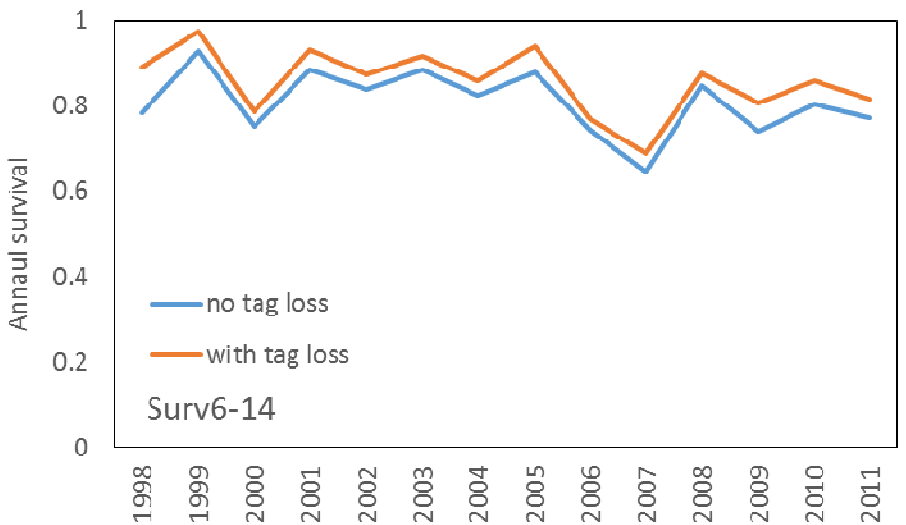
Tag loss model (tag observations only)

- Partitions for 2 tags, 1 tag and 0 tag (Presight0tag set to zero)
- Retagged animals - assume same tag frequency in all subsequent years
- Two parameters for probability of losing 1 tag in a year (time-invariant):
  - $T_{age0} = 0.085$; $T_{age1+} = 0.049$
  - Compares with 0.15 (2>1) & 0.09 (1>0) MacKenzie & Chilvers (2012)





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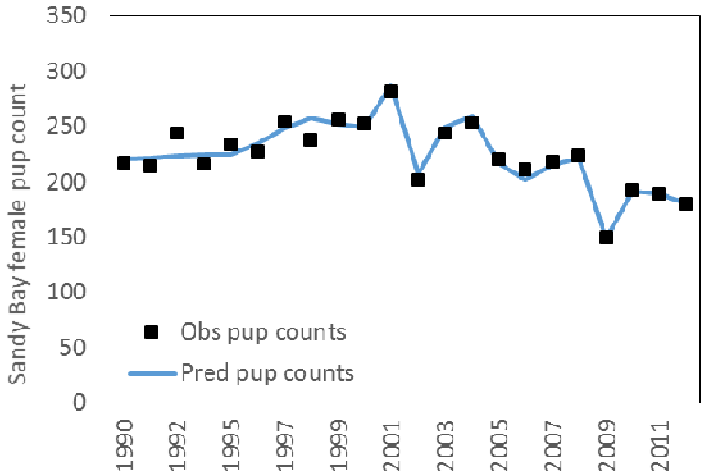
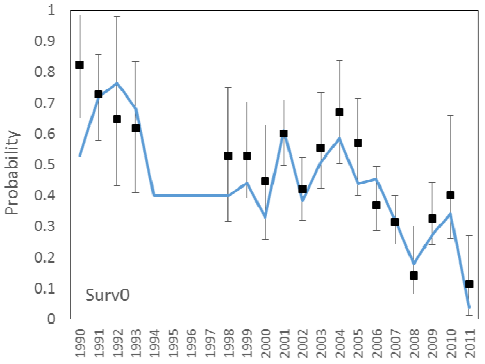
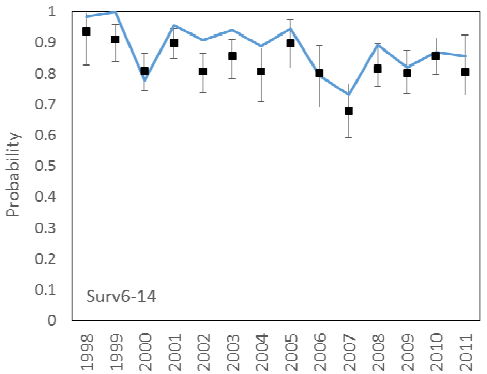
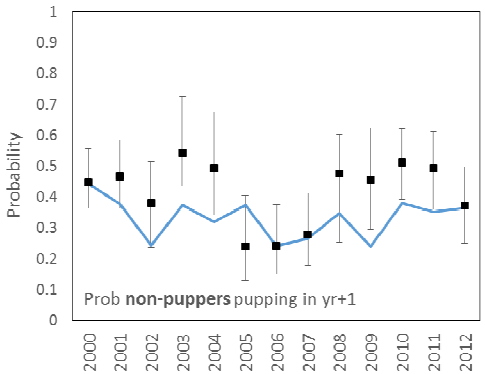
Fitting to pup count observations with tag loss

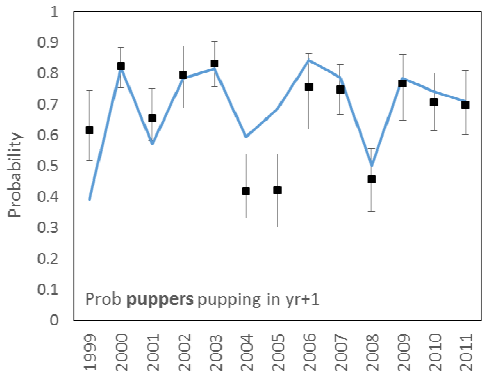


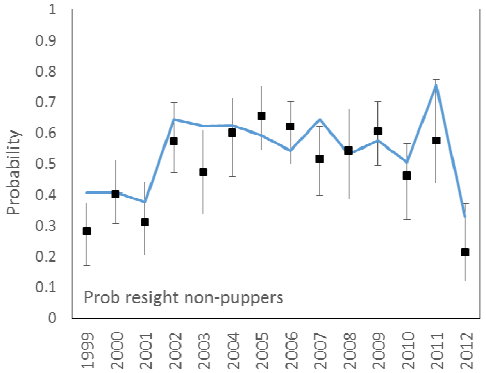
- C.V. of 0.03
- Good fits (including low pup counts in 2009 – low prob puppers pupping)
- Minimal conflict with estimates from tag only though increased survival of groupings Age2+
- T_{age0} = 0.103; T_{age0} = 0.063











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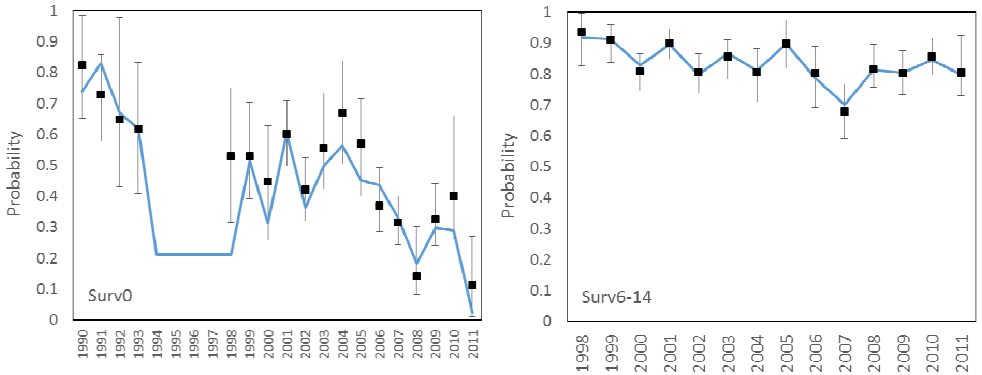
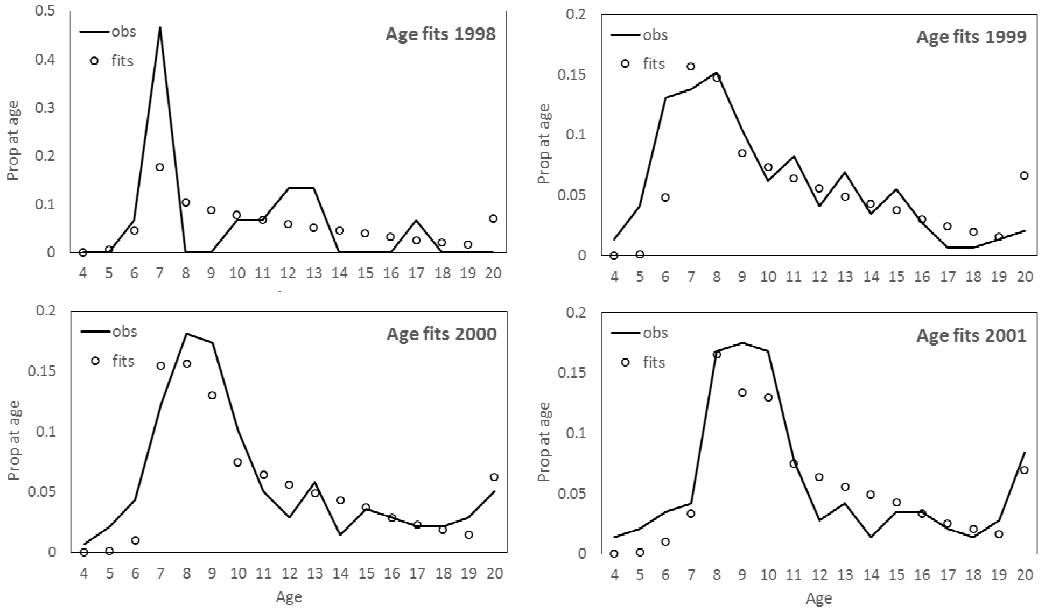
Fitting to age distribution observations

- Good fits to lactating female age distribution observations 1998 to 2001 (Childerhouse et al 2010)





- Only really informative for survival at ages 0-5
- Confirms strong cohorts (1990-1993) evident from mark-resighting analysis
- Cohort effect on survival of animals - not just tags!

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Summary model development

- Goals of demographic modelling
- Conflict between observations
- More pups born than calculated from tag only survival and pupping rates
  - Relocation effects?
  - Underestimating tag shedding?
- Biases and uncertainty around estimates
- Final model development

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Proximate causes of “population decline”

Survival

•Decline in survival at ages 0 and 1 relative to strong cohorts in 1990-93

•Some very weak cohorts e.g. 1998 (disease epidemic year) with reduced survival at different ages

•2008 may be another very weak cohort

•Cohort (e.g. 1998) & year (e.g. 2007) effects on adult survival

•A need to better understand biology of juvenile animals – low resighting probability at breeding rookeries (~0.1 per annum)

Pupping

•Year effects on pupping rates, e.g. 2009, cause single-year declines in pup production. Also potential cohorts effects.

•Increased age at first pupping during period of decline & low proportion pupping each year for an otariid species (0.6-0.7)

•Do non-pupping animals breed then abort? Do they skip breeding/suckle yearlings?

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