Black petrel demography

Bayesian estimation of black petrel demographic parameters from mark-recapture data

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Preliminary analysis

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Key questions

The Great Barrier Island black petrel population has apparently declined since the late 1990's

- Could apparent changes in the population be due to changes in the attendance of birds at the colony?
- Have there been changes in the survival of black petrel over this period?

Mark-recapture data

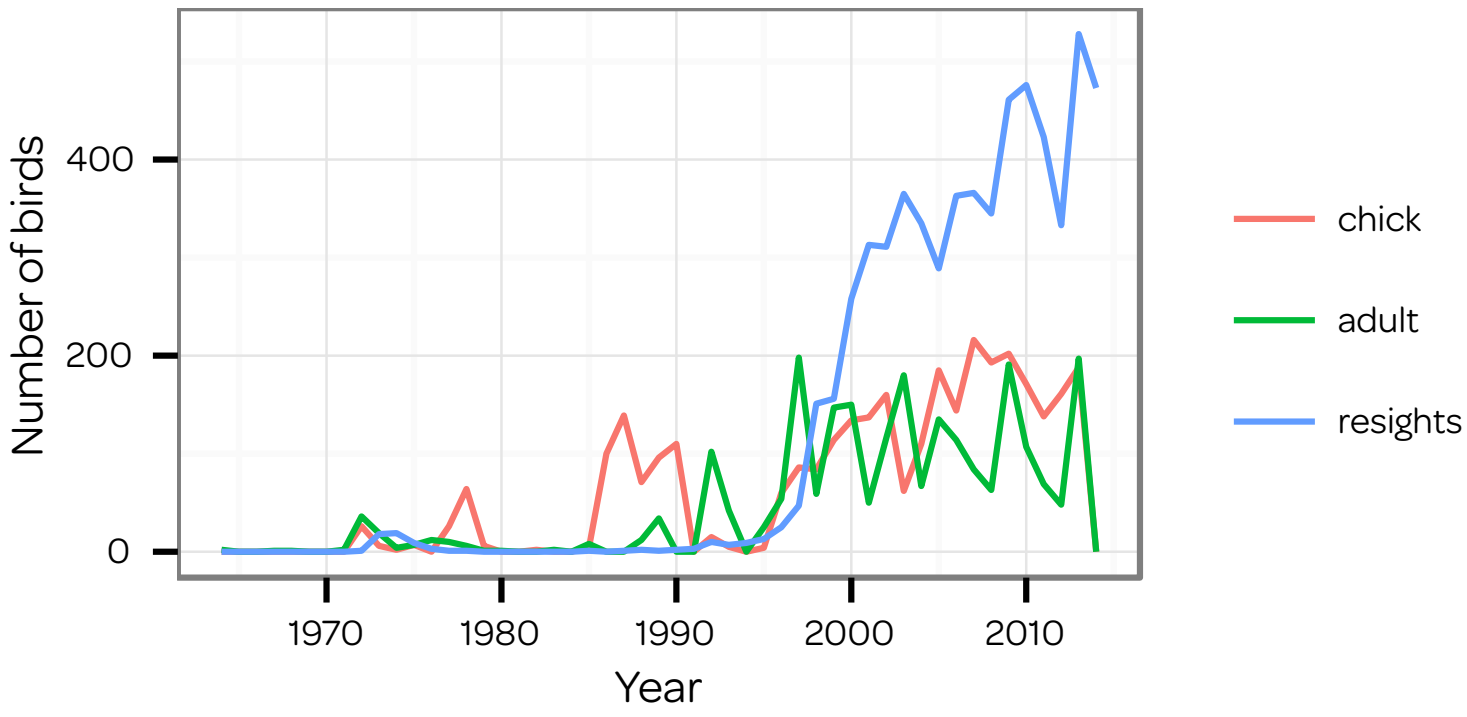
- Annual record of whether a not a bird was seen at the colony
- Birds banded as both chicks and adults (of unknown age)
- Most birds banded inside the study area, some outside
- Within the study area, there is variation in how frequently different burrows are visited

Example records for six birds banded in 2009

Band number	2009	2010	2011	2012	2013	2014
1154	1	-	-	-	-	-
1155	1	1	1	1	1	1
1156	1	-	-	-	-	-
1157	1	1	1	-	-	-
1158	1	-	-	-	-	-

Mark-recapture data

- There was some banding before 1995, but very limited numbers of resights
- Relatively consistent effort since 2000



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Mark-recapture analyses

Previous analyses of the black petrel data:

- Paul Scofield: Estimation of adult survival and probability of resight, using a Cormack-Jolly-Seber (CJS) model, fitted with MARK
- Chris Francis: Population model of black petrel (based on mark-recapture data, breeding data, and population counts), fitted using NIWA software SEABIRD

In this analysis, we fit CJS-family mark-recapture models, but use a Bayesian framework that allows flexible model specification.

Model of mark-recapture data

- Initially, we are only using annual sightings data, with no breeding state or sex of individual birds
- Estimate a resight probability, given that the bird is alive
- Separate probability for 'juvenile'[1], 'adolescent', and 'adult' birds
- Separate probability for birds outside the study area
- Estimate an adult and pre-adult survival

[1] Birds three years or less are called juvenile, birds seven years or over are adult, and birds in between may be adolescent or adult

Most birds are not seen again

- Around 5584 birds have been banded
- But, around 72% of banded birds have not been seen again since they were banded
- Only 254 of the birds banded as chicks have been resighted

Banded as chicks

	Study	Non-study
Total	2447	781
Seen again	213	41

Banded as adults

	Study	Non-study
Total	1693	663
Seen again	1174	89

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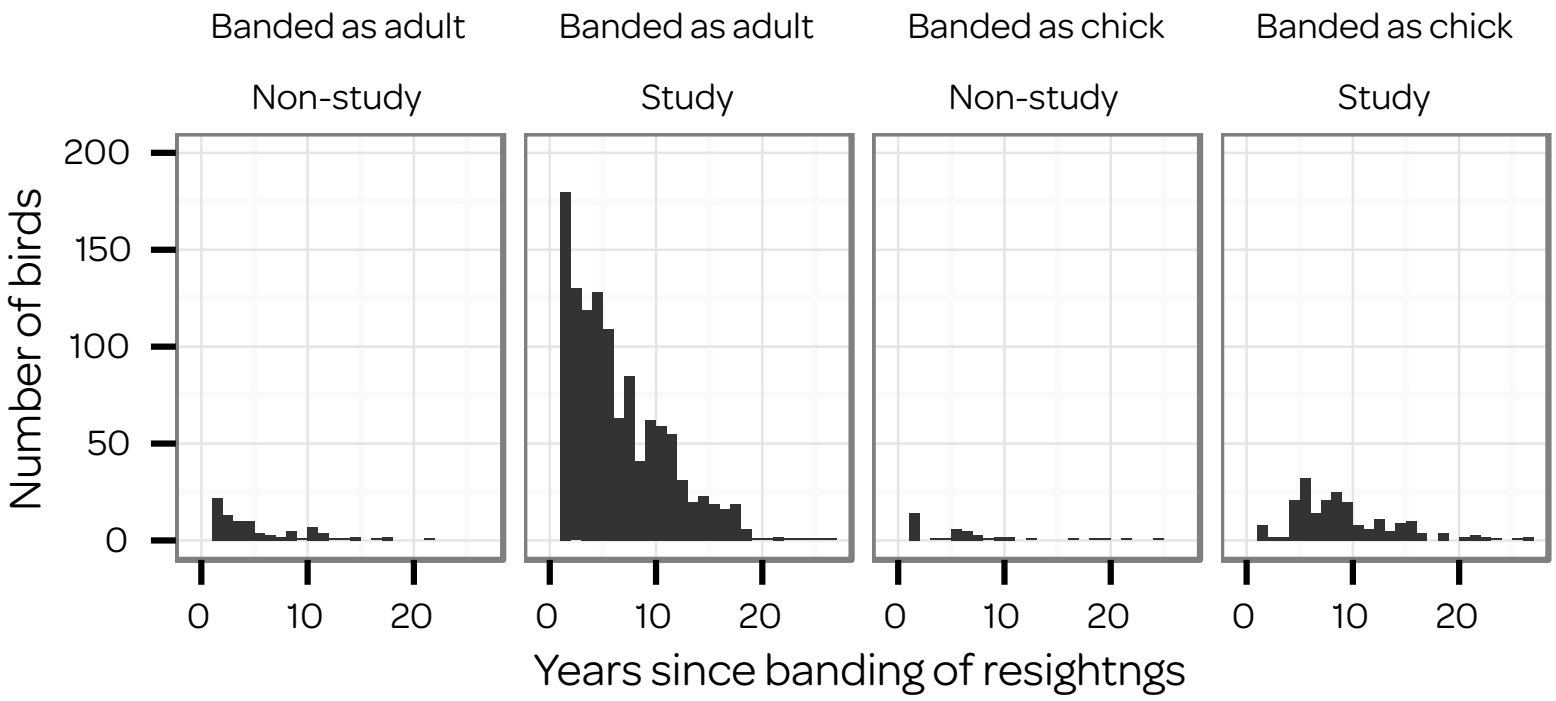
Years since banding

Maximum number of years since banding that a bird has been resighted is 26



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Resighting probability

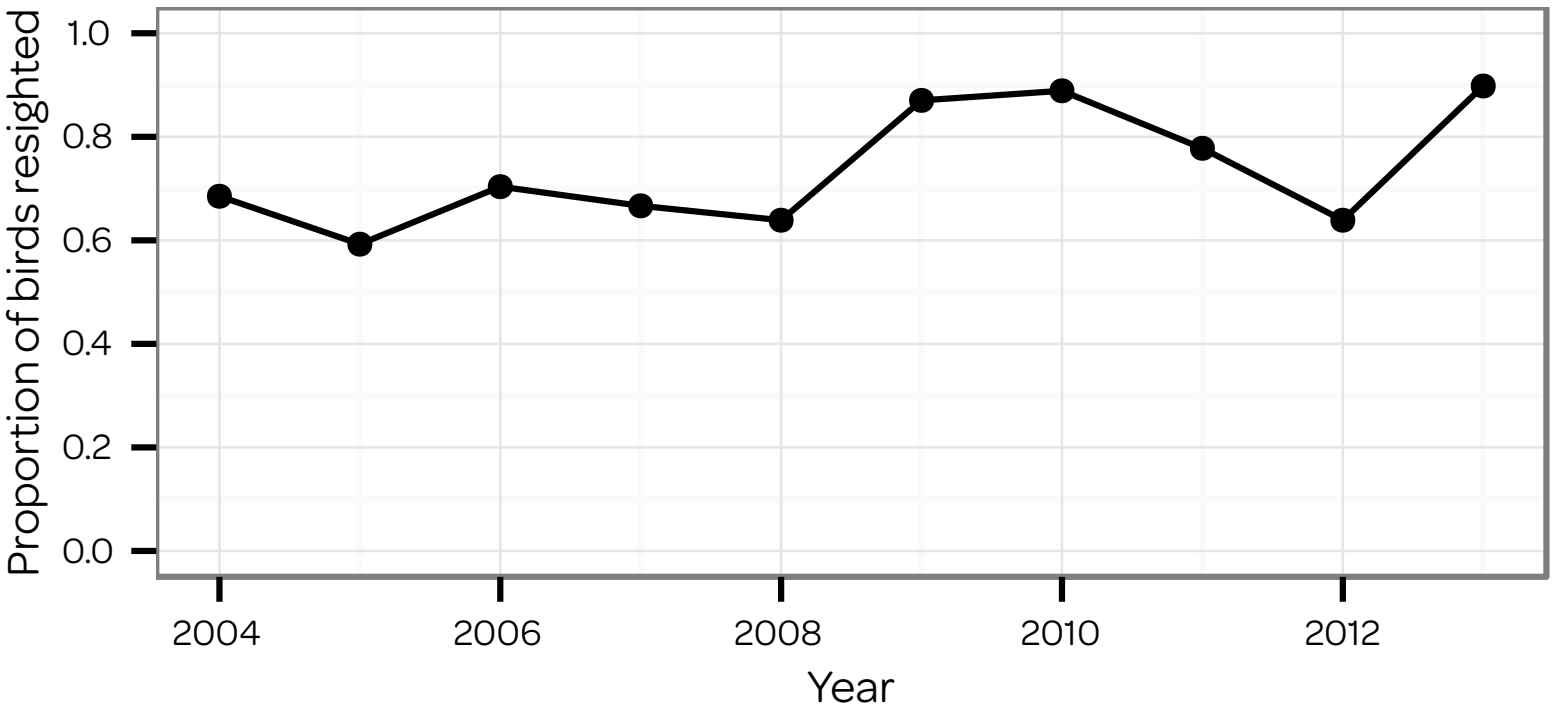
The key to mark-recapture modelling is separating the reasons why a bird was not seen in a year:

1. Because it was dead
2. Because it was alive, but not at the colony
3. Because it was alive and at the colony, but there was only limited resighting effort where that bird lived, in that year

Without information on dispersal, it is not possible to separate emigration from mortality (in either case, the bird is never seen again)

Annual variation in resighting probability

Proportion of birds banded as adults in the study area before 2004, and seen in 2014, that were resighted in each year:



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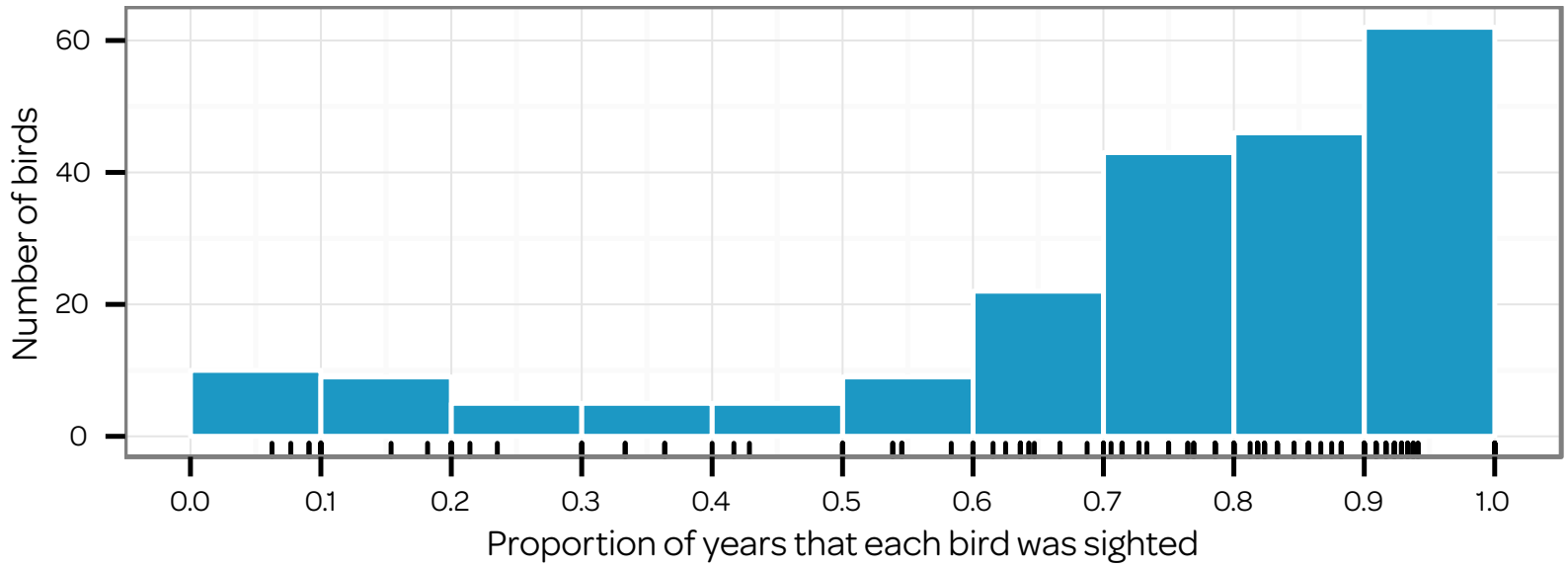
Variation in resighting probability between birds

Proportion of years that birds were resighted, restricted to birds banded as adults in the study area after 1996, and that were recorded at least 10 years after banding. Data restricted to years that the bird was known to be alive.



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Fixed effects

- Fixed effects are each drawn from separate distributions
- For example, fixed annual resight probabilities, C_y, are each independently drawn from a uniform prior:

$$C_y \sim U(0, 1)$$

- Fixed effects require relatively few assumptions, but are poorly constrained in years where there is little data

Random effects

- Random effects are each drawn from an underlying distribution
- For example, random annual resight probabilities, C_y, are assumed to be normally distributed around a mean value (on the logit scale):

$$\text{logit}(C_y) \sim \text{logit}(C_\mu) + N(0, C_\sigma)$$

- The model estimates the mean value (C_μ) and the spread (C_σ) of the underlying distribution
- Random effects allow a reasonable estimate to be made, even in cases where there is little data

Model choices

Resighting probability:

- Constant
- Annual fixed - effect
- Annual random - effect
- Random effect for each bird

Adult survival:

- Constant
- Annual fixed - effect
- Annual random - effect

Other parameters (juvenile survival, juvenile resight probability, adolescent resight probability, non - study resight ratio, probability of a juvenile maturing) are all constant.

Model selection

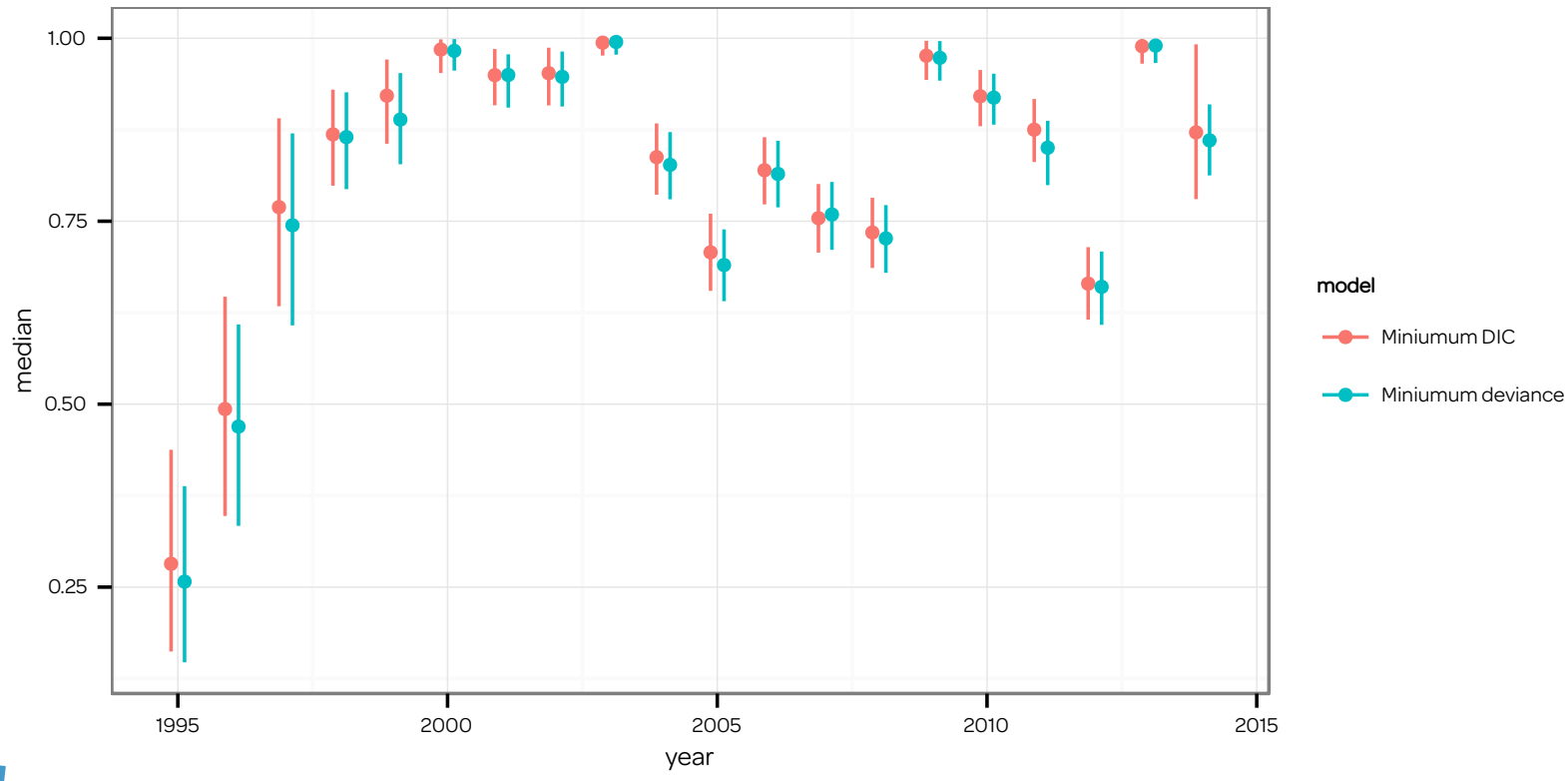
Models compared using model fit (deviance) and the Deviance Information Criterion (DIC) (in both cases, smaller is better):

Annual survival	Annual resight	Bird resight	Deviance	DIC
Constant	Fixed	Random	10 521	15 041
Constant	Fixed		12 578	16 726
Fixed	Constant		13 239	17 475
Random	Random	Random	10 491	18 140
Fixed	Fixed	Random	10 509	18 662
Fixed	Fixed		12 529	25 411

(Haven't yet tried Constant+Random+Random)

Annual resight probability

- Includes effects of birds being away from colony, and variations in resighting effort
- Increase in resighting effort from 1995 through 2000
- Varies between 60% and 100% since then



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Other model parameters

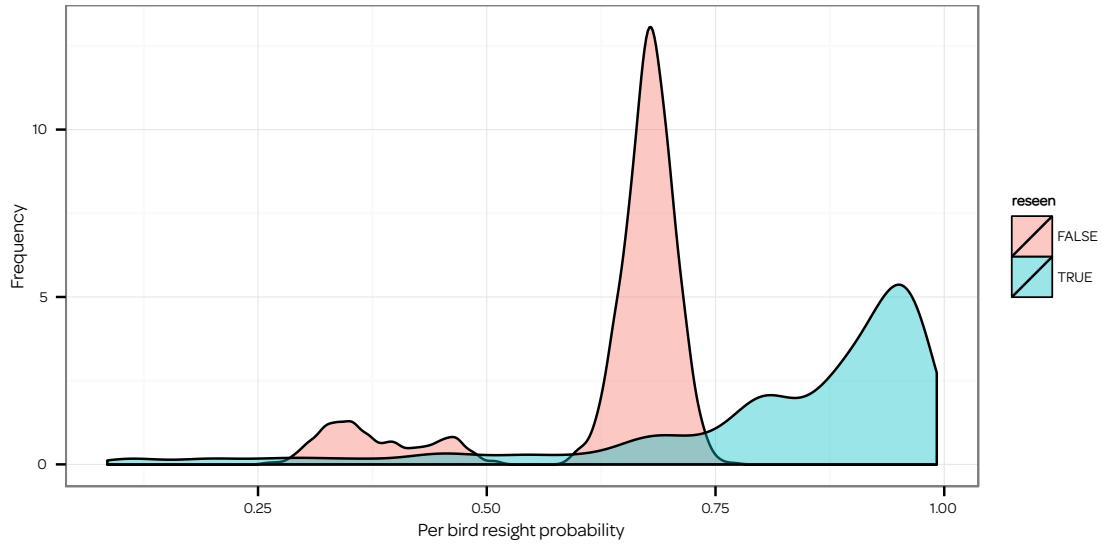
A summary of the other model parameters (from the minimum DIC model)

Parameter	Median (%)	95% c.i.
Apparent adult survival	89.7	(89.0–90.4)
Apparent pre-adult survival	69.7	(67.7–71.7)
Juvenile presence	0.3	(0.1–0.5)
Adolescent presence	5.8	(2.4–9.1)
Non-study presence ratio	6.2	(4.8–7.8)
Juvenile to adult	15.6	(11.1–21.0)

Resight probability per bird

- Effect accounts for some birds being in parts of the study area that are less visited, and possibly for different behaviour between birds
- Improves the fit of the models
- Including this effect increases the apparent adult survival (from a median of 87.0 to 89.7)

Frequency of resight probabilities for each bird, grouped by whether the bird is ever reseen or not



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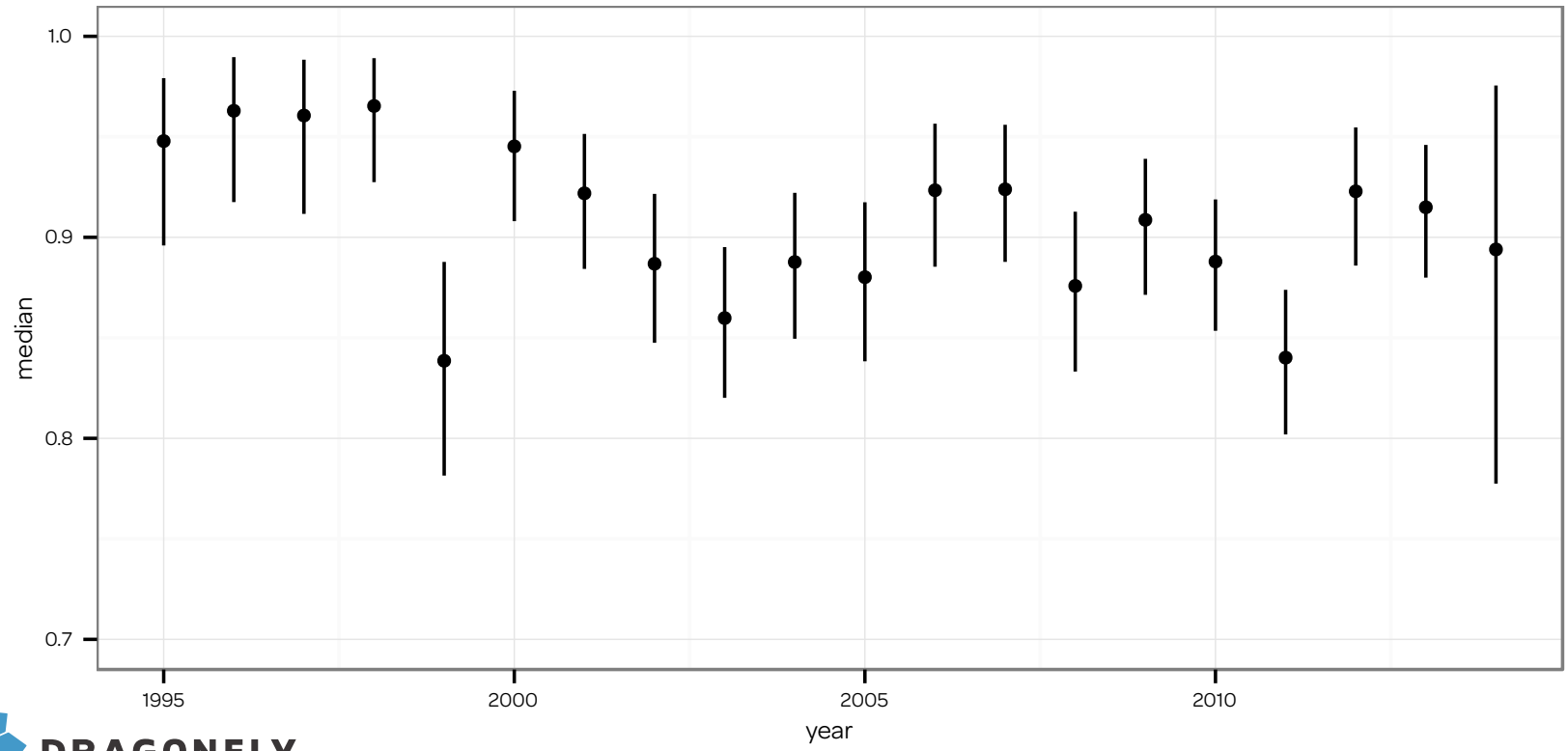
Annual variation in adult survival (minimum deviance model)

- Evidence of coherent multi - year fluctuations
- High survival in early years may be an artefact of low numbers of observations



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Next steps

- The key next step is to include a measure of effort within each season, ideally from a record of visits to each burrow, and a record of association between birds and burrows
- Will also include recorded state information (sex, breeding, etc.) to allow affect of state on presence and on survival to be estimated