# Journal of Avian Biology

## Supplementary material

**Appendix 1**

Table A1. Coefficient values for survival parameters in the top-ranked apparent survival model structure for kittiwakes involved in a long-term cost of reproduction experiment at the Shoup Bay colony in Prince William Sound, Alaska. The top-ranked model did not include the manipulation term, indicating that forced nest failures during 1991-1994 had little effect on long-term survival.

| Beta | Estimate | SE | 85% CI | | Significant |
|------|----------|-----|--------|------|-------------|
| *intercept* | 2.86 | 0.19 | 2.58 | 3.14 | * |
| *state (breeders)* | 0.06 | 0.28 | -0.34 | 0.45 | |
| *trend* | -0.13 | 0.02 | -0.16 | -0.10 | * |
| *state (breeders) X trend* | 0.11 | 0.04 | 0.05 | 0.17 | * |

1    Table A2. Coefficient values for transition parameters in the top-ranked transition model structure for

2    kittiwakes involved in a long-term cost of reproduction experiment at the Shoup Bay colony in Prince

3    William Sound, Alaska. The top-ranked model included the manipulation term, indicating that forced

4    nest failures during 1991-1994 increased the probability of breeding over the long term.

| Beta | Estimate | SE | 85% CI | | Significant | Comments |
|---|---|---|---|---|---|---|
| *intercept* | 1.70 | 0.42 | 1.09 | 2.31 | * | |
| *state (breeders)* | -0.78 | 0.73 | -1.84 | 0.28 | | |
| *manip* | -0.13 | 0.04 | -0.18 | -0.08 | * | |
| *1995* | -0.54 | 0.48 | -1.23 | 0.15 | | *fixed* |
| *1996* | -0.82 | 0.47 | -1.50 | -0.14 | * | |
| *1997* | -0.85 | 0.46 | -1.51 | -0.19 | * | |
| *1998* | -0.93 | 0.46 | -1.58 | -0.27 | * | |
| *1999* | -0.05 | 0.47 | -0.73 | 0.62 | | |
| *2000* | -0.94 | 0.45 | -1.58 | -0.30 | * | |
| *2001* | -0.55 | 0.45 | -1.21 | 0.10 | | |
| *2002* | -0.82 | 0.45 | -1.47 | -0.18 | * | |
| *2003* | -0.37 | 0.46 | -1.04 | 0.29 | | |
| *2004* | 0.80 | 0.50 | 0.08 | 1.53 | * | |
| *2005* | -0.53 | 0.46 | -1.19 | 0.12 | | |
| *2006* | -0.17 | 0.49 | -0.87 | 0.53 | | |
| *2007* | -0.75 | 0.49 | -1.45 | -0.04 | * | |
| *2008* | 0.51 | 0.60 | -0.35 | 1.37 | | |
| *2009* | | | | | | *confounded* |
| *state (breeders) X 1995* | -2.86 | 0.79 | -3.99 | -1.72 | * | *fixed* |
| *state (breeders) X 1996* | -1.57 | 0.77 | -2.69 | -0.46 | * | |
| *state (breeders) X 1997* | -1.16 | 0.77 | -2.27 | -0.06 | * | |
| *state (breeders) X 1998* | -1.00 | 0.76 | -2.11 | 0.10 | | |
| *state (breeders) X 1999* | -1.11 | 0.77 | -2.22 | 0.00 | | |
| *state (breeders) X 2000* | -0.31 | 0.76 | -1.41 | 0.79 | | |
| *state (breeders) X 2001* | -0.45 | 0.77 | -1.56 | 0.66 | | |
| *state (breeders) X 2002* | -0.14 | 0.77 | -1.25 | 0.97 | | |
| *state (breeders) X 2003* | -0.12 | 0.78 | -1.24 | 1.00 | | |
| *state (breeders) X 2004* | -0.17 | 0.82 | -1.36 | 1.02 | | |
| *state (breeders) X 2005* | 0.74 | 0.85 | -0.48 | 1.97 | | |
| *state (breeders) X 2006* | -0.12 | 0.82 | -1.31 | 1.06 | | |
| *state (breeders) X 2007* | -0.35 | 0.84 | -1.56 | 0.86 | | |
| *state (breeders) X 2008* | 0.75 | 0.95 | -0.62 | 2.12 | | |
| *state (breeders) X 2009* | | | | | | *confounded* |

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Table A3. *Tag loss sensitivity analysis:* Performance of multi-state models estimating the encounter probability (p) for black-legged kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 with all individuals with degraded marks and reconstructed identities removed. Model structures for apparent survival and transition probability were held constant as state X time. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.09. Boldface denotes top scoring model.

| Model | $\Delta QAIC_c$ | $w_i$ | K |
|---|---|---|---|
| **P(state + year)** | **0.00** | **>0.99** | **77** |
| P(state * linear time trend) | 13.57 | <0.01 | 64 |
| P(state + linear time trend) | 17.85 | <0.01 | 63 |
| P(state) | 18.99 | <0.01 | 62 |
| P(state * year) | 29.22 | <0.01 | 92 |
| P(linear time trend) | 369.19 | <0.01 | 62 |
| P(year) | 371.19 | <0.01 | 76 |
| P(constant) | 429.53 | <0.01 | 61 |

Table A4. *Tag loss sensitivity analysis:* Performance of multi-state models estimating the probability of apparent survival ($\varphi$) for black-legged kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 with all individuals with degraded marks and reconstructed identities removed. Model structure for transition probability was held constant as state X time, and encounter probability model structure was set to the best competing structure from Table S5. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.09. Boldface denotes top scoring model.

| Set | Model | $\Delta QAIC_c$ | $w_i$ | K | Notes |
|---|---|---|---|---|---|
| *General structure* | $\Phi_{(state * trend)}$ | 0.00 | 0.58 | 50 | |
| | $\Phi_{(state + trend)}$ | 0.81 | 0.39 | 49 | |
| | $\Phi_{(state + period)}$ | 6.23 | 0.03 | 51 | |
| | $\Phi_{(state * period)}$ | 11.62 | <0.01 | 54 | |
| | $\Phi_{(trend)}$ | 11.79 | <0.01 | 48 | |
| | $\Phi_{(state + year)}$ | 12.30 | <0.01 | 62 | |
| | $\Phi_{(state)}$ | 15.92 | <0.01 | 48 | |
| | $\Phi_{(year)}$ | 24.10 | <0.01 | 61 | |
| | $\Phi_{(state * year)}$ | 30.13 | <0.01 | 76 | |
| | $\Phi_{(constant)}$ | 41.23 | <0.01 | 47 | |
| *Temporal covariates* | $\Phi_{(state * trend)}$ | 0.00 | >0.99 | 50 | |
| | $\Phi_{(state * prod)}$ | 10.60 | <0.01 | 50 | |
| | $\Phi_{(state * PDO)}$ | 19.04 | <0.01 | 50 | |
| *Other covariates* | $\mathbf{\Phi_{(state * trend)}}$ | **0.00** | **0.73** | **50** | |
| | $\Phi_{(state * trend + manip)}$ | 2.03 | 0.27 | 51 | *Insignificant manipulation effect* |
| | $\Phi_{(state * trend + 9194\ skip)}$ | 14.22 | <0.01 | 64 | *Insignificant 1991-1994 skipped breeding effect* |

Table A5. *Tag loss sensitivity analysis:* Performance of competing structures for multi-state models estimating the probability of transition ($\Psi$) between breeding and non-breeding states for Black-legged Kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 with all individuals with degraded marks and reconstructed identities removed. Model structure for apparent survival probability was held constant as state X time, and encounter probability model structure was set to the best competing structure from Table A5. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.09. Boldface denotes top scoring model.

| Set | Model | $\Delta QAIC_c$ | $w_i$ | K | Notes |
|---|---|---|---|---|---|
| *General structure* | $\Psi_{(state\ *\ year)}$ | 0.00 | >0.99 | 76 | |
| | $\Psi_{(state\ *\ trend)}$ | 20.28 | <0.01 | 50 | |
| | $\Psi_{(state\ +\ year)}$ | 91.15 | <0.01 | 62 | |
| | $\Psi_{(state\ +\ trend)}$ | 122.17 | <0.01 | 49 | |
| | $\Psi_{(state\ +\ period)}$ | 169.75 | <0.02 | 51 | |
| | $\Psi_{(state)}$ | 218.15 | <0.01 | 48 | |
| | $\Psi_{(year)}$ | 424.70 | <0.01 | 61 | |
| | $\Psi_{(trend)}$ | 448.13 | <0.01 | 48 | |
| | $\Psi_{(period)}$ | 523.83 | <0.01 | 50 | |
| | $\Psi_{(constant)}$ | 702.86 | <0.01 | 47 | |
| *Temporal covariates* | $\Psi_{(state\ *\ year)}$ | 0.00 | >0.99 | 76 | |
| | $\Psi_{(state\ *\ prod)}$ | 177.25 | <0.01 | 50 | |
| | $\Psi_{(state\ *\ PDO)}$ | 209.43 | <0.01 | 50 | |
| *Other covariates* | **$\Psi_{(state\ *\ year\ +\ manip)}$** | **0.00** | **0.54** | **77** | ***Significant manipulation effect*** |
| | $\Psi_{(state\ *\ year)}$ | 0.63 | 0.40 | 76 | |
| | $\Psi_{(state\ *\ year\ +\ 9194\ skip)}$ | 4.40 | 0.06 | 78 | *Insignificant 1991-1994 skipped breeding effect* |

Table A6. *Breeding state designation sensitivity analysis:* Performance of multi-state models estimating the encounter probability (p) for black-legged kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 using a criterion of two sightings on a nest site to designate breeding status, rather than the three sightings used in the primary analysis. Model structures for apparent survival and transition probability were held constant as state X time. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.03. Boldface denotes top scoring model.

| Model | $\Delta QAIC_c$ | $w_i$ | K |
|---|---|---|---|
| **P(state + year)** | **0.00** | **0.58** | 77 |
| P(state) | 1.82 | 0.23 | 62 |
| P(state * linear time trend) | 3.21 | 0.12 | 64 |
| P(state + linear time trend) | 4.20 | 0.07 | 63 |
| P(state * year) | 17.91 | 0.00 | 92 |
| P(year) | 413.12 | 0.00 | 76 |
| P(linear time trend) | 421.82 | 0.00 | 62 |
| P(constant) | 543.12 | 0.00 | 61 |

Table A7. *Breeding state designation sensitivity analysis:* Performance of multi-state models estimating the probability of apparent survival ($\varphi$) for black-legged kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 using a criterion of two sightings on a nest sight to designate breeding status, rather than the three sightings used in the primary analysis. Model structure for transition probability was held constant as state X time, and encounter probability model structure was set to the best competing structure from Table A8. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.03. Boldface denotes top scoring model.

| Set | Model | $\Delta QAIC_c$ | $w_i$ | K | Notes |
|---|---|---|---|---|---|
| *General structure* | $\varphi_{(state + trend)}$ | 0.00 | 0.62 | 49 | |
| | $\varphi_{(state * trend)}$ | 1.86 | 0.25 | 50 | |
| | $\varphi_{(state + year)}$ | 3.35 | 0.12 | 62 | |
| | $\varphi_{(state + period)}$ | 7.62 | 0.01 | 51 | |
| | $\varphi_{(state * period)}$ | 13.49 | 0.00 | 54 | |
| | $\varphi_{(state * year)}$ | 24.30 | 0.00 | 76 | |
| | $\varphi_{(trend)}$ | 34.19 | 0.00 | 48 | |
| | $\varphi_{(state)}$ | 35.62 | 0.00 | 48 | |
| | $\varphi_{(year)}$ | 40.58 | 0.00 | 61 | |
| | $\varphi_{(constant)}$ | 101.29 | 0.00 | 47 | |
| *Temporal covariates* | $\varphi_{(state + trend)}$ | 0.00 | 1.00 | 49 | |
| | $\varphi_{(state + prod)}$ | 14.11 | 0.00 | 49 | |
| | $\varphi_{(state + PDO)}$ | 29.62 | 0.00 | 49 | |
| *Other covariates* | **$\varphi_{(state + trend)}$** | **0.00** | **0.48** | **49** | |
| | $\varphi_{(state + trend + 9194\ skip)}$ | 0.72 | 0.34 | 51 | *Insignificant 1991-1994 skipped breeding effect* |
| | $\varphi_{(state + trend + manipulation)}$ | 2.01 | 0.18 | 50 | *Insignificant manipulation effect* |

Table A8. *Breeding state designation sensitivity analysis:* Performance of multi-state models estimating the probability of transition ($\Psi$) between breeding and non-breeding states for black-legged kittiwakes at the Shoup Bay colony, Prince William Sound, Alaska, during 1995-2010 using a criterion of two sightings on a nest sight to designate breeding status, rather than the three sightings used in the primary analysis. Model structure for survival was held constant as state X time, and encounter probability model structure was set to the best competing structure from Table A8. Model weights are denoted by $w_i$, and K represents the number of estimable parameters in each model adjusted for any parameters fixed during analysis. Significance of covariate effects noted in comments for competitive models. $\Delta QAIC_c$ values reflect $\Delta AIC_c$ values adjusted according to a median $\hat{c}$ estimate of 1.03. Boldface denotes top scoring model.

| Set | Model | $\Delta QAIC_c$ | $w_i$ | K | Notes |
|---|---|---|---|---|---|
| *General structure* | $\Psi_{(state\ *\ year)}$ | 0.00 | >0.99 | 76 | |
| | $\Psi_{(state\ *\ trend)}$ | 16.15 | <0.01 | 50 | |
| | $\Psi_{(state\ +\ year)}$ | 110.96 | <0.01 | 62 | |
| | $\Psi_{(state\ +\ trend)}$ | 136.07 | <0.01 | 49 | |
| | $\Psi_{(state\ +\ period)}$ | 169.30 | <0.01 | 51 | |
| | $\Psi_{(state)}$ | 218.26 | <0.01 | 48 | |
| | $\Psi_{(year)}$ | 498.21 | <0.01 | 61 | |
| | $\Psi_{(trend)}$ | 518.63 | <0.01 | 48 | |
| | $\Psi_{(period)}$ | 566.67 | <0.01 | 50 | |
| | $\Psi_{(constant)}$ | 703.17 | <0.01 | 47 | |
| *Temporal covariates* | $\Psi_{(state\ *\ year)}$ | 0.00 | >0.99 | 76 | |
| | $\Psi_{(state\ *\ prod)}$ | 148.93 | <0.01 | 50 | |
| | $\Psi_{(state\ *\ PDO)}$ | 208.19 | <0.01 | 50 | |
| *Other covariates* | $\boldsymbol{\Psi_{(state\ *\ year\ +\ manip)}}$ | **0.00** | **0.99** | **76** | ***Significant negative manipulation effect*** |
| | $\Psi_{(state\ *\ year)}$ | 9.00 | 0.01 | 76 | |
| | $\Psi_{(state\ *\ year\ +\ 9194\ skip)}$ | 11.33 | <0.01 | 78 | *Insignificant 1991-1994 skipped breeding effect* |

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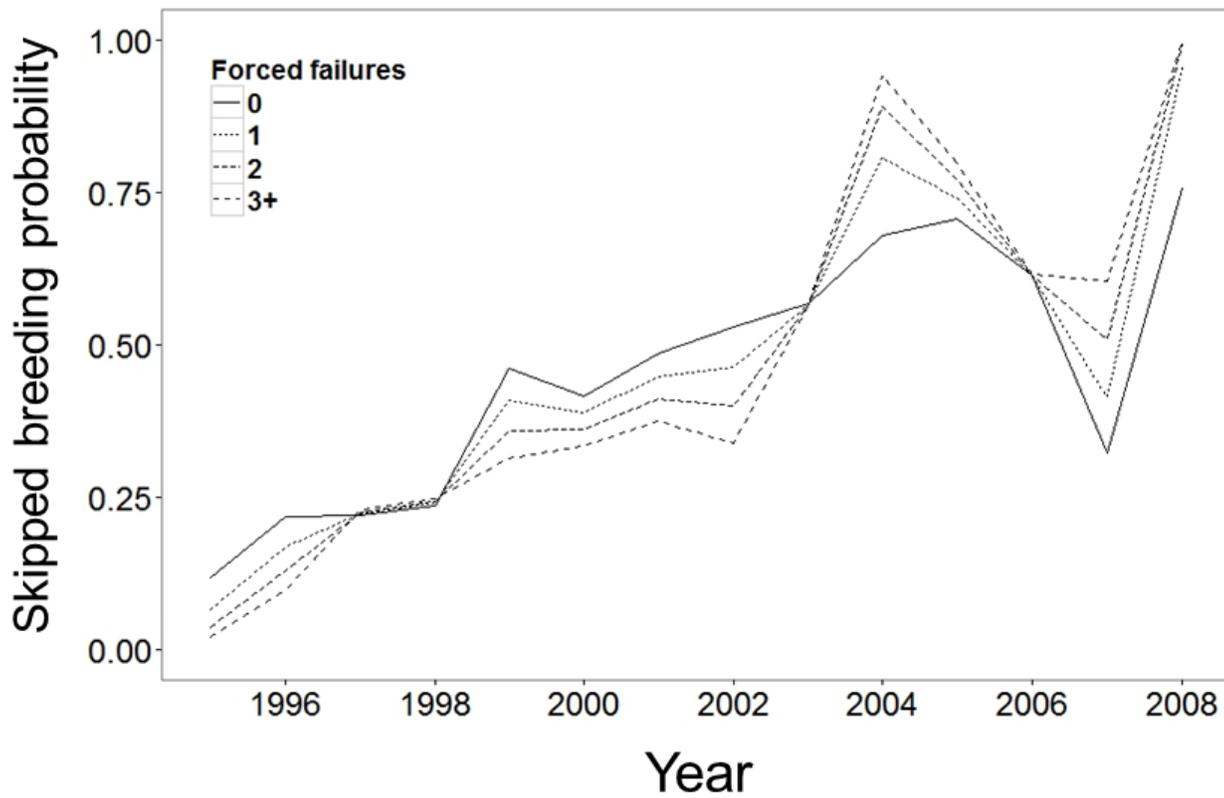
Figure A1. *Manipulation effect over time:* Annual probabilities of transitioning from a breeding to a

non-breeding state for Shoup Bay, Alaska, kittiwakes by the number of experimentally forced nest

failures during 1991-1994, from the multi-state transition model with a three way interaction among

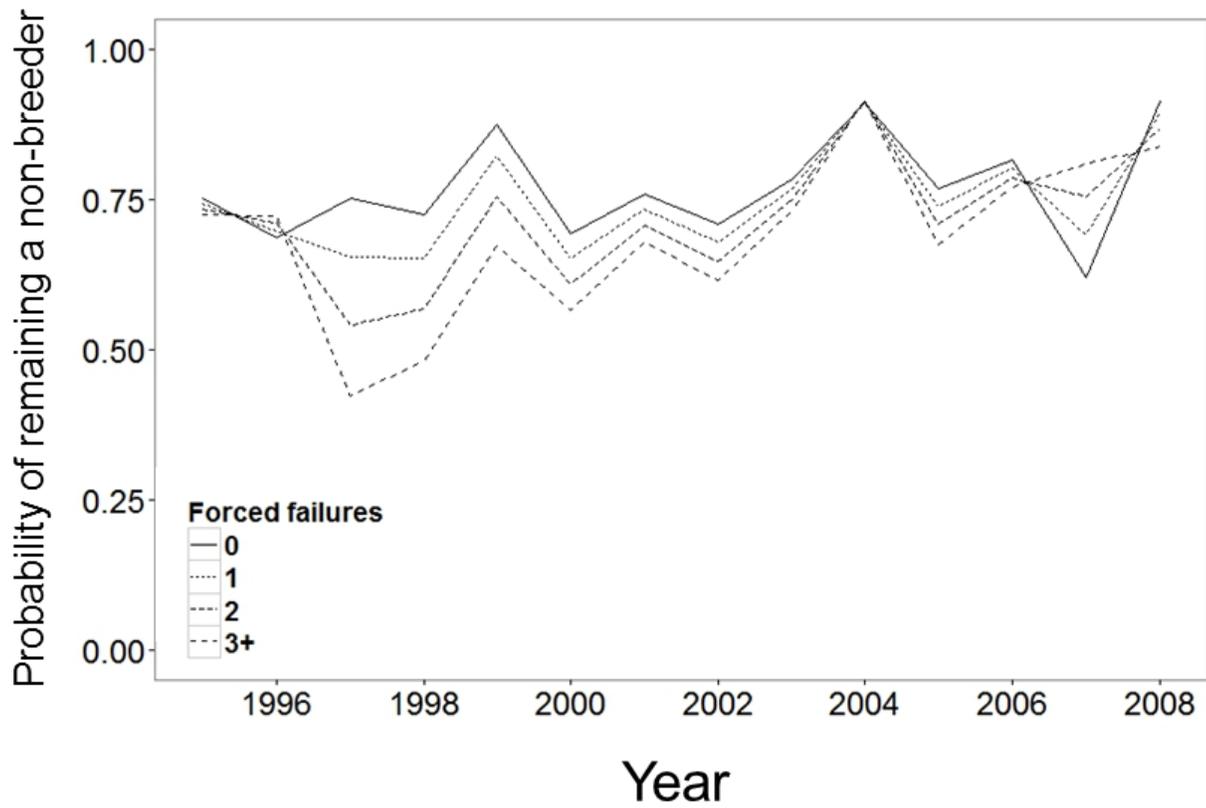breeding state, manipulation category, and year ($\Delta QAIC_c$ = 19.23, $w_i$ < 0.01).

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2   Figure A2. *Manipulation effect over time:* Annual probabilities of remaining in a non-breeding state for

3   Shoup Bay, Alaska, kittiwakes by the number of experimentally forced nest failures during 1991-1994,

4   from the multi-state transition model with a three way interaction among breeding state, manipulation

5   category, and year ($\Delta QAIC_c$ = 19.23, $w_i$ < 0.01).

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