Supplementary materials

Table A1. Results from the goodness of fit tests performed for 2 colonies on three species capture-recapture data from west Svalbard (data from 2005 to 2021). χ²: Pearson statistic (that tests the null hypothesis that data are homogeneous), df: degree of freedom, c-hat: variance inflation factor.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species | Colony | Test | χ² | P value | df | c-hat |
| Brünnich guillemot | Isfjorden | 3.SR | 41.42 | <0.001 | 13 |  |
| 3.SM | 16.06 | 0.516 | 17 |  |
| 2.CT | 117.14 | <0.001 | 14 |  |
| 2.CL | 42.03 | 0.009 | 23 |  |
| Kongsfjorden | 3.SR | 18.69 | 0.147 | 13 |  |
| 3.SM | 15.01 | 0.240 | 12 |  |
| 2.CT | 115.57 | <0.001 | 12 |  |
| 2.CL | 14.50 | 0.151 | 10 |  |
| Global | | 381.00 | <0.001 | 114 |  |
| Reduced (without 3.SR and 2.CT) | | 87.6 | 0.0179 | 62 | 1.41 |
| Little auk | Isfjorden | 3.SR | 33.43 | 0.002 | 15 |  |
| 3.SM | 36.53 | 0.013 | 20 |  |
| 2.CT | 213.41 | <0.001 | 14 |  |
| 2.CL | 59.36 | <0.001 | 28 |  |
| Kongsfjorden | 3.SR | 100.32 | <0.001 | 13 |  |
| 3.SM | 22.23 | 0.074 | 14 |  |
| 2.CT | 151.67 | <0.001 | 13 |  |
| 2.CL | 38.83 | 0.001 | 16 |  |
| Global | | 655.78 | <0.001 | 133 |  |
| Reduced (without 3.SR and 2.CT) | | 156.98 | <0.001 | 78 | 2.01 |
| Black- legged kittiwake | Isfjorden | 3.SR | 43.09 | <0.001 | 11 |  |
| 3.SM | 16.53 | 0.085 | 10 |  |
| 2.CT | 24.07 | 0.012 | 11 |  |
| 2.CL | 7.07 | 0.215 | 5 |  |
| Kongsfjorden | 3.SR | 229.55 | <0.001 | 11 |  |
| 3.SM | 83.37 | <0.001 | 21 |  |
| 2.CT | 118.77 | <0.001 | 11 |  |
| 2.CL | 34.67 | 0.094 | 25 |  |
| Global | | 557 | <0.001 | 105 |  |
| Reduced (without 3.SR and 2.CT) | | 141.64 | <0.001 | 51 | 2.78 |

Table A2. Results of the model selection procedure used to select the best reference model structure for brünnich guillemots, little auk and black legged kittiwake breeding in west Svalbard over the study periods. Dev: deviance of the model. QAICc: corrected quasi-likelihood Akaike Information Criterion. np: number of parameters estimated. Symbol “\*” indicates interaction, “+” indicates an additive effect, “f” indicates state “trap aware” or “trap-unaware”, “c” indicates colony, “t” indicates time (year), “a” age (2 age classes defined in a CMR sense as the number of years following the 1st capture). Parameters modelled were apparent survival (Φ) and recapture probability (p). Models in bold were the retained models.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Species | No | Model | np | Dev | QAICc |
| Black legged kittiwake | **Starting model** | | | | |
| 1 | Φ (a\*c\*t) p(f \*c\*t) | 94 | 6521.07 | 2539.36 |
| **Modelling recapture probability** | | | | |
| 2 | Φ (a\*c\*t) p([f +c]\*t) | 83 | 6530.79 | 2519.60 |
| 3 | Φ (a\*c\*t) p([f +t]\*c) | 74 | 6586.30 | 2520.66 |
| 4 | Φ (a\*c\*t) p(f \*t) | 71 | 6834.14 | 2603.54 |
| 5 | Φ (a\*c\*t) p(f \*c) | 52 | 6688.79 | 2511.76 |
| **6** | **Φ (a\*c\*t) p(f +c)** | **51** | **6689.75** | **2510.04** |
| 7 | Φ (a\*c\*t) p(f) | 50 | 6949.30 | 2601.34 |
| **Modelling survival probability** | | | | |
| 8 | Φ (a(1)\*c\*t)+a(2)\*t p(f +c) | 39 | 6726.54 | 2498.59 |
| 9 | Φ (a(1)\*c\*t)+a(2)\*c p(f +c) | 29 | 6773.08 | 2494.90 |
| 10 | Φ (a(1)\*c\*t)+a(2)\*[c+t] p(f +c) | 40 | 6724.14 | 2499.77 |
| **11** | **Φ (a(1)\*c\*t)+a(2) p(f +c)** | **28** | **6777.16** | **2494.33** |
| Brünnich guillemot | **Starting model** | | | | |
| 1 | Φ (a\*c\*t) p(f \*c\*t) | 111 | 5386.57 | 4032.85 |
| **Modelling recapture probability** | | | | |
| 2 | Φ (a\*c\*t) p([f +c]\*t) | 99 | 5439.37 | 4062.44 |
| **3** | **Φ (a\*c\*t) p([f +t]\*c)** | **87** | **5433.66** | **4032.85** |
| 4 | Φ (a\*c\*t) p(f \*t) | 86 | 5626.74 | 4167.66 |
| 5 | Φ (a\*c\*t) p(f \*c) | 61 | 5761.63 | 4210.80 |
| 6 | Φ (a\*c\*t) p(f +t) | 73 | 5648.75 | 4155.84 |
| 7 | Φ (a\*c\*t) p(f +c) | 60 | 5782.02 | 4223.18 |
| 8 | Φ (a\*c\*t) p(f) | 59 | 5893.79 | 4300.37 |
| **Modelling survival probability** | | | | |
| 9 | Φ (a(1)\*c\*t)+a(2)\*t p([f +t]\*c) | 76 | 5453.70 | 4023.82 |
| 10 | Φ (a(1)\*c\*t)+a(2)\*c p([f +t]\*c) | 63 | 5495.52 | 4026.24 |
| 11 | Φ (a(1)\*c\*t)+a(2)\*[c+t] p([f +t]\*c) | 77 | 5453.67 | 4025.91 |
| **12** | **Φ (a(1)\*c\*t)+a(2) p([f +t]\*c)** | **62** | **5496.53** | **4024.87** |
| Little auk | **Starting model** | | | | |
| 1 | Φ (a\*c\*t) p(f \*c\*t) | 115 | 9291.17 | 4858.34 |
| **Modelling recapture probability** | | | | |
| 2 | Φ (a\*c\*t) p([f +c]\*t) | 102 | 9318.66 | 4844.76 |
| **3** | **Φ (a\*c\*t) p([f +t]\*c)** | **90** | **9368.11** | **4844.33** |
| 4 | Φ (a\*c\*t) p(f \*t) | 88 | 9429.34 | 4870.64 |
| 5 | Φ (a\*c\*t) p(f \*c) | 63 | 9557.36 | 4882.66 |
| 6 | Φ (a\*c\*t) p(f +t) | 75 | 9499.39 | 4878.55 |
| 7 | Φ (a\*c\*t) p(f +c) | 62 | 9557.79 | 4880.82 |
| 8 | Φ (a\*c\*t) p(f) | 61 | 9593.28 | 4896.42 |
| **Modelling survival probability** | | | | |
| 9 | Φ (a(1)\*c\*t)+a(2)\*t p([f +t]\*c) | 78 | 9406.07 | 4838.33 |
| 10 | Φ (a(1)\*c\*t)+a(2)\*c p([f +t]\*c) | 65 | 9435.17 | 4825.98 |
| 11 | Φ (a(1)\*c\*t)+a(2)\*[c+t] p([f +t]\*c) | 79 | 9396.60 | 4835.68 |
| **12** | **Φ (a(1)\*c\*t)+a(2) p([f +t]\*c)** | **64** | **9440.12** | **4826.39** |

Table A3. Results of the ANODEV from the models testing for linear or quadratic trends on survival probability of brünnich guillemots, little auk and black legged kittiwake breeding in west Svalbard over the study periods. Dev: deviance. J: number of parameters describing the relationship between the survival probability and the trend. ANODEV is the F-statistic (F(df1,df2)) testing the null hypothesis that there is no trend on survival. R²: proportion of deviance explained by the trend. QAICc: corrected quasi-likelihood Akaike Information Criterion

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Trend | Dev | J | F-statistic | P-value | R² | QAICc |
| Black legged kittiwake | Linear | 6776.57 | 2 | 0.13 | 0.726 | 0.002 | 2495.61 |
| Quadratic | 6755.23 | 3 | 3.82 | 0.059 | 0.09 | 2489.94 |
| Brünnich guillemot | Linear | 5490.80 | 2 | 2.16 | 0.164 | 0.13 | 2860.45 |
| Quadratic | 5490.64 | 3 | 2.23 | 0.157 | 0.14 | 2862.46 |
| Little auk | **Linear** | **9420.22** | **2** | **19.68** | **<0.001** | **0.53** | **4818.55** |
| Quadratic | 9420.20 | 3 | 19.75 | <0.001 | 0.53 | 4820.59 |

Table A4. Results of the model testing for linear on breeding success of brünnich guillemot, black legged kittiwake and little auk breeding in west Svalbard over the study period. Bold characters give the models that best describe the shape of the trend (ΔAIC >2).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | Model | df | AICc | ΔAICc |
| Black legged kittiwake | Null | 1 | 678.99 | 14.94 |
| **Linear** | **2** | **664.05** | **0** |
| Brünnich guillemot | **Null** | **1** | **467.73** | **0** |
| Linear | 2 | 469.74 | 2.01 |
| Little auk | **Null** | **1** | **552.16** | **1.04** |
| Linear | 2 | 551.13 | 0 |



Figure A1. Residuals’ distribution for the binomial regression model testing for temporal trend in little auk breeding success.

Chart, line chart

Description automatically generatedChart, line chart, scatter chart

Description automatically generatedFigure A2. Residuals’ distribution for the binomial regression model testing for temporal trend in black legged kittiwake breeding success.

Chart, line chart

Description automatically generated

Figure A3. Residuals’ distribution for the binomial regression model testing for temporal trend in Brünnich guillemot breeding success.

Diagram

Description automatically generated

Figure A4. Survival estimates of Brünnich guillemot (A), black legged kittiwake (B) and little auk (C) modelled as function of the fjord.

Diagram

Description automatically generated

Figure A5. Estimate survival (from time dependent model) of Brünnich guillemot (A,D,G,J), black legged kittiwake (B,E,H,K) and little auk (C,F,I) according to maximum sea ice concentration without lag (A,B,C), with a one-year lag (D,E,F), with two-year lag (G,H,I) and with three-year lag (J,K). Plain line corresponds to the significant relationship between survival and maximum sea ice concentration.

Diagram, engineering drawing

Description automatically generated

Figure A6. Breeding success (residuals) of Brünnich guillemot (A,D,G,J), black legged kittiwake (B,E,H,K) and little auk (C,F,I) according to maximum sea ice concentration without lag (A,B,C), with a one-year lag (D,E,F), with two-year lag (G,H,I) and with three-year lag (J,K). Plain line corresponds to the significant relationship between breeding success and maximum sea ice concentration.