Supplemental Information:

Contrasting phenological and demographic responses of Atlantic Puffin (*Fratercula arctica*) and Razorbill (*Alca torda*) to climate change in the Gulf of Maine

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Table S1. Candidate models assessing change in Atlantic Puffin hatch date, reproductive success, and hatch success at Machias Seal Island, New Brunswick between 1995 – 2020 (1995 – 2019 for reproductive success and hatch success).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Model Predictors** | **k** | **AICc** | **ΛAICc** | **ω*i*** |
| **Hatch Date** *ARMA correlation structure: ~1|Year, p=1,q=1* | Year | 5 | 10614.95 | 0.00 | 0.61 |
| Null | 4 | 10615.80 | 0.86 | 0.39 |
| **Reproductive Success** *Models weighted by # active nests* | Year | 2 | 281.96 | 0.00 | 0.75 |
| Null | 1 | 284.19 | 2.23 | 0.25 |
| **Hatch Success** *Models weighted by # of nests with eggs* | Null | 2 | 171.12 | 0.00 | 0.61 |
| Year | 1 | 171.99 | 0.87 | 0.39 |

Table S2. Summary results of model-averaged Atlantic Puffin hatch date, reproductive success, hatch success, and year at Machias Seal Island, New Brunswick between 1995 – 2020 (1995 – 2019 for reproductive success and hatch success). Important parameters are in bold font.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Parameter** | **Estimate** | **Unconditional SE** | **Relative Importance** |
| **Hatch Date** | (Intercept) | -121.714 | 323.69 |  |
| **Year** | **0.243** | **0.140** | **0.61** |
| **Reproductive Success** | (Intercept) | 23.545 | 18.351 |  |
| **Year** | **-0.015** | **0.007** | **0.75** |
| **Hatch Success** | (Intercept) | 18.531 | 18.749 |  |
| **Year** | **-0.014** | **0.008** | **0.61** |

Table S3. Candidate models assessing change in Razorbill hatch date, reproductive success, and hatch success at Machias Seal Island, New Brunswick between 1995 – 2020 (1995 – 2019 for reproductive success and hatch success).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Model Predictors** | **k** | **AICc** | **ΛAICc** | **ω*i*** |
| **Hatch Date** *ARMA correlation structure: ~1|Year, p=5,q=1* | Year | 9 | 6815.99 | 0.00 | 0.59 |
| Null | 8 | 6816.68 | 0.69 | 0.41 |
| **Reproductive Success** *Models weighted by # active nests* | Year | 2 | 153.22 | 0.00 | 1.00 |
| Null | 1 | 167.00 | 13.78 | 0.00 |
| **Hatch Success** *Models weighted by # of nests with eggs* | Year | 2 | 146.08 | 0.00 | 1.00 |
| Null | 1 | 159.32 | 13.24 | 0.00 |

Table S4. Summary results of model-averaged Razorbill hatch date, reproductive success, hatch success, and year at Machias Seal Island, New Brunswick between 1995 – 2020 (1995 – 2019 for reproductive success and hatch success). Important parameters are in bold font.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Parameter** | **Estimate** | **Unconditional SE** | **Relative Importance** |
| **Hatch Date** | (Intercept) | 378.919 | 229.701 |  |
| **Year** | **-0.172** | **0.100** | **0.59** |
| **Reproductive Success** | (Intercept) | 61.573 | 15.504 |  |
| **Year** | **-0.031** | **0.008** | **1.00** |
| **Hatch Success** | (Intercept) | 65.108 | 16.547 |  |
| **Year** | **-0.032** | **0.008** | **1.00** |

Table S5. Spearman rank correlation coefficients for all environmental variables included in our candidate models evaluating the relationships between Atlantic Puffin phenology, productivity, and fledgling body condition (puffins only) between 1996 – 2020. Correlation coefficients >0.70 are highlighted in grey, these were considered important and not included in any candidate models together.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Prey Quality | NAO | Winter SST | Spring SST | Summer SST | Spring Air Temperature | Spring Precipitation | Summer Air Temperature | Summer Precipitation |
| Prey Quality |  |  |  |  |  |  |  |  |  |
| NAO | 0.22 |  |  |  |  |  |  |  |  |
| Winter SST | 0.13 | 0.36 |  |  |  |  |  |  |  |
| Spring SST | 0.19 | 0.09 | 0.75 |  |  |  |  |  |  |
| Summer SST | -0.13 | -0.21 | 0.73 | 0.77 |  |  |  |  |  |
| Spring Air Temperature | 0.02 | -0.33 | 0.67 | 0.83 | 0.95 |  |  |  |  |
| Spring Precipitation | 0.37 | -0.56 | 0.13 | 0.21 | 0.42 | 0.52 |  |  |  |
| Summer Air Temperature | 0.01 | -0.32 | 0.68 | 0.84 | 0.94 | 0.99 | 0.53 |  |  |
| Summer Precipitation | 0.54 | -0.54 | -0.12 | 0.14 | 0.20 | 0.36 | 0.92 | 0.37 |  |

Table S6. Spearman rank correlation coefficients for all environmental variables included in our candidate models evaluating the relationships between Razorbill phenology, productivity, and fledgling body condition (puffins only) between 1996 – 2020. Correlation coefficients >0.70 are highlighted in grey, these were considered important and not included in any candidate models together.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Prey Quality | NAO | Winter SST | Spring SST | Summer SST | Spring Air Temperature | Spring Precipitation | Summer Air Temperature | Summer Precipitation |
| Prey Quality |  |  |  |  |  |  |  |  |  |
| NAO | -0.41 |  |  |  |  |  |  |  |  |
| Winter SST | 0.82 | -0.37 |  |  |  |  |  |  |  |
| Spring SST | 0.58 | -0.16 | 0.59 |  |  |  |  |  |  |
| Summer SST | 0.31 | -0.33 | 0.53 | 0.79 |  |  |  |  |  |
| Spring Air Temperature | 0.38 | -0.43 | 0.47 | 0.83 | 0.81 |  |  |  |  |
| Spring Precipitation | 0.24 | -0.54 | 0.13 | 0.15 | 0.01 | 0.52 |  |  |  |
| Summer Air Temperature | 0.35 | -0.41 | 0.50 | 0.81 | 0.79 | 0.99 | 0.50 |  |  |
| Summer Precipitation | 0.43 | -0.43 | 0.21 | -0.01 | -0.28 | 0.25 | 0.87 | 0.24 |  |

Table S7. List of *a priori* candidate model sets evaluating the relationships between puffin and Razorbill phenology, productivity, and fledgling body condition (puffins only) 1) between 1995 – 2020 (hatch success to 2019) and at Machias Seal Island, New Brunswick, Canada and 2) with environmental conditions. Models with a “1” were run for puffins only, those with a “2” were run for Razorbills only.

1) 1995 – 2020 (Hatch success 1995-2019)

|  |
| --- |
| Phenology – Hatch Date |
| NULL  Year  Species  Year + Species + Year × Species |
| Phenology – Fledge Date (puffins only) |
| NULL  Year |
| Productivity |
| NULL  Year  Species  Year + Species + Year × Species |
| Productivity – Hatch Success |
| NULL  Year  Species  Year + Species + Year × Species |
| Productivity – Fledge Success |
| NULL  Year  Species  Year + Species + Year × Species |
| Fledgling Body Condition Index (puffins only) |
| NULL  Year |

2) Environmental Conditions:

|  |
| --- |
| Phenology – Hatch Date |
| NULL  Occupancy  Winter SST  Spring SST  Occupancy + Winter SST  Occupancy + Spring SST  2Occupancy + Winter SST + Spring SST  2Winter SST + Spring SST  NAO  NAO + Occupancy  NAO + Winter SST  NAO + Spring SST  2NAO + Winter SST + Spring SST  NAO + Occupancy + Winter SST  NAO + Occupancy + Spring SST  2NAO + Occupancy + Winter SST + Spring SST |
| Productivity – Hatch Success |
| NULL  Spring SST  Winter SST  Spring Air Temperature  Spring Precipitation  2Spring SST + Winter SST  Winter SST + Spring Air Temperature + Spring Precipitation  Spring Air Temperature + Spring Precipitation  Spring SST + Spring Precipitation  Winter SST + Spring Precipitation  2Spring SST + Winter SST + Spring Precipitation  Winter SST + Spring Air Temperature  NAO  NAO + Spring Air Temperature + Spring Precipitation  NAO + Spring Air Temperature  NAO + Spring Precipitation  NAO + Spring SST  NAO + Spring Precipitation + Spring SST |
| Productivity – Fledge Success |
| NULL  Hatch Date  Summer Air Temperature  Summer Precipitation  Prey Quality  Hatch Date + Summer Air Temperature  Hatch Date + Summer Precipitation  Hatch Date + Prey Quality  Hatch Date + Summer Air Temperature + Summer Precipitation  Hatch Date + Summer Air Temperature + Prey Quality  Summer Air Temperature + Summer Precipitation  Summer Air Temperature + Prey Quality  Summer Air Temperature + Summer Precipitation + Prey Quality  Summer Precipitation + Prey Quality |
| Fledgling Body Condition Index (puffins only) |
| NULL  Summer SST  Summer Air Temperature  Summer Precipitation  Prey Quality  Fledge Date  Summer SST + Summer Precipitation  Summer Air Temperature + Summer Precipitation  Summer SST + Prey Quality  Summer SST + Fledge Date  Summer SST + Fledge Date + Prey Quality  Summer SST + Summer Precipitation + Prey Quality  Summer SST + Summer Precipitation + Fledge Date  Summer SST + Summer Precipitation + Prey Quality + Fledge Date  Summer Air Temperature + Prey Quality  Summer Air Temperature + Fledge Date  Summer Air Temperature + Prey Quality + Fledge Date  Summer Air Temperature + Summer Precipitation + Prey Quality  Summer Air Temperature + Summer Precipitation + Fledge Date  Summer Air Temperature + Summer Precipitation + Prey Quality + Fledge Date  Summer Precipitation + Prey Quality  Summer Precipitation + Fledge Date  Summer Precipitation + Prey Quality + Fledge Date  Prey Quality + Fledge Date |