S.I. Figure 1. Flight altitudes (mASL) and ground elevation during migratory flights (*n* = 24) undertaken by four female continental black-tailed godwits carrying GPS trackers. Prefixes refer to the individual godwit and the number corresponds with the flights detailed in Table 1.

SI Figure 2. (A) Relationship between wing beat frequency and rate of altitudinal change during migratory flights undertaken by female continental black-tailed godwits carrying GPS trackers. Wing beat frequencies were derived from accelerometer data collected throughout each migratory flight. (B) Relationship between wing beat frequency and flight altitude (mASL). (C) Relationship between air speed and flight altitude (mASL). Colours represent measurements from different individual godwits.

Supplementary Information Table 1. Comparison of random effects among models relating in-flight behaviour to abiotic factors during migratory flights in black-tailed godwits tracked with GPS trackers, 2013 – 2014 (*n* = 4). Global models were used to determine which random effects were included in our final set of candidate models (see S.I. Tables 2, 3). Only those random effects that were included in the model with the lowest AICc score were included in the final model set.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Response Variable | Fixed Effects | Random Effect(s) | Variable | σ2 | St. Dev. | p-value | AICc |
| Flight Altitude | Ground Elevation | Flight | Flight | 661692 | 813.4 | <0.01 | 17368.7 |
|  |  | Individual + Flight | Flight | 661692 | 813.4 | <0.01 | 17370.7 |
|  |  |  | Individual | 0 | 0 | 1 |  |
|  |  | Individual|Flight | Flight | 488050 | 698.6 | 0.9 | 17382.7 |
|  |  |  | Individual B | 866331 | 930.8 |  |  |
|  |  |  | Individual C | 1204288 | 930.8 |  |  |
|  |  |  | Individual D | 560014 | 748.3 |  |  |
|  |  | Individual | Individual | 238492 | 488.4 | <0.01 | 17678.6 |
| Wing Beat Frequency | Rate of Change in Altitude | Individual + Flight | Individual | 0.12 | 0.35 | 0.02 | 1321.2 |
|  |  |  | Flight | 0.12 | 0.35 | <0.01 |  |
|  |  | Individual|Fight | Flight | 0.12 | 0.35 | 0.03 | 1322.5 |
|  |  |  | Individual C | 0.12 | 0.35 |  |  |
|  |  |  | Individual D | 0.41 | 0.64 |  |  |
|  |  | Flight | Flight | 0.37 | 0.61 | <0.01 | 1324.5 |
|  |  | Individual | Individual | 0.09 | 0.31 | <0.01 | 1485.5 |
| Wing Beat Frequency | Flight Altitude | Individual + Flight | Individual | 0.16 | 0.39 | 0.04 | 1410.0 |
|  |  |  | Flight | 0.16 | 0.40 | <0.01 |  |
|  |  | Flight | Flight | 0.28 | 0.52 | <0.01 | 1412.3 |
|  |  | Individual|Flight | Flight | 0.21 | 0.46 | 0.7 | 1419.4 |
|  |  |  | Individual C | 0.07 | 0.27 |  |  |
|  |  |  | Individual D | 0.40 | 0.65 |  |  |
|  |  | Individual | Individual | 0.12 | 0.35 | <0.01 | 1593.3 |
| Air Speed | Flight Altitude | Flight | Flight | 2.03 | 1.42 | <0.01 | 5673.0 |
|  |  | Individual + Flight | Individual | 2.3 x 10-14 | 1.5 x 10-7 | 1 | 5675.0 |
|  |  |  | Flight | 2.03 | 1.42 | <0.01 |  |
|  |  | Individual|Flight | Flight | 2.19 | 1.48 | 0.9 | 5687.9 |
|  |  |  | Individual B | 4.32 | 2.08 |  |  |
|  |  |  | Individual C | 1.86 | 1.37 |  |  |
|  |  |  | Individual D | 1.06 | 1.03 |  |  |
|  |  | Individual | Individual | 11.89 | 3.45 | 0.02 | 5780.6 |
| Ground Speed | Flight Altitude | Flight | Flight | 15.03 | 3.88 | <0.01 | 6523.2 |
|  |  | Individual + Flight | Individual | 0.00 | 0.00 | 1 | 6525.2 |
|  |  |  | Flight | 15.03 | 3.88 | <0.01 |  |
|  |  | Individual|Flight | Flight | 22.00 | 4.69 | 1 | 6538.5 |
|  |  |  | Individual B | 12.59 | 3.55 |  |  |
|  |  |  | Individual C | 10.28 | 3.21 |  |  |
|  |  |  | Individual D | 34.09 | 5.84 |  |  |
|  |  | Individual | Individual | 0.68 | 0.82 | <0.01 | 6918.1 |
| Flight Altitude (mAGL) | Ground Temperature + Ground Humidity + Altitude with Maximum Wind Support + Time Since Departure + Ground Wind Support | Flight | 815757 | 903.2 | <0.01 | 17026.8 |  |
|  |  | Flight | 815757 | 903.2 | <0.01 | 17028.8 |  |
|  |  | Individual | 0 | 0 | 1 |  |  |
|  |  | Flight | 593180 | 770.2 | 0.4 | 17035.3 |  |
|  |  | Individual B | 544364 | 737.8 |  |  |  |
|  |  | Individual C | 1859608 | 1363.7 |  |  |  |
|  |  | Individual D | 648915 | 805.6 |  |  |  |
|  |  | Individual | 682076 | 825.9 | <0.01 | 17310.91 |  |
| Rate of Change in Altitude | Time Since Departure + Previous Temperature + Previous Wind Support + Altitude with Maximum Wind + Previous Humidity + Previous Ground Elevation | Flight | 8.4 x 10-4 | 0.03 | 0.40 | 1039.8 |  |
|  |  | Individual | 1.2 x 10-16 | 1.1 x 10-8 | 1 | 1040.5 |  |
|  |  | Flight | 8.4 x 10-4 | 0.03 | 0.4 | 1041.8 |  |
|  |  | Individual | 0.00 | 0.00 | 1 |  |  |
|  |  | Flight | 6.9 x 10-18 | 2.6 x 10-9 | 1 | 1055.5 |  |
|  |  | Individual B | 3.7 x 10-3 | 0.06 |  |  |  |
|  |  | Individual C | 3.7 x 10-3 | 0.06 |  |  |  |
|  |  | Individual D | 4.5 x 10-4 | 0.37 |  |  |  |

Supplemental Information Table 2. Highest-ranked models (with lowest AICc scores) in candidate sets for models testing the relationship between in-flight behaviour and abiotic factors during migratory flights in continental black-tailed godwits tracked with GPS trackers for up to two consecutive years, 2013 – 2014 (*n* = 4). *K* indicates the number of parameters in each model. Only models with *wi* > 0.10 are included.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Response Variable | Predictor Variable(s) | *K* | Deviance | AICc | ΔAICc | *wi* |
| Flight Altitude Above Sea Level | Ground Elevation | 4 | 17361 | 17368.7 | 0.0 | 1.00 |
|  | Intercept | 3 | 17569 | 17575.4 | 206.7 | 0.00 |
| Wing Beat Frequency | Rate of Change in Altitude | 9 | 1311 | 1321.2 | 0.00 | 1.0 |
|  | Intercept | 8 | 1436 | 1451.7 | 130.5 | 0.0 |
| Wing Beat Frequency | Flight Altitude | 4 | 1398 | 1406.1 | 0.00 | 1.0 |
|  | Intercept | 3 | 1445 | 1451.3 | 45.1 | 0.0 |
| Air Speed | Flight Altitude | 4 | 5770 | 5671.3 | 0.00 | 1.0 |
|  | Intercept | 3 | 5802 | 5729.1 | 57.8 | 0.0 |
| Ground Speed | Flight Altitude | 4 | 6516 | 6524.2 | 0.00 | 1.0 |
|  | Intercept | 3 | 6540 | 6546.1 | 21.9 | 0.0 |
| Flight Altitude Above Ground Level | Ground Temperature + Ground Humidity + Altitude with Maximum Wind Support + Time Since Departure × Ground Wind Support | 9 | 17088 | 17106.1 | 0.0 | 0.97 |
|  | Ground Temperature + Ground Humidity + Altitude with Maximum Wind Support + Time Since Departure + Ground Wind Support | 8 | 17098 | 17113.7 | 7.6 | 0.02 |
| Rate of Change in Altitude | Time Since Departure + Previous Temperature × Previous Wind Support | 6 | 1011 | 1023.0 | 0.0 | 0.28 |
|  | Previous Ground Elevation + Previous Temperature × Previous Wind Support | 7 | 1010 | 1024.1 | 1.1 | 0.16 |

Supplementary Information Table 3. *β* coefficients for the factors from model relating in-flight behaviour to abiotic factors during the migratory flights of black-tailed godwits tracked with GPS trackers, 2013 – 2014 (*n* = 4). St. *β* = standardized *β* coefficients; Unst. *β* = unstandardized *β* coefficients. Model averaging was employed when no single model had a *wi* > 0.90 (see S.I. Table 2).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | Variable | St. *β* | Unst. *β* | SE | 95% CI | Random Effect | σ2 | St. Dev. |
| Flight Altitude Above Sea Level | Intercept | 1484.80 | 1042.64 | 171.20 | 1148.97, 1820.72 | Flight | 661692 | 813.4 |
|  | Ground Elevation | 1214.30 | 1.82 | 79.6 | 1058.14, 1370.53 |  |  |  |
| Wing Beat Frequency | Intercept | 6.43 | 6.43 | 0.05 | 6.33, 6.52 | Flight | 0.12 | 0.35 |
|  | Rate of Change in Altitude | 0.52 | 0.69 | 0.04 | 0.44, 0.61 | Ind. | 0.12 | 0.35 |
| Flight Altitude | Intercept | 6.28 | 6.07 | 0.13 | 6.03, 6.54 | Flight | 0.26 | 0.51 |
|  | Flight Altitude | 0.39 | 1.4 x 10-4 | 0.06 | 0.28, 0.50 | Ind. | 0.16 | 0.39 |
| Air Speed | Intercept | 16.93 | 15.95 | 0.31 | 16.33, 17.52 | Flight | 1.93 | 1.39 |
|  | Flight Altitude | 1.75 | 6.35 x 10-4 | 0.22 | 1.31, 2.19 |  |  |  |
| Ground Speed | Intercept | 17.73 | 16.82 | 0.79 | 16.18, 19.28 | Flight | 14.36 | 3.79 |
|  | Flight Altitude | 1.62 | 5.9 x 10-4 | 0.33 | 0.98, 2.27 |  |  |  |
| Flight Altitude Above Ground Level | Intercept | 1295.06 | 733.09 | 183.74 | 919.15, 1669.59 | Flight | 770239 | 877.6 |
|  | Ground Humidity | -554.75 | -13.20 | 160.17 | -870.29, -237.11 |  |  |  |
|  | Ground Temperature | 953.84 | 75.09 | 216.89 | 525.43, 1386.78 |  |  |  |
|  | Ground Wind Support | -359.57 | -82.45 | 95.97 | -547.92 -171.28 |  |  |  |
|  | Altitude with Maximum Wind Support | 689.91 | 0.20 | 82.43 | 528.18, 851.65 |  |  |  |
|  | Time Since Departure | -195.79 | -371.97 | 86.83 | -366.37, -25.16 |  |  |  |
|  | Time Since Departure × Ground Wind Support | 475.40 | 81.10 | 152.53 | 175.73, 775.05 |  |  |  |
| Rate of Change in Altitude | Intercept | -0.01 | -4.6 x 10-3 | 0.01 | -0.03, 0.02 | Flight | 8.4 x 10-4 | 0.03 |
|  | Time Since Departure | -0.06 | -0.08 | 0.02 | -0.10, -0.01 |  |  |  |
|  | Previous Temperature | 0.10 | 8.1 x 10-3 | 0.03 | 0.04, 0.16 |  |  |  |
|  | Previous Ground Elevation | 0.06 | 1.1 x 10-4 | 0.03 | 0.01, 0.11 |  |  |  |
|  | Previous Wind Support | 0.06 | 6.2 x 10-3 | 0.02 | 0.02, 0.11 |  |  |  |
|  | Previous Temperature × Previous Wind Support | -0.14 | -7.3 x 10-4 | 0.05 | -0.24, -0.05 |  |  |  |