

SUPPORTING INFORMATION

North or south? Niche separation of endemic red-legged kittiwakes and sympatric black-legged kittiwakes during their non-breeding migrations

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Appendix S1 Morphometrics of red-legged and black-legged kittiwakes.

Morphometrics of red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*, from colonies on St George and St Paul islands of the Pribilof Islands, Alaska, USA, were tested for species, sex and colony differences. The degree of sexual dimorphism in each morphometric was assessed using an index of sexual size dimorphism (SSD), where positive values indicate males are larger than females, defined as $SSD = (\text{male} - \text{female})/\text{female} \times 100$ (Table S1). Comparisons between the sexes are the result of one-way ANOVAs within each species. Species' *P*-values are the result of a two-way ANOVA with species and sex as factors (Table S2). Colony differences were tested for BLKIs only, as just two RLKIs were tracked from St Paul, with a two-way ANOVA including sex as a factor (Table S1). Mass was measured at first capture, prior to instrument attachment, during the chick brooding phase of breeding. Natural wing chord was measured in the field as the measurement from the carpal joint to the tip of the primary feathers, while wing chord (or width) was calculated from measurements at five equally spaced points along each tracing following Pennycuick (2008). Culmen indicates the straight-line measurement from the tip of the beak to the point where feathering starts at the base of the bill. Head+bill indicates the straight-line measurement from the tip of the beak to the back of the head. Tarsus was measured as the diagonal distance between the notch at the tarsal joint to the end of the tarsus.

REFERENCE

Pennycuick, C.J. (2008) *Modelling the flying bird*. Elsevier Inc., London.

Table S1 Morphometric characteristics (mean \pm SD) of male and female red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*, from colonies on St George and St Paul islands of the Pribilof Islands, Alaska, USA. Significant differences are highlighted in bold. Sample sizes are shown in parentheses.

| Size metric | Female | Male | SSD | F | P |
|--|-----------------------|-----------------------|--------------|--------------|------------------|
| RLKI | | | | | |
| Mass (g) | 365.6 \pm 45.9 (14) | 379.1 \pm 24.2 (18) | 3.69 | 77.63 | 0.800 |
| Culmen (mm) | 29.0 \pm 1.8 (14) | 29.8 \pm 1.4 (18) | 2.76 | 1.89 | 0.180 |
| Head + bill (mm) | 81.8 \pm 3.9 (14) | 84.3 \pm 2.7 (18) | 3.06 | 4.70 | 0.038 |
| Tarsus (mm) | 31.8 \pm 1.9 (14) | 31.5 \pm 1.5 (18) | -0.94 | 0.21 | 0.650 |
| Natural wing chord (mm) | 308.5 \pm 6.8 (14) | 310.8 \pm 6.6 (18) | 0.75 | 0.96 | 0.336 |
| Wing span (B, cm) | 95.15 \pm 3.24 (4) | 96.13 \pm 6.70 (3) | 1.03 | 0.068 | 0.804 |
| Wing area (S_{wing} , cm ²) | 898 \pm 106 (4) | 939 \pm 81 (3) | 4.57 | 0.308 | 0.603 |
| Wing chord [c_m , (S_{wing}/B), cm] | 9.44 \pm 0.81 (4) | 9.78 \pm 0.27 (3) | 3.60 | 0.477 | 0.521 |
| Wing loading (N/m ²) | 40.41 \pm 5.4 (4) | 39.67 \pm 3.04 (3) | -1.83 | 0.044 | 0.842 |
| Aspect ratio (B/c_m) | 10.12 \pm 0.58 (4) | 9.83 \pm 0.61 (3) | -2.87 | 0.415 | 0.548 |
| BLKI | | | | | |
| Mass (g)* | 380.6 \pm 30.8 (24) | 435.3 \pm 36.3 (26) | 14.37 | 26.66 | <0.001 |
| Culmen (mm) | 38.5 \pm 1.4 (24) | 40.8 \pm 1.6 (26) | 5.97 | 23.35 | <0.001 |
| Head + bill (mm) | 93.5 \pm 2.2 (24) | 98.5 \pm 2.2 (26) | 5.35 | 45.87 | <0.001 |
| Tarsus (mm) | 34.5 \pm 1.6 (24) | 36.7 \pm 1.7 (26) | 6.38 | 18.26 | <0.001 |
| Natural wing chord (mm)* | 311.4 \pm 7.4 (24) | 320.9 \pm 6.1 (26) | 3.08 | 17.45 | <0.001 |
| Wing span (B, cm) | 101.4 \pm 2.5 (17) | 105.0 \pm 2.4 (10) | 3.55 | 7.72 | <0.001 |
| Wing area (S_{wing} , cm ²) | 1063 \pm 77 (17) | 1125 \pm 77 (10) | 5.83 | 4.046 | 0.055 |
| Wing chord [c_m , (S_{wing}/B), cm] | 10.50 \pm 0.59 (17) | 10.72 \pm 0.60 (10) | 2.10 | 0.90 | 0.351 |
| Wing loading (N/m ²)* | 35.71 \pm 4.85 (17) | 38.64 \pm 4.07 (10) | 8.20 | 2.578 | 0.121 |
| Aspect ratio (B/c_m) | 9.67 \pm 0.44 (17) | 9.82 \pm 0.49 (10) | 1.55 | 0.601 | 0.444 |

*Colony significantly different: mass, St Paul 419 \pm 40.7 (19), St George 387.9 \pm 38.2 (22), $F = 13.66$, $P < 0.001$; natural wing chord, St Paul 317.9 \pm 7.7 (19), St George 312.9 \pm 8.1 (22), $F = 7.10$, $P = 0.011$; wing loading, St Paul 38.3 \pm 4 (18), St George 33.7 \pm 4.7 (9), $F = 6.91$, $P = 0.015$).

Table S2 Comparison of species morphometric characteristics between red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*, from the Pribilof Islands, Alaska, USA. Results are from two-way ANOVAs with species and sex as factors. Significant differences are highlighted in bold.

| Size metric | <i>F</i> | <i>P</i> |
|---|-----------------|------------------|
| Mass (g) | 13.25 | <0.001 |
| Culmen (mm) | 768.07 | <0.001 |
| Head + bill (mm) | 88.02 | <0.001 |
| Tarsus (mm) | 356.69 | <0.001 |
| Natural wing chord (mm) | 11.42 | 0.001 |
| Wing span (B, cm) | 31.87 | <0.001 |
| Wing area (S_{wing} , cm ²) | 24.85 | <0.001 |
| Wing chord [c_m , (S_{wing}/B), cm] | 15.35 | <0.001 |
| Wing loading (N/m ²) | 2.87 | 0.101 |
| Aspect ratio (B/c_m) | 1.72 | 0.200 |

Appendix S2 Migration characteristics of red-legged and black-legged kittiwakes.

Migration characteristics of red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*, from the subarctic North Pacific, tracked with geolocation loggers from September 2010 to May 2011 (Table S3). Utilization distributions (UDs) were calculated using smoothed locations for the pooled samples and for each individual. The grid cell size was set at 80 km. The smoothing parameter was selected using the entire dataset (latitude 0.0171, longitude 0.00681; Sheather & Jones, 1991). Portions of UD overlapping land were subtracted from area calculations. To calculate departure and return dates, sea-surface temperatures were used to estimate latitudes for those loggers that recorded temperature (BLKI = 27, RLKI = 8) and then the tracks were speed filtered (Shaffer *et al.*, 2005).

REFERENCES

- Shaffer, S.A., Tremblay, Y., Awkerman, J.A., Henry, R.W., Teo, S.L.H., Anderson, D.J., Croll, D.A., Block, B.A. & Costa, D.P. (2005) Comparison of light- and SST-based geolocation with satellite telemetry in free-ranging albatrosses. *Marine Biology*, **147**, 833–843.
- Sheather, S.J. & Jones, M.C. (1991) A reliable data-based bandwidth selection method for kernel density estimation. *Journal of the Royal Statistical Society B: Methodological*, **53**, 683–690.

Table S3 Migration characteristics (mean \pm SD) of red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*, from the subarctic North Pacific; *P*-values indicate species differences and are the result of two-way ANOVAs with species and sex as factors. ANOVAs did not assume that variances were equal. Sample sizes are given in parentheses. Significant differences are highlighted in bold.

| | RLKI | BLKI | <i>F</i> | <i>P</i> |
|---|------------------------------|--------------------------------|-----------------|--------------------|
| Departure date | 28 September \pm 21 (8) | 24 September \pm 17 (26) | 0.36 | 0.058 |
| Return date | 22 March \pm 3 (8) | 26 March \pm 23 (25) | 0.24 | 0.626 |
| Trip duration (days) | 175 \pm 22 (8) | 183 \pm 30 (25) | 0.51 | 0.480 |
| Maximum range (km) | 2,600 \pm 400 (17) | 2,800 \pm 800 (34) | 0.85 | 0.361 |
| Date at maximum range | 16 January \pm 15 (17) | 25 January \pm 27 (34) | 1.51 | 0.224 |
| Bearing to maximum range ($^{\circ}$) | 259 \pm 11 (17) | 220 \pm 43 (34) | 14.62 | < 0.001* |
| Individual area of 50% UD (km ²) [†] | 468,000 \pm 202,000 (17) | 674,000 \pm 249,000 (34) | 8.59 | 0.005 |
| Individual area of 95% UD (km ²) [†] | 2,212,000 \pm 672,000 (17) | 3,197,000 \pm 1,062,000 (34) | 11.80 | 0.001 |
| Area of 50% UD (km ²) | 1,281,000 (17) | 2,219,000 (34) | – | – |
| Area of 95% UD (km ²) | 5,534,000 (17) | 9,874,000 (34) | – | – |

*Bearing to maximum range (location at the maximum distance from the colony), female 224.5 \pm 45.7, male 248.5 \pm 22.1, *F* = 6.81, *P* = 0.012.

[†]Average area of utilization distribution (UD) for individual birds.

Appendix S3 Overlap of utilization distributions between colonies and sexes of kittiwakes.

To determine spatial partitioning between species [red-legged kittiwakes (RLKIs), *Rissa brevirostris*, and black-legged kittiwakes (BLKIs), *Rissa tridactyla*], colonies (BLKIs only, due to the small sample size of RLKIs from St Paul Island) and sexes, the amount of overlap between observed distributions in the subarctic North Pacific was compared with the overlap from 1000 bootstrapped selections from the pooled dataset (Fig. S1). The area of overlap divided by the area of the 95% utilization distributions (UDs) of the overall dataset was used as the test statistic, and the *P*-value was determined as the proportion of iterations that resulted in a smaller overlap than observed (Breed *et al.*, 2006).

REFERENCE

Breed, G.A., Bowen, W.D., McMillan, J.I. & Leonard, M.L. (2006) Sexual segregation of seasonal foraging habitats in a non-migratory marine mammal. *Proceedings of the Royal Society B: Biological Sciences*, **273**, 2319–2326.

Figure S1 Bootstrap area of overlap for 1000 iterations at 50% and 95% utilization distributions (UDs) and kernel density plots of observed distributions in the subarctic North Pacific between (a) colonies of black-legged kittiwakes (BLKIs), *Rissa tridactyla* (St Paul Island, green, $n = 15$; St George Island, grey, $n = 19$), (b) sexes of BLKI (male, blue, $n = 10$; female, grey, $n = 24$) and (c) sexes of red-legged kittiwakes (RLKIs), *Rissa brevirostris* (male, blue, $n = 10$; female, grey, $n = 7$). Coloured circles on box plots correspond to the percentage of area overlapped by the observed groups.

