

Supplementary material

Appendix 1: Body Condition Scoring Protocol

Fat Scoring: Many different fat scoring systems exist, and they are not all easily comparable—even systems with the same number of categories do not necessarily have the same cut-off points between categories. Our protocol uses the fat scoring system that Danner (2012) devised for use on swamp sparrows (*Melospiza georgiana*). In this system, the fat scores for the furcular hollow and the abdomen are taken separately (most systems use scores that combine information for these two areas).

Hold the bird in banded's grip in one hand and hold its legs in your other hand so that the bird is secure and you have an open view of its throat and breast. From a few inches away, gently blow to part the feathers around the upper and lower breast so you can see the skin. Subcutaneous fat is stored just under the skin. You will be able to recognize it based both on color, which is yellow or orange in contrast to the red/pink areas where the skin covers muscle. Look for fat stores in two places: 1) in the furcular hollow, which is between the throat and the keel; and 2) along the lower abdomen, at the edge of the keel. If there is no fat stored in the furcular hollow, it will appear convex. If there is fat, the surface of the fat will appear flat, unless it exceeds the furcular hollow, in which case it will have a bulging shape. Along the abdomen, fat stores will begin in a line—along the edge of the keel—and, as more fat is deposited, will spread to cover more of the abdomen.

Assign a separate score for furcular hollow and abdominal fat according to the following descriptions:

Furcular hollow fat scores:

0 = No visible fat

1 = Fat fills <25% of furcular hollow

2 = Fat fills 26–50% of furcular hollow

3 = Fat fills 51–75% of furcular hollow

4 = Fat fills 76–99% of furcular hollow

5 = Fat flush with furcular hollow

6 = Fat convex (exceeding furcular hollow)

Abdominal fat scores:

0 = No visible fat

1 = Light fat under ribcage, none on abdomen

2 = Heavy fat under ribcage, none abdomen

3 = Fat under ribcage and partially covering abdomen

4 = Fat under ribcage and completely covering abdomen

5 = Fat on abdomen flush with ribcage

6 = Fat convex (exceeding the ribcage)

Pectoral muscle scoring: Pectoral muscles should be scored through a combination of tactile and visual inspection. The system is based on examining two related characters, the prominence of the keel and the shape of the muscles. Hold the bird in a standard bander's grip on its back in the palm of your hand so that you are looking at its belly. Gently roll your index finger over the pectoralis muscle on either side of the bird's mid-line, to assess its size relative

to the keel. Secondly, you can assess the size of the muscle visually by blowing the feathers apart and looking down the long axis of the bird in a manner similar to that described for fat scores (above).

Pectoral muscle scores:

0 = Pectoral muscle not detectable

1 = Muscle concave and not covering all of the ribs, keel very prominent (keel sharp to the touch)

2 = Muscle concave and covering all of the ribs (keel sharp to the touch)

3 = Muscle concave, half way up keel (keel sharp to the touch)

4 = Muscle concave, almost flush with keel (can feel keel)

5 = Muscle flush with keel (cannot feel keel)

6 = Muscle convex (bulging past keel)

Note that “concave” here refers to the shape of the muscle with respect to the keel – i.e., if you can feel the keel then the muscle is concave. Farther down towards the wings, the muscle will always be concave because the underlying ribcage is concave. In other words, for levels 5 and 6, the muscle should slope in a simple curve from the keel down under the wings. In contrast, for levels 4 and lower, the muscle will have a sinusoidal “S-like” shape following the contour of the underlying skeleton.

Reference:

Danner, R. 2012. The effects of limited winter food availability on the population dynamics, energy reserves, and feather molt of the Swamp Sparrow. – PhD Dissertation. Biological Sciences. Virginia Polytechnic Institute.

Appendix 2: Scaled Mass Index

Following the method of Peig and Green (2009), we calculated a scaled mass index (SMI) for each individual. The SMI is a mass-based body condition proxy that accounts for the fact that increases in mass are correlated with increases in body size (Green 2001; Peig and Green 2009, 2010). In the field, we weighed each bird to the nearest 0.1 g using a Pesola scale and collected the following morphological measurements: tarsus length, unflattened wing chord, culmen length, nares to bill-tip (nalospi), and head length (back of the head to bill tip). The SMI adjusts mass to a standard body size, using the slope from a standardized major axis (SMA) regression

as a scaling coefficient in the following equation: $\hat{M}_i = M_i \left[\frac{L_0}{L_i} \right]^{b_{SMA}}$ where L_0 is an average length measurement, L_i and M_i are the length and mass measurements of a particular individual, and b_{SMA} is the slope from an SMA regression (Peig and Green 2009). This method accounts for error in structural length measurements and leaves the standardized mass in the same units as the original mass (Peig and Green 2009).

To be used in an assessment of body condition, a body size measurement should correlate linearly with, yet be independent of mass, be independent of body condition, and reflect overall body size (Green 2001). As numerous body length measurements could fulfill these conditions, Peig and Green (2009) recommend selecting the measurement that correlates most strongly with mass. To select a morphological measurement for use in calculating the SMI scaling coefficient, we assessed the correlation between mass and each structural measurement on a natural log scale. Because mass can change throughout the annual cycle, based on fluctuations in muscle development, fat storage, and, for females, egg growth and

laying (Cresswell 2009), we assessed the mass by length correlations for five groups of saltmarsh sparrows representing different periods of the year: 1) all captured on the breeding grounds, 2) all captured during the winter; 3) all captured on the breeding grounds before 1 June (“spring”); 4) all captured on the breeding grounds during the breeding season (1 June through 31 August); 5) all captured on the breeding grounds after 1 September (“fall”).

Tarsus and wing chord had the highest correlations with mass in four of the five groups, including all winter birds and all breeding birds (Table 1, Figure 1). Because wing chord can vary throughout the entire annual cycle due to feather wear (Flinks and Salewski 2012), we chose to use tarsus as the measurement for calculating the scaling coefficient. Although tarsus was most strongly correlated with mass for fall birds (Table 1), we decided not to use birds captured in the fall because our sample size, particularly for seaside sparrows, was lower than during the breeding or winter seasons, and because the fall birds had a wide range of fat scores. We chose to use winter birds rather than breeding birds to avoid including females carrying egg mass.

We used the R package *smatr* (Warton et al. 2012) to run SMA regressions to fit the relationship between $\ln(\text{mass})$ and $\ln(\text{tarsus})$ in winter sparrows. To evaluate sensitivity to our decision to use tarsus as the structural measurement, we also ran SMA regressions with the other structural measurements for male and female saltmarsh and seaside sparrows caught on the wintering grounds. Tarsus had the best SMA regression fit for male Saltmarsh, and male and female seaside sparrows, and the second best fit (after wing chord) for female saltmarsh sparrows (Table S2). We also conducted pairwise comparisons of the SMA regressions between males and females of each species to evaluate the consistency in slopes between sexes. In nine of the ten comparisons, via likelihood ratio tests (Warton et al. 2006), there was no difference

in the SMA slopes between conspecific males and females (Table 2, Figures 2A,B). Next, we combined data from both sexes of each species and compared the SMA slopes for $\ln(\text{mass})$ vs. $\ln(\text{tarsus})$ for wintering saltmarsh and seaside sparrows and found no difference (likelihood ratio statistic = 0.67, 1 df, $p = 0.413$), for a combined slope of 2.06 (Figure 2C). We used the SMA slope of $\ln(\text{mass})$ vs. $\ln(\text{tarsus})$ from all wintering birds as the scaling coefficient in all SMI calculations following the formula used by Peig and Green (2009), as indicated above.

References:

- Cresswell, W. 2009. The use of mass and fat reserve measurements from ringing studies to assess body condition. – *Ringing and Migration*. 24: 227-232.
- Danner, R. 2012. The effects of limited winter food availability on the population dynamics, energy reserves, and feather molt of the Swamp Sparrow. – PhD Dissertation. Virginia Polytechnic Institute Blacksburg, VA.
- Flinks, H. and Salewski, V. 2012. Quantifying the effect of feather abrasion on wing and tail lengths measurements. – *J. Ornithol.* 153: 1053-1065.
- Green, A. J. 2001. Mass/length residuals: measures of body condition or generators of spurious results? – *Ecology* 82: 1473-1483.
- Peig, J. and Green, A. J. 2009. New perspectives for estimating body condition from mass/length data: the scaled mass index as an alternative method. – *Oikos* 118: 1883-1891.
- Peig, J. and Green, A. J. 2010. The paradigm of body condition: a critical reappraisal of current methods based on mass and length. – *Funct. Ecol.* 24: 1323-1332.

Warton, D. I., Duursma, R. A., Falster, D. S. and Taskinen, S. 2012. smatr 3 - and R package for estimation and inference about allometric lines. – *Methods Ecol. Evol.* 3: 257-259.

Warton, D. I., Wright, I. J., Falster, D. S. and Westoby, M. 2006. Bivariate line-fitting methods for allometry. – *Biol. Rev.* 81: 259-291.

Table A1: Correlation coefficients depicting correlations between $\ln(\text{mass})$ and the natural log of each structural measurement for the following categories of saltmarsh sparrows: captured on the breeding grounds before 1 June (Spring); captured on the breeding grounds after 31 August (Fall), captured on the breeding grounds between 1 June to 31 August (Breeding), captured on the breeding grounds (All breeding grounds); captured on the wintering grounds (Winter).

	Spring	Fall	Breeding	All Breeding grounds	Winter
Wing by mass	0.35	0.61	0.48	0.46	0.42
Tarsus by mass	0.29	0.53	0.33	0.34	0.46
Culmen by mass	0.20	0.33	0.11	0.14	0.26
Nalospa by mass	0.26	0.41	0.02	0.15	0.23
Head by mass	0.38	0.44	0.25	0.28	0.50

Table A2: Slopes and R^2 values from SMA regressions between $\ln(\text{mass})$ and the natural log of each structural measurement for male and female saltmarsh and seaside sparrows. The p values are from likelihood ratio tests of the difference between the slopes for males and females for each structural measurement.

Saltmarsh sparrow							
	Males		Females		Likelihood ratio statistic	df	p
	Slope	R²	Slope	R²			
Wing	2.41	0.097	2.42	0.19	2.635e-05	1	0.99
Tarsus	2.19	0.13	2.55	0.17	2.64	1	0.10
Culmen	1.96	0.03	2.19	0.06	0.93	1	0.33
Nalosp	2.03	0.03	2.33	0.06	2.05	1	0.15
Head	0.06	0.04	0.07	0.03	2.24	1	0.13
Seaside sparrow							
	Males		Females		Likelihood ratio statistic	df	p
	Slope	R²	Slope	R²			
Wing	2.24	0.05	2.10	0.20	0.36	1	0.54
Tarsus	1.98	0.17	2.42	0.22	4.15	1	0.04
Culmen	2.00	0.10	2.13	0.13	0.32	1	0.58
Nalosp	1.64	0.03	1.71	0.06	0.15	1	0.70
Head	3.90	0.14	3.80	0.17	0.07	1	0.79

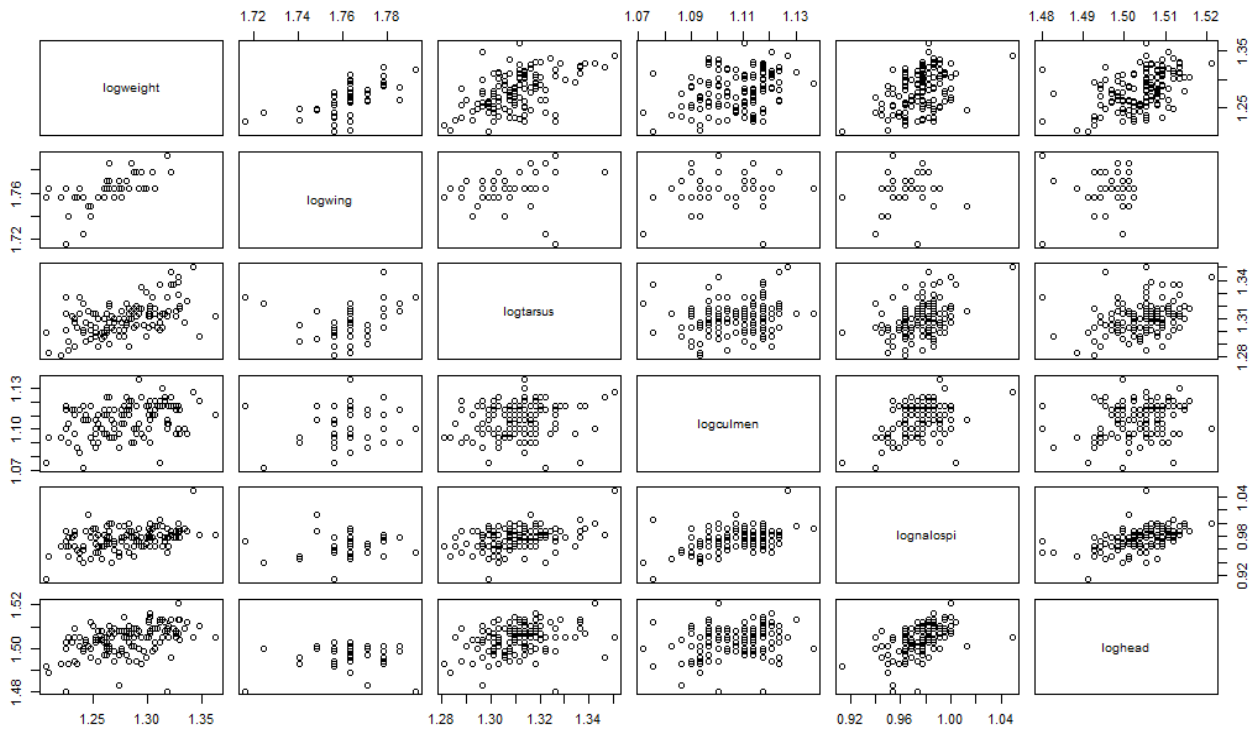


Figure A1: Pairs plot depicting correlations between $\ln(\text{mass})$ and natural log of each structural measurement. From left, the measurements are wing chord, tarsus, culmen, nalospi, and head length. The data are from all adult saltmarsh sparrows caught on the breeding grounds.

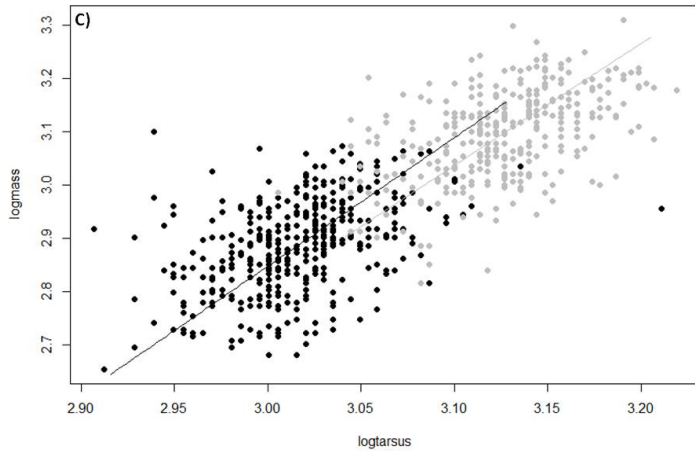
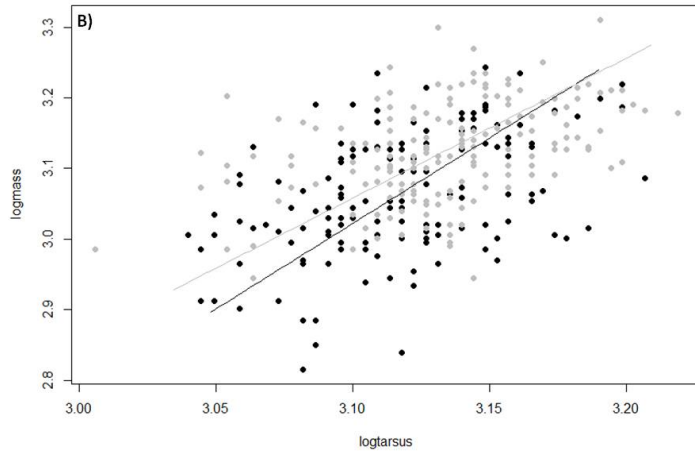
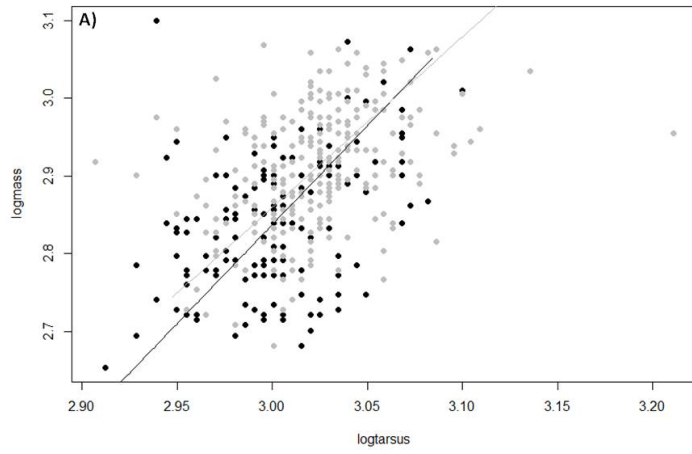


Figure A2: SMA regressions for $\ln(\text{mass})$ by $\ln(\text{tarsus})$ in A) winter saltmarsh sparrows; B) winter seaside sparrows; C) all winter birds. In figures A and B, females are in black and males are in gray. In figure C, Saltmarsh Sparrows are in black and seaside sparrows are in gray. There was no difference in the slopes for male vs. female saltmarsh sparrows (likelihood ratio statistic = 2.64; $df = 1$, $p = 0.104$) or saltmarsh vs. seaside sparrows (likelihood ratio statistic = 0.6701; $df = 1$, $p = 0.413$). There was a significant difference between the slopes for male and female seaside sparrows (likelihood ratio statistic = 4.15; $df = 1$, $p = 0.042$).

Appendix 3: Model Code

Model for apparent annual survival:

uninformative priors for sd and precision terms (tau) for distribution of regression coefficients (sd for coefficients for S; sd2 for coefficients for p); the prior for sd is narrower to keep likely values for S on a biologically relevant 0-1 scale

```
sd ~ dunif(0, 1)
```

```
tau <- 1/(sd*sd)
```

```
sd2 ~ dunif(0, 1000)
```

```
tau2 <- 1/(sd2*sd2)
```

priors for intercepts of regression equations for S and p; the lower bound for C is constrained by previous estimates of annual survival (0.44 for saltmarsh, 0.52 for seaside), and the upper bound is constrained by a biologically plausible limit for weekly survival (0.999)

for saltmarsh

```
C ~ dunif(-0.241, 6.91)
```

for seaside

```
C ~ dunif(0.0802, 6.91)
```

capture probability

```
Cp ~ dnorm(0, 0.001)
```

#three coefficients for S

```
for(e in 1:3){
```

```
B[e] ~ dnorm(0, tau)
```

```

}

# four coefficients for p

for(e in 1:4){

Bp[e] ~ dnorm(0, tau2)

}

# E is the number of individuals

# I is the number of sampling occasions plus one

for(i in 1:E){

# index for z starts at two to accommodate index to previous year (A[i, z-1]); first column of
capture-recapture matrix (capmat[i, z]) contains zeros and column two contains capture record
for first sampling occasion

for(z in 2:I){

# regression equation for apparent survival (S)

logit(R[i, z]) <- C + B[1]*male[i] + B[2]*PC1[i] + B[3]*SMI[i]

# apparent survival probability can only be positive if individual was alive in previous year

S[i, z] <- A[i, z-1]*R[i, z]

A[i, z] ~ dbin(S[i, z], 1)

# regression equation for capture probability (p)

logit(q[i, z]) <- Cp + Bp[1]*HA[i] + Bp[2]*ER[i] + Bp[3]*male[i] + Bp[4]*(z-2.5)

# capture probability can only be positive if individual is alive in current year

p[i, z] <- q[i, z]*A[i, z]

```



```
# capmat is capture-recapture matrix (rows are individuals; columns are sampling occasions,  
with initial column of zeros to accommodate index to previous year)
```

```
capmat[i, z] ~ dbin(p[i, z], 1)
```

```
}
```

```
}
```

Model for condition analyses:

```
# uninformative priors for sd and precision terms (tau) for model error
```

```
sd ~ dunif(0, 1000)
```

```
tau <- 1/(sd*sd)
```

```
# uninformative priors for sd and precision terms (tau) for distribution of regression
```

```
coefficients
```

```
sd2 ~ dunif(0, 1000)
```

```
tau2 <- 1/(sd2*sd2)
```

```
# uninformative prior for intercept of regression equation
```

```
C ~ dnorm(0, 0.001)
```

```
# eight coefficients for regression equation, with shared variance term
```

```
for(e in 1:8){
```

```
B[e] ~ dnorm(0, tau2)
```

```
}
```

```
# I is the number of individuals
```

```
for(i in 1:I){
```

```
# regression equation
```

```
q[i] <- C + B[1]*sex[i] + B[2]*species[i] + B[3]*season[i] + B[4]*day[i] + B[5]*sex[i]*species[i] +  
B[6]*sex[i]*season[i] + B[7]*sex[i]*day[i] + B[8]*sex[i]*species[i]*season[i]
```

```
# sampling distribution; response variable is SMI (normal) or fat/muscle (truncated Poisson;  
uses log link for regression equation)
```

```
SMI[i] ~ dnorm(q[i], tau)
```

```
muscle[i] ~ dpois(q[i]); T(0, 6)
```

```
}
```