Wenker, E. S., E. L. Kendrick, M. Maslanka, and M. L. Power. 2022. Fat scoring in four sparrow species as an estimation of body condition: a validation study. Journal of Field Ornithology 93(2):5. [online] URL: https://doi.org/10.5751/JFO-00119-930205

*Ornithological Methods*

# Fat scoring in four sparrow species as an estimation of body condition: a validation study

## Puntuación de grasa en cuatro especies de gorriones como una estimación de la condición corporal: un estudio de validación

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ABSTRACT. In avian biology, body condition has been positively correlated with survivability, reproduction, migration, and habitat quality. A common method of assessing avian body condition, which typically refers to measures of energy stores, is a qualitative scale based on visible subcutaneous fat. However, the only accurate way to determine the lipid composition of a bird is to chemically extract it, which is fatal to the bird and time-consuming for researchers. The goal of this study was to determine the relationship between fat score and percent body fat measured by lipid extraction in two sparrow genera: 41 White-throated Sparrows (*Zonotrichia albicollis*), and 19 Song Sparrows (*Melospiza melodia*), 5 Swamp Sparrows (*Melospiza georgiana*), and 3 Lincoln's Sparrows (*Melospiza lincolnii*). All birds died from building collisions. All birds measured within the standard weight range for their species and scored within the 0.5–4 range using the European Science Foundation (ESF) system from the British Trust for Ornithology, which is typical for wild birds. Each bird was dissected ventrally to remove fat pads, the remaining carcass was blended with distilled water, and then the fat pads and slurries were dried separately at 100°C for 24 hours. Crude fat content of fat pads and the homogenized carcass was measured through high-temperature solvent extraction. Fat score and percent body fat was significantly positively correlated for all species, and linear across all sparrows. A unit increase in fat score equaled a mean increase of 0.52±0.06g or 2.1±0.3% of percent body fat. However, the variance in percent body fat increased with fat score, suggesting that the relationship may become less reliable in fat scores above 4. We conclude that fat scoring offers a quick method of assessing body condition in small wild passerines but may not provide accurate lipid content, especially for fatter birds.

RESUMEN. En biología de aves, la condición corporal ha sido correlacionada positivamente con la supervivencia, reproducción, migración y calidad de hábitat. Un método común para determinar la condición corporal de las aves, el cual se refiere típicamente a medidas de reservas de energía, está basado en una escala cualitativa de la grasa subcutánea visible. Sin embargo, la única manera precisa para determinar la composición de lípidos de un ave es extraerlos químicamente, lo cual es fatal para el ave y dispendioso para los investigadores. El objetivo de este estudio fue el de determinar la relación entre el puntaje de grasa y el porcentaje de grasa corporal medido mediante extracción de lípidos en dos géneros de gorriones: 41 *Zonotrichia albicollis* y 19 *Melospiza melodía*, 5 *Melospiza georgiana* y 3 *Melospiza lincolnii*. Todas las aves murieron por colisiones contra edificios. Todas las aves medidas estuvieron dentro del rango estándar de peso para su especie y tuvieron un puntaje entre 0.5-4 usando el sistema de la Fundación de Ciencia Europea (ESF) de la Fundación Británica de Ornitología, el cual es típico para aves silvestres. Cada ave fue disectada ventralmente para remover los colchones de grasa, el resto de cuerpo fue licuado con agua destilada y luego los colchones de grasa y el cuerpo licuado fueron secados separadamente a 100°C pro 24 horas. El contenido crudo de los colchones de grasa y el cuerpo homogenizado fue medido por medio de extracción en solvente a alta temperatura. El puntaje de grasa y el porcentaje de grasa corporal estuvieron significativamente correlacionados para todas las especies y linealmente para todos los gorriones. Un incremento en una unidad del puntaje de grasa equivale a un incremento promedio de 0.52±0.06g o 2.1±0.3% del porcentaje de grasa corporal. Sin embargo, la varianza en la proporción de grasa corporal incrementó con el puntaje de grasa, sugiriendo que la relación puede ser menos confiable en puntajes de grasa por encima de 4. Concluimos que estimar el puntaje de grasa puede ser una método rápido para determinar la condición corporal de aves silvestres paseriformes pequeñas pero puede no proveer estimados

Key Words: *body fat; energy stores; passerine*

## INTRODUCTION

Body condition indices are used to assess the individual health of many animals and often used in correlation to other biological conditions. The definition of body condition varies by researcher and study goals but typically refers to some measure of energy reserves; most commonly fat stores (Labocha and Hayes 2012). In avian biology in particular, body condition has been positively correlated with individual survivability (Blums et al. 2005), reproduction (Chastel et al. 1995, Bêty et al. 2003), and migration (Bêty et al. 2003, McWilliams et al. 2004, Laursen et al. 2019). Avian body condition can also be a strong indicator of environmental factors like poor habitat quality (Angelier et al. 2011, Balbontin et al. 2012), abnormal climate (du Plessis et al. 2012, McLean et al. 2018), and pollution (Ackerman et al. 2012, Lavers et al. 2014) because it is often negatively correlated to these factors.

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Despite the importance of such a measurement, there is no one way to determine body condition. Instead, morphological (e.g., fat mass, body size) or physiological (e.g., hormone or plasma-lipid levels) methods are used as indirect measures (Stevenson and Woods 2006, Labocha and Hayes 2012). Common morphometric methods entail using body mass or size to produce some form of scaled condition index (Rogers 2003, Stevenson and Woods 2006, Labocha and Hayes 2012). Body size is typically determined via some linear measurement like wing chord or tarsus length. Such measurements are feasible in the field and highly repeatable making this a popular method among biologists to define condition. However, body mass is more significantly positively correlated with structural size than fat mass and regression calculations might not be translatable across species or even populations (Freeman and Jackson 1990, Labocha and Hayes 2012, Schulte-Hostedde et al. 2005). Physiological methods of determining avian body condition include using total body electrical conductivity (TOBEC), magnetic resonance imaging (MRI), quantitative magnetic resonance (QMR), and deuterium dilution (Wirestam et al. 2008, McWilliams and Whitman 2013, Kelsey et al. 2019). These techniques can be time consuming and expensive and like morphological measurements, are often not translatable across species.

One of the oldest and most common methods of determining avian condition is fat scoring: using a qualitative scale to score visible subcutaneous fat (Blanchard 1941, Helms and Drury 1960). Scores are determined by using the fullness and color of furcular and/or abdominal regions of a bird to estimate fat reserve size and can be determined in under a minute. Fat pad size and fat score are highly correlated, making this a quick and effective means of estimating body condition (Kaiser 1993, Labocha and Hayes 2012). Additionally, fat score can be used in tandem with other morphological measurements to predict fat mass more accurately (Labocha and Hayes 2012, McWilliams and Whitman 2013). However, fat score is a qualitative measurement, and therefore subjective, and multiple scales can be used (Rogers 2003, LaBocha and Hayes 2012, McWilliams and Whitman 2013). Furthermore, not all bird species carry fat in the same manner and so this method might be species-specific (Seewagan 2008, Schamber et al. 2009). These issues can be mitigated with observer training and validation studies.

The only way to determine complete lipid composition of an individual (including non-fat pad lipids) is to chemically extract it from the body, which is fatal to the bird and time-consuming for researchers. The number of studies using such methodologies is limited because of the need to sacrifice the individual and are not representative of all avian species as most studies focus only on waterfowl or a subset of passerines (Conway et al. 1994, Seewagen 2008, Schamber et al. 2009, McWilliams and Whitman 2013, Beuth et al. 2016). The goal of this study is to determine the relationship between fat score and total body lipid composition of four sparrow species in two genera via chemical extraction: White-throated Sparrows (*Zonotrichia albicollis*), Song Sparrows (*Melospiza melodia*), Swamp Sparrows (*Melospiza georgiana*), and Lincoln's Sparrows (*Melospiza lincolnii*). These two genera differ in body size (*Z. albicollis* are larger), allowing an assessment of whether body size may affect the relationship between fat score and percent body fat. We predict that fat scoring will be a good indicator of fat content across sparrow species regardless of genus.

## METHODS

A total of 41 White-throated (hereafter referred to as WTSP), 19 Song (hereafter referred to as SOSP), 5 Swamp (hereafter referred to as SWSP), and 3 Lincoln's Sparrows (hereafter referred to as LISP) were collected opportunistically by City Wildlife (Washington, D.C.) as part of their Lights Out DC initiative in the spring and fall seasons of 2017–2019. Birds were not sexed because of the difficulty in identification outside of the breeding season and because all species have minimal size differences between species. All birds died via building collisions and were donated to the Department of Nutrition Science at the Smithsonian National Zoo and Conservation Biology Institute. Time between death and collection is unknown but is estimated to be no more than a few hours. Only WTSPs and SOSPs had individuals collected in the spring but all spring WTSPs were collected in April or very early May (n = 8), and the SOSP in March (n = 2), which is prior to either's breeding season. Collection at these dates therefore eliminates any associated weight fluctuations (Witter and Cuthill 1993, Bêty et al. 2003, Arcese et al. 2020, Falls and Kopachena 2020). Individuals were frozen and stored in individual Ziploc bags at -30 °C until processing.

### Visual assessment

Birds were thawed and given a fat score using a modified 0-8 European Science Foundation (ESF) system from the British Trust for Ornithology (BTO 2021). The modification was the addition of a 0.5 score indicating the observation of trace amounts of fat (Table 1). The same procedures were followed as if scoring live (Krementz and Pendleton 1990). To eliminate inter-observer variation, all fat scoring was performed by a clinical zoo nutritionist (EK) with extensive body scoring experience.

**Table 1**. Avian body score system (F = Furcular region; A = Abdomen) used in this study based on the commonly used European Science Foundation (ESF) system and a suggested score scale alteration to use in future studies based on our findings.

| Score (Used) | Description | Score (Suggested) |
|---|---|---|
| 0 | No visible fat. | 0 |
| 0.5 | Trace fat on one or both of F and A. | 1 |
| 1 | F: wide wedge of fat.<br>A: trace of fat. | 2 |
| 2 | F: Completely covered but deeply concave.<br>A: slips of fat. | 3 |
| 3 | F: Moderate fat reserves cover ends of inter-clavicles but concave.<br>A: flat or slightly bulging pad. | 4 |
| 4 | F: filled up to far end of clavicles.<br>A: covered by clearly bulging pad of fat. | 5 |
| 5 | F: convex bulge, perhaps overlapping breast muscles.<br>A: extreme convex bulge. | 6 |
| 6 | F and A: fat covering breast muscles by several mm. | 7 |
| 7 | F and A: 0.75 of breast muscles covered. | 8 |
| 8 | F and A: breast muscles not visible. | 9 |

### Fat determination

Initial body weight was measured for all birds to the nearest 0.1 g in addition to wing chord and tarsus lengths to the nearest 0.1

**Table 2**. Body composition and measurements of four sparrow species collected in Washington, D.C. spring and fall of 2017–2019. Birds were all window-strike victims. Mean values ± standard error (SEM) with the range in parentheses. Crude Fat (CF) measured on either a dry matter (DM) or fresh weight basis.

| | White-throated sparrow (*Z. albicollis*) | Song sparrow (*M. melodia*) | Swamp sparrow (*M. georgiana*) | Lincoln's sparrow (*M. lincolnii*) |
|---|---|---|---|---|
| n | 41 | 19 | 5 | 3 |
| Body mass (g) | 28.1 ± 0.72 (14.6-34.9) | 20.5 ± 0.34 (18.1-23.1) | 16.0 ± 0.67 (13.8-18.0) | 15.4 ± 0.38 (14.7-15.9) |
| Fat Score | 2.17 ± 0.19 (0.5-4) | 2.55 ± 0.23 (0.5-4) | 2.6 ± 0.51 (1-4) | 2.3 ± 0.67 (1-3) |
| Total CF (g)† | 1.89 ± 0.14 (0.6-5.1) | 1.90 ± 0.17 (0.2-3.5) | 1.66 ± 0.28 (0.8-2.4) | 1.04 ± 0.35 (0.4-1.8) |
| Fat Pad CF (%)† | 79.7 ± 2.5 (39.0-100.0) | 82.9 ± 2.4 (6.0-95.2) | 79.7 ± 8.0 (49.4-92.1) | 96.4 ± 0.036§ (92.7-100.0) |
| Carcass CF (%)† | 25.5 ± 1.3 (9.92-48.8) | 27.6 ± 1.9 (6.2-39.7) | 31.6 ± 5.2 (17.4-43.5) | 20.9 ± 6.2 (10.8-32.1) |
| Body Fat (%)‡ | 6.77 ± 0.5) (2.5-18.8) | 9.17 ± 0.78 (1.3-15.5) | 10.42 ± 1.76 (4.6-15.2) | 6.64 ± 2.13 (2.6-11.5) |
| Wing chord length (mm) | n/a | 64.2 ± 0.49 (61.5-68.1) | 58.9 ± 1.19 (56.3-61.8) | 58.0 ± 1.1 (56.4-60.2) |
| Tarsus length (mm) | n/a | 24.1 ± 0.18 (22.6-25.9) | 23.0 ± 0.48 (22.0-24.4) | 23.3 ± 0.75 (21.1-23.7) |

†Measured on a DM basis
‡Measured on a fresh weight basis
§Sample size for this group is 2

mm in all species except WTSP. The WTSP was the only species studied in an initial pilot study that focused simply on a possible correlation of fat score to fat composition. No morphometric measurements other than body mass were taken for WTSP. When the *Melospiza* spp. birds were added, morphometric measurements were taken additionally for these individuals.

Individuals were defeathered manually and dissected ventrally to remove their fat pads as completely as possible. We use the term fat pads to refer to both the furcular and abdominal subcutaneous fat deposits. Beaks were removed at their base, and legs were removed via severance at or just above the intertarsal joint to aid in the homogenizing process. Lipid content in these areas is absent or negligible. Birds were then reweighed. The remaining carcasses were blended with distilled water in a household blender until a homogenized slurry was produced. The slurries were dried in aluminum pans at 100 °C in a forced air convection oven for 24 hours. Dried slurries were scraped into whirl-pack bags, which resulted in a homogenized powder. Crude fat (CF) content of the fat pads and the homogenized carcass powder was extracted separately by high-temperature solvent extraction using petroleum ether (AOCS 2017) in an ANKOM fat apparatus (ANKOM XT15 Extractor, Macedon, NY). We measured fat content of fat pads to assess the extent to which the percent fat of the fat pads would vary with fat score. All values for percent fat for fat pads and carcasses are expressed on a dry matter basis.

### Statistics

The primary parameters for analysis were the fat score, the total body lipid (Total CF), and the proportion of body mass comprising lipids, from here on referred to as "%Body Fat."

Total CF was calculated as:

Total CF = (Fat pad CF mass + Carcass extracted CF mass)

and %Body Fat was calculated as:

%Body Fat = ((Fat pad CF mass + Carcass extracted CF mass)/ Original Body Weight) * 100

Secondary parameters for analysis were the proportion of the fat pad mass that was fat (Fat Pad %CF), the proportion of the remaining body mass that was fat (Carcass %CF), and the morphometric values measured for the *Melospiza* spp. All values are given as mean ± SEM. All variables were tested for normality using the Shapiro-Wilk's Test. Following the suggestion of Labocha and Hayes, the relationships between variables were tested using Pearson's Correlation. All variables were normally distributed ($p > 0.05$) or were non-normal ($p < 0.05$) but unimodal. Because of the small sample size of two species, individuals were grouped by genus (*Zonotrichia* and *Melospiza*) and differences in major compositional indices between genera were tested using ANOVA. In *Zonotrichia*, total lipid content, fat score, and season collected were compared using ANOVA, predictive powers of indices were compared with linear regression. A predictive model using condition indices was created for *Melospiza* using a forward stepwise regression. All statistics performed using R v.3.5.2 (R Core Team 2021).

## RESULTS

Morphometric and compositional metrics for each species are summarized in Table 2. All 68 individuals had some visible subcutaneous fat, but none received a score above 4 (average = 2.29 ± 0.14; Table 2). Fat score was positively correlated with Total CF (r = 0.689, $p < 0.001$) and %Body Fat across the sparrow species (r = 0.709, $p < 0.001$; Fig. 1). Between the two genera, *Zonotrichia* were significantly heavier (28.1 ± 0.7 g versus 19.2 ± 0.5 g, $F_{(1,66)}$ = [107.8], $p < 0.001$) but the *Melospiza spp.* were higher, on average, in %Body Fat (9.4 ± 0.7% versus 6.8 ± 0.5%, p = 0.003; Fig. 2). Linear regression found significant equations

**Fig. 1**. Mean ± SEM percent body fat for each fat score category measured in 68 sparrows: n = 41 White-throated Sparrows (*Z. albicollis*), n = 19 Song Sparrows (*M. melodia*), n = 5 Swamp Sparrows (*M. georgiana*), and n = 3 Lincoln's Sparrows (*M. lincolnii*). All birds were window-strike victims collected in D.C. in fall and spring of 2017–2019.

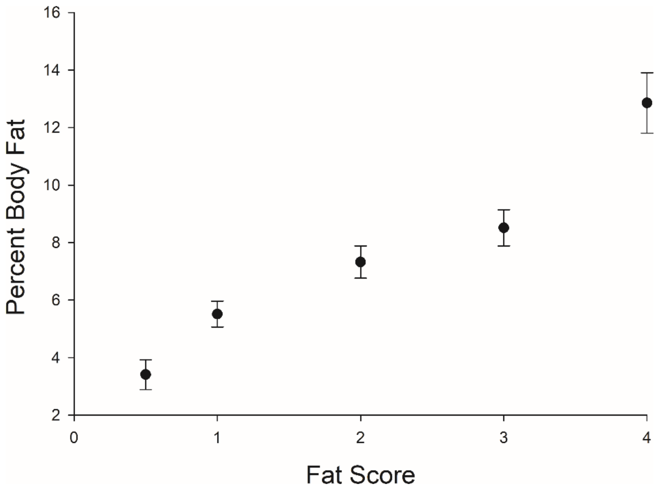
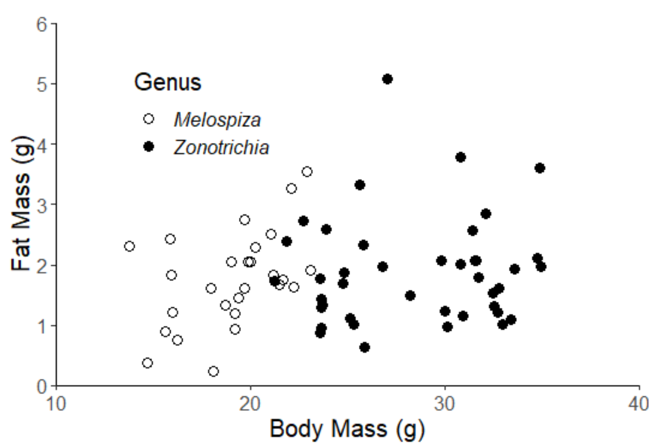



**Fig. 2**. Fat mass by body mass of 68 sparrows by genus: n = 41 Zonotrichia (*Z. albicollis*), n = 27 *Melospiza*: n = 19 (*M. melodia*), n = 5 (*M. georgiana*), and n = 3 (*M. lincolnii*). All birds were window-strike victims collected in D.C. in fall and spring of 2017–2019.




for the relationship between Fat score and both %Body Fat (Fig. 1) and Total CF (Fig. 3) across all sparrows. Total CF in grams was equal to 0.70 + 0.52*Fat Score (F = 58.6, df = 1, $p < 0.001$) and %Body Fat was equal to 0.255 + 2.33*Fat Score (F = 65.6, df = 1, $p < 0.001$). A similar pattern was seen in the CF content of both the fat pads and carcasses as well ($F_{(1,3)}$ = [12.44] and $F_{(1,3)}$ = [63.16], $p < 0.05$, respectively; Fig. 4).

**Fig. 3**. Mean ± SEM Total body fat (g) for each fat score category measured in 68 sparrows: n = 41 White-throated Sparrows (*Z. albicollis*), n = 19 Song Sparrows (*M. melodia*), n = 5 Swamp Sparrows (*M. georgiana*), and n = 3 Lincoln's Sparrows (*M. lincolnii*). All birds were window-strike victims collected in D.C. in fall and spring of 2017–2019.

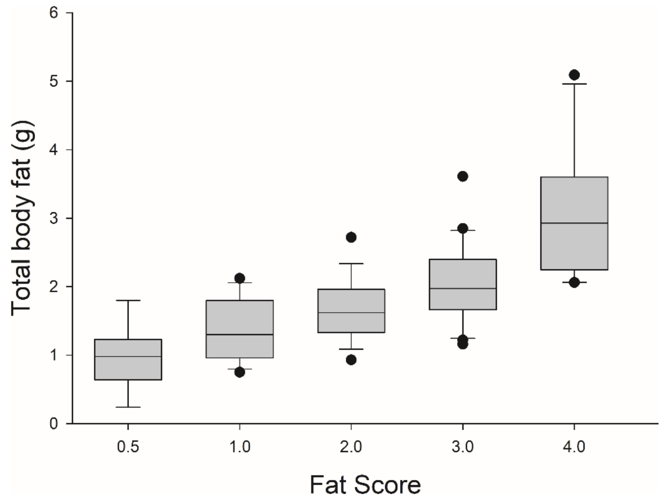
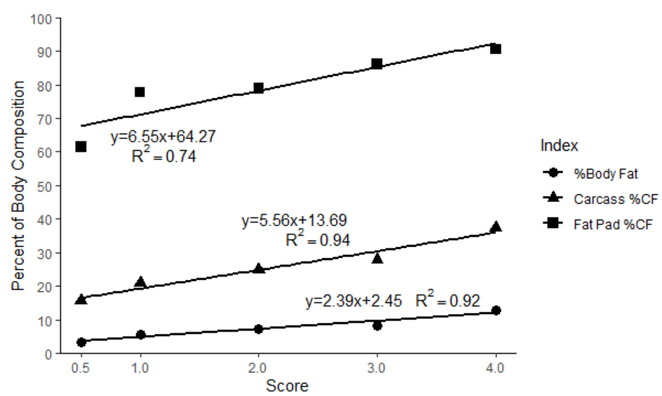



**Fig. 4**. Fat Score as related to the crude fat (CF) composition of the bodies, fat pads (Fat Pad %CF), and remaining body fat deposits (Carcass %CF) measured in 68 sparrows: n = 41 White-throated Sparrows (*Z. albicollis*), n = 19 Song Sparrows (*M. melodia*), n = 5 Swamp Sparrows (*M. georgiana*), and n = 3 Lincoln's Sparrows (*M. lincolnii*). All birds were window-strike victims collected in D.C. in fall and spring of 2017–2019.




*Zonotrichia*

The average fat score for WTSP was 2.17 (± 0.19; Table 2) and the modal score was 3 (n = 14). Both mean Total CF (1.89 ± 0.14g) and mean %Body Fat (6.77 ± 0.52%) were positively correlated with fat score (r = 0.666 and r = 0.644, respectively, $p < 0.001$; Table 3). Fat score was also positively correlated with the CF content of both fat pads and carcasses (r = 0.538, and r = 0.664, respectively, $p < 0.001$; Table 3) but not overall body mass (Fig.

2). There was no significant difference between fat score or %Body Fat and season in which the birds were collected ($F_{(1,39)} = 1.80$, $p = 0.19$ and $F_{(1,39)} = 2.04$, $p = 0.16$, respectively).

**Table 3**. Correlations (r) between fat scores and chemically derived anatomical factors for 41 White-throated sparrows (*Zonotrichia albicollis*) collected in Washington, D.C. All birds were window-strike victims and collected in the spring and fall of 2017–2019.

| | Fat Score | Body Wt (g) | Fat Pads % CF | Carcass % CF | %Body Fat |
|---|---|---|---|---|---|
| Body Weight (g) | 0.0168 | | | | |
| Fat Pads %CF | 0.538** | -0.309* | | | |
| Carcass %CF | 0.664** | 0.0893 | 0.384* | | |
| %Body Fat | 0.644** | -0.233 | 0.501** | 0.914** | |
| Total CF (g) | 0.666** | 0.0769 | 0.428* | 0.960** | 0.945** |

*$p < 0.05$, **$p < 0.001$

Linear regression was used to test if body score significantly predicted Total CF and %Body Fat. For Total CF the regression model was 0.831 + 0.501*Fat Score (adjusted $R^2 = 0.429$, $p < 0.001$). Adding Body Mass to the regression did not improve the model and the coefficient for Body Mass was not significant. For %Body Fat, the fitted regression model was: %Body fat = 2.963 + 1.794(Fat Score) and was statistically significant (adjusted $R^2 = 0.400$, $F_{(1,39)} = [27.57]$, $p < 0.001$). The addition of Body Mass to the equation produced a new equation, slightly stronger in predictive power of %Body fat = 8.428 + 1.809(Fat Score) - 0.1929 (Body Mass) which was also statistically significant (adjusted $R^2 = 0.447$, $F_{(1,39)} = [17.17]$, $p < 0.001$). The coefficient for body mass was significant ($p = 0.045$).

*Melospiza*

The average fat score for SOSP, SWSP, and LISP was 2.55, 2.60, and 2.30, respectively, and all had modal scores of 3 (Table 2). Both mean Total CF (1.76 ± 0.15 g) and mean %Body Fat (9.12 ± 0.70%) were positively correlated with fat score (r = 0.730 and r = 0.715, respectively, $p < 0.001$; Table 4). Fat score was significantly correlated to the CF content of the carcass (r = 0.709, $p < 0.001$; Table 4) but not to the CF content of the fat pads (r = 0.128, $p = 0.079$). Total CF was correlated with body mass though not strongly (r = 0.513, $p < 0.05$; Table 4). A forward stepwise regression was used to see which, if any, of the morphometric or compositional indices best predicted %Body fat. The regression reduced the 7 potential predictor indices, presented in Table 4, to only one: fat score. The resulting equation is as follows: %Body Fat = 2.202 + 2.728(Fat Score), which was statistically significant (adjusted $R^2 = 0.526$, $F_{(1,25)} = [29.79]$, $p < 0.001$).

## DISCUSSION

Overall, our results indicated that fat scoring is a valid method for predicting body condition of these four sparrow species, as is evident by the strong positive correlations between fat score and total body fat (Total CF) and %Body Fat in both genera (Tables 3 and 4; Figs. 1 and 3). This is consistent with literature regarding other small passerines (Conway et al. 1994, Stevenson and Woods 2006, Seewagen 2008, Labocha and Hayes 2012). Based on our data, in sparrows, an increase in one unit of fat score is equivalent to an increase of approximately 0.5 g of body fat or about 2 percentage points higher in percent body fat (Fig. 3, Table 5). Because the mean increase in percent body fat between fat score 0.5 and 1 was essentially the same as between any other consecutive fat score, we suggest that the ESF system from the British Trust for Ornithology be adjusted to become a scale of 0 to 9 with the 0.5 score becoming 1 and all other scores increasing by 1 unit (Table 1). In that way, at least for fat scores between 1 and 4 for sparrows, the fat score will be a linear estimate of both total body fat and percent body fat. Assuming a metabolic energy value of approximately 9kcal/g of fat (37.7kj/g) an increase in one unit of fat score indicates an increase in 4.5kcal (18.8kj) in energy stores.

Our fat score values correlated to both Total CF and %Body Fat but not as strongly as seen in other sparrow studies. A 1986 study mentioned in Labocha and Hayes (2012) regressed body mass and fat score against total body fat in WTSP. They found $R^2$ values of 0.48 and 0.66, respectively (Blem and Shelor 1986). Another study found the mean fat score of WTSP produced an $R^2$ of 0.697 when regressed against total body fat (Krementz and Pendleton 1990). When we regressed fat score against %Body Fat, our data had a lower $R^2$ value of 0.40. When Body Mass was added into the equation, the equation better fit the data with an $R^2$ of 0.447 but not by much. This increased fit is supported by other literature that similarly found better predictive power when using morphometric indices in addition to fat score to estimate body fat (Conway et al. 1994, Labocha and Hayes 2012, McWilliams and Whitman 2013). Interestingly, despite that more morphological measured were taken in the three *Melospiza* species, our stepwise regression found fat score alone to be the best predictor of %Body Fat. The addition of Body Mass reduced the $R^2$ value from 0.526 to 0.509 and the addition of the other morphometric indices lowered the value further. Although this does not follow the pattern seen in some literature (Conway et al. 1994, McWilliams and Whitman 2013), perhaps this is not entirely unsurprising as none of the morphometric indices were significantly correlated with %Body Fat (Table 4). As stated in Labocha and Hayes (2012), not one single condition index is universally best. The relationships between the predicative power of multiple indices should be explored further and with a larger sample size.

All birds measured within the standard size and/or weight range for their species (Ammon 2020, Arcese et al. 2020, Falls and Kopachena 2020, Herbert and Mowbray 2020) and scored within the 0.5–4 range, which is indicative of a typical wild population (Witter and Cuthill 1993). However, our results suggest that body condition of birds in poor condition may be relatively overestimated based on the visual appearance of fat pad size, as their fat pads likely contain a lower fat content. The lipid content of fat pads of all birds ranged from 39% to 100% (Table 2) with an overall average of 81.0 ±1.70%. In commercial species like broiler chickens, fat pads only account for 20% of total body fat content in adults (Buyse and Decuypere 2015) with the remaining contents being made of vascular and connective tissue. In our data, low percent fat in fat pads were found in birds with low body condition scores (0.5 or 1). Dissection may remove some surrounding tissue, which possibly represented a greater proportion of tissue to fat compared to large pads that routinely had high percentage fat values. In addition, fat pads contain connective tissue and vascular tissue that also may represent a

**Table 4**. Correlations (r) between fat scores, morphometric indices, and chemically derived anatomical factors for 27 sparrows (*Melospiza* spp.) collected in Washington, D.C. All birds were window-strike victims and collected in the spring and fall of 2017–2019. Species include n =19 Song sparrows (*M. melodia*), n = 5 Swamp sparrows (*M. georgiana*), and n = 3 Lincoln's sparrows (*M. lincolnii*).

| | Fat Score | Body Wt (g) | Wing Chord Length (mm) | Tarsus Length (mm) | BW/WC | BW/T | Fat Pad % CF | Carcass %CF | %Body Fat |
|---|---|---|---|---|---|---|---|---|---|
| Body Wt (g) | 0.168 | | | | | | | | |
| Wing Chord Length (mm) | -0.227 | 0.845** | | | | | | | |
| Tarsus Length (mm) | 0.117 | 0.547* | 0.474* | | | | | | |
| BW/WC | 0.335 | 0.954** | 0.657** | 0.517* | | | | | |
| BW/T | 0.139 | 0.943** | 0.802** | 0.242 | 0.900** | | | | |
| Fat Pad %CF | 0.128 | 0.261 | 0.113 | -0.0223 | 0.288 | 0.291 | | | |
| Carcass %CF | 0.709** | 0.201 | -0.151 | -0.0684 | 0.349 | 0.250 | 0.551* | | |
| %Body Fat | 0.730** | 0.226 | -0.147 | -0.0163 | 0.386* | 0.257 | 0.529* | 0.971** | |
| Total CF (g) | 0.715** | 0.513* | 0.128 | 0.200 | 0.641** | 0.504* | 0.507* | 0.893** | 0.943** |

*$p < 0.05$, **$p < 0.001$

**Table 5**. Percent body fat and total crude fat by fat score category for 68 sparrows: n = 41 White-throated sparrows (*Z. albicollis*), n = 19 Song sparrows (*M. melodia*), n = 5 Swamp sparrows (*M. georgiana*), and n = 3 Lincoln's sparrows (*M. lincolnii*).

| | | % Body Fat | | | Total Crude Fat (%) | | |
|---|---|---|---|---|---|---|---|
| Fat score | n | Mean | Median | SD | Mean | Median | SD |
| 0.5 | 7 | 3.4% | 3.3% | 1.4 | 0.977 | 0.98 | 0.45 |
| 1 | 13 | 5.5% | 5.5% | 1.6 | 1.38 | 1.30 | 0.44 |
| 2 | 15 | 7.3% | 7.3% | 2.2 | 1.65 | 1.62 | 0.44 |
| 3 | 22 | 8.5% | 8.4% | 3.3 | 1.96 | 1.93 | 0.66 |
| 4 | 10 | 12.14% | 12.7% | 3.6 | 3.06 | 2.93 | 0.90 |

greater proportion of mass for birds in low body condition. Nevertheless, the %CF in the fat pads was positively correlated with %Body Fat as is supported in literature regarding commercial chicken species (Hood 1982, Griffin et al. 1992, Newman et al. 2002, Buyse and Decuypere 2015).

Interestingly, it appears that %CF of the carcasses, rather than fat pads, appeared to be a stronger predictor of %Body Fat across all species. Birds typically accumulate lipid stores in the following area sequentially: subcutaneous layers of feather tracts, subcutaneously in the furcular area, subcutaneously in the abdominal region, and finally mesenteric tissue (Blem 1976, Guglielmo 2018). It is logical then, to conclude that the fat pads would have the majority of lipid reserves, but our birds showed a surprising amount of fat outside of these designated regions. The average lipid content of the carcasses on a dry matter basis ranged from 20.9 to 31.6% across species (Table 2) with the lowest percentage at 6.2% in a SOSP (fat score = 0.5) and the highest at 48.8% in a WTSP (fat score = 4). Upon dissection, additional lipid stores were primarily seen lining the intestines, at the shoulder joint, and above the caudal vertebrae. In both genera, the correlation between %Body Fat and Carcass %CF was stronger than that of the former and Fat Pad %CF. In *Zonotrichia*, the correlation coefficients of Fat Pad %CF and Carcass %CF to %Body Fat were r = 0.501 and r = 0.914, respectively (Table 3). In *Melospiza*, the values were r = 0.521 and r = 0.879, respectively (Table 4). Sparrows are a small passerine that readily present subcutaneous fat deposits but the same cannot be said of other avian species (Blem 1976, Bêty et al. 2003, Graham and McWilliams 2022, Rogers 2003). It is important for researchers to understand that although the subcutaneous fat pads are the primary lipid reservoirs of birds, mesenteric fat can play an important part when these stores are depleted.

Birds with higher fat scores are more likely to have variable amounts of fat outside of their fat pads. Across all species, birds with a score of 4 had more fat in their carcasses than those with lower scores. This may explain why the variance in total body fat and percent body fat increased with fat score. Our data suggest that fat scores higher than 5 may become less reliable indicators of actual total body fat and percent body fat in sparrows because of the saturation of the fat pads at high fat scores and the more variable amounts of other fat stores, but that needs testing with fatter birds. We conclude that fat scoring offers a quick and relatively accurate method of assessing body condition in small wild passerines like sparrows within the range of body fat typical for wild sparrows. However, because variance increased with fat score, the estimate of percent body fat becomes less reliable with fatter birds.

*Responses to this article can be read online at:*
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**Acknowledgments:**

*We would like to thank staff and volunteers at City Wildlife and their Lights Out DC program for their specimen collection and donation. Thank you to Michael Jakubasz for his guidance and to Virginia Glick, Jenna Pastel, Joanne Unite, and other nutrition lab interns at the National Zoo for their assistance in sample processing.*

**Data Availability:**

*Data available from corresponding author (E. Wenker) upon reasonable request.*

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