

Relationship between Body Size and Migratory Fat Stores in *Catharus* thrushes

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Summary

Migration is an energetically demanding and high-risk phase of the annual cycle of intercontinental migrant songbirds. Many accumulate large fat deposits to fuel their semiannual journey. However, the amount of migratory fat stored by birds may be subject to a trade-off. Fat deposition powers the birds' migration and reduces the risk of starvation, but it increases the cost of carrying large fat loads and the risk of predation. I examined the relationship between the body size and fat deposition of Veery (*Catharus fuscescens*), Swainson's thrush (*Catharus ustulatus*), and Gray-cheeked thrush (*Catharus minimus*) passing through northeastern Illinois during spring migration. My results contrasted strongly with the results of a previous study (Yong and Moore 1994), which found a negative relationship between the wing length and fat stores both within and among species of North American *Catharus* thrushes. Within species, I found a statistically significant positive relationship between the wing size and the energy stores of Swainson's thrushes. Between species, I also found evidence of a positive relationship between wing length and fat deposition, with Gray-cheeked thrushes the longest-winged and fattest, and Veeries the shortest-winged and leanest. It is evident that the populations of Gray-cheeked thrushes and Veeries in my sample were morphologically different from the populations sampled by Yong and Moore (1994). These differences may be accounted for by geographic variations. Wing length is not negatively correlated with fat deposition in *Catharus* thrushes as Yong and Moore (1994) suggested. It is therefore still unclear what factors govern the deposition of fat by migratory *Catharus* thrushes. While our data provide some evidence that body size may be an important factor, with larger birds storing more fat, other factors such as migration distance and/or phylogenetic constraints may be important as well.

Introduction

In preparation for migration, birds store supplies of energy. Subcutaneous fat deposits provide the majority of the energy used in a long-distance migration (Gannes 2001). Variations in the quantity of fat individuals store result from a cost-benefit trade-off (Rogers and Smith 1993). The costs of fat storage include increased mass, reduction in maneuverability, increased risk of predation, and increased cost of transportation of fat reserves (Vezina et al. 2000, Katti and Price 1999). Added weight is detrimental to flight performance of birds because the weight of the fat reduces the lifting force on the wing and increases drag, thus reducing the optimal speed of migration (Lewis 1990). The benefit of fat stores is the reduced risk of starvation. When food resources are scarce, birds with high fat stores can survive longer than those with low fat stores (Rogers and Smith 1993).

In a study of spring migrant thrushes arriving on woodlands of Louisiana after trans-Gulf passage, Yong and Moore (1994) found that longer-winged birds carry less fat stores. This pattern held both across and within species. Yong and Moore (1994) explained this pattern by suggesting that individuals with long, pointed wings generate more power during migration at lower cost than the birds with short and rounded wings (Yong and Moore 1994). Longer-winged birds have lower wing loading, which reduces drag and the cost of flight, resulting in reduced need for fat reserves relative to the birds with shorter wings (Yong and Moore 1994).

Building upon this previous work, I examined the relationship between the body size and the fat reserves of migratory *Catharus* thrushes passing through northeastern Illinois during spring migration. The findings of Yong and Moore (1994) comprised my null hypothesis.

Results

Within species comparisons: longer-winged Swainson's thrushes had higher fat reserves than shorter-winged individuals.

The only species for which I found a significant relationship between the wing size and the fat score was the Swainson's thrush, for which I found a positive correlation (Figure 1).

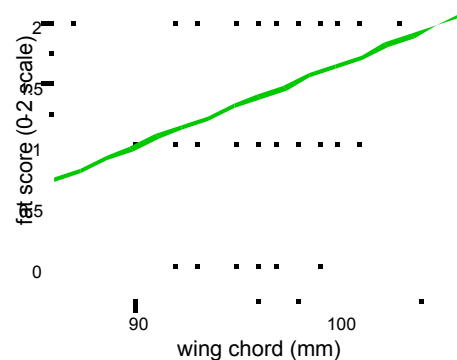


Figure 1.

*This paper was written as an independent study with Dr. Caleb E. Gordon.

Linear least squares regression demonstrates a positive relationship between the wing chord and fat score of Swainson's thrush. $r^2=0.09046$, one-way ANOVA ($p<0.0001$, $n=236$).

Across species comparisons: Larger species carried more fat than smaller species.

I found no statistically significant differences among species in lean body mass (Figure 2). All species were significantly different from

each other in wing chord, with the Gray-cheeked thrush the longest-winged, followed by the Swainson's thrush and Veery (Figure 2). Gray-cheeked and Swainson's thrushes did differ from each other in fat score, but were significantly fatter than the Veeries (Figure 4). Gray-cheeked and Swainson's thrushes had consistent values for the mass of fat carried by birds with fat scores of 1 and 2 (Table 2). Veeries had less fat than Gray-

Table 1. Between species comparisons

Within each column, different letters indicate a statistically significant difference between the means. ($p<0.05$, student's t-test)

Species Common Name	fat condition (0-2 scale)	wing chord (mm)	weight (g) of birds with fat condition 0	weight (g) of birds with fat condition 1	weight (g) of birds with fat condition 2
Gray-cheeked Thrush	1.57±0.08 A (n=49)	101.28±0.54 A (n=49)	31.00±1.00 A (n=2)	34.26±0.74 A (n=17)	38.15±0.59 A (n=30)
Swainson's Thrush	1.42±0.04 A (n=236)	96.22±0.19 B (n=236)	28.85±0.98 A (n=20)	32.39±0.35 B (n=97)	36.47±0.36 B (n=119)
Veery	1.08±0.05 B (n=133)	95.39±0.27 C (n=133)	30.47±0.58 A (n=18)	32.10±0.30 B (n=87)	35.93±0.56 B (n=28)

Table 2. The mass of fat carried by birds with different fat scores

Species Name	mean mass (g) of fat (birds with a fat score of 1)	mean mass (g) of fat (birds with a fat score of 2)
Gray-cheeked Thrush	3.26	7.15
Swainson's Thrush	3.54	7.62
Veery	1.63	5.46

cheeked and Swainson's thrushes with the same fat score (Table 2).

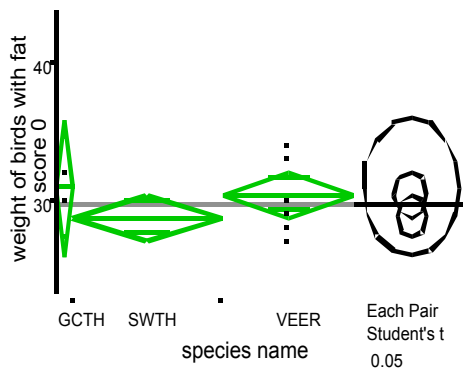


Figure 2.

The lean mass (weight of birds with fat score of 0) of the three species: GCTH= Gray-cheeked thrush, SWTH= Swainson's thrush, VEER=Veery. Distribution of the means by species is represented by the diamonds. The middle of the line is the mean of the group and the x-axis of the diamond is divided proportionally by group sample size. At right, the center of each circle is aligned with corresponding group mean and the radius of a circle is the 95% confidence interval for its group mean. The angle of intersection of the circles greater than 90° indicates that means are significantly different ($p<0.05$). None of these means are significantly different from each other.

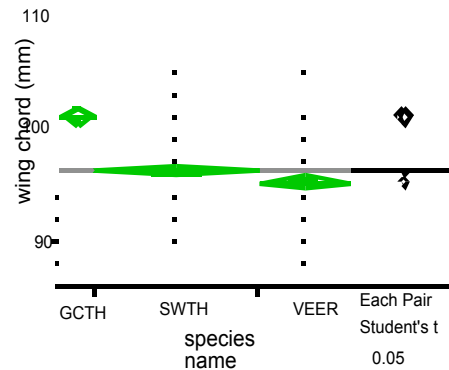


Figure 3. Between species comparison of wing chord

Species abbreviations and statistical symbols are as in Figure 2. All three species are significantly different from each other.

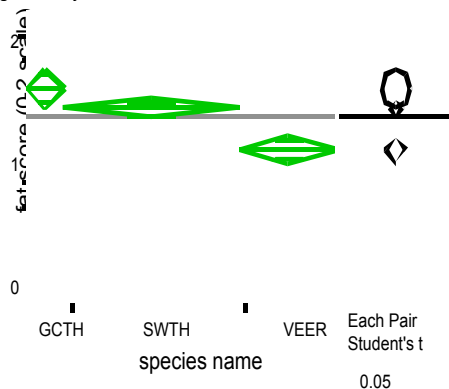


Figure 4. Between species comparison of fat score

Species abbreviations and statistical symbols are as in Figures 2 and 3. Gray-cheeked and Swainson's thrushes are statistically indistinguishable from each other, and fatter than Veery.

Discussion

Within species longer-winged individuals do not have lower fat stores

Our results for both between and within species comparisons suggest that the negative relationship between the wing size and fat stores found by Yong and Moore (1994) must be questioned. Yong and Moore (1994) used a principal-components analysis to explain morphological variation between individual birds. They called principal component I (PCI) "wing –size factor", which was associated with overall large wing size, relatively long and pointy wings, and reduced wing loading (Yong and Moore 1994). Yong and Moore (1994) found that wing size factor was negatively correlated with the fat in all three species. I used wing chord, the length from the wrist to the tip of the longest primary flight feather in folded wing position, as an index of body size for within species comparisons (Yong and Moore 1994). The only significant relationship between wing chord and fat score within species that I found was a positive relationship in Swainson's thrush.

Across species longer-winged individuals do not have lower fat stores

Yong and Moore (1994) also found a negative relationship between the wing size factor and both the relative size of the birds and the fat stores in between species comparisons. They found that Gray-cheeked thrushes and Veeries were long-winged, smaller-bodied and had lower fat stores than the relatively short-winged, large-bodied, and fat Swainson's thrushes. Our results differ from this in several ways. In our study, Gray-cheeked thrushes were long-winged, but not small-bodied and not low in fat as in Yong and Moore (1994) (Table 1). The fat score of Gray-cheeked thrushes was statistically indistinguishable from the fat score of Swainson's thrushes, but both scores were higher than the Veeries (Table 1). Though there were no significant differences in lean mass across species, Gray-cheeked thrushes were consistently the heaviest at all fat scores (Table 1), suggesting that Gray-cheeked thrushes are the largest-bodied of the three species. In a direct comparison of our data and Yong and Moore's (1994) data for Gray-cheeked thrushes, ours are clearly heavier and fatter. In contrast, our thrushes were very similar to those sampled by Yong and Moore (1994) in terms of lean body mass, wing length, and fat. Our Veeries were also very different from those of Yong and Moore (1994). In our sample, Veeries were larger-bodied and shorter-winged than Swainson's thrushes, with less fat (Table 1). Yong and Moore (1994) found Veeries to be 1.36 g lighter than Swainson's thrushes, even though Veeries and Swainson's thrushes had almost the same wing length. Overall, our results suggest that there may be a positive relationship between body size and migratory fat deposition in North American *Catharus* thrushes.

Between-study differences

The differences in our results and those of Yong and Moore (1994) may be explained by geographic variation in morphology. Such variation is known to exist in North American *Catharus* thrushes, particularly between eastern and western races (Pyle 1997). Though our studies were conducted at similar longitudes, perhaps we in northeastern Illinois were sampling geographically distinct, morphologically different populations of Gray-cheeked thrushes and Veeries than were Yong and Moore (1994) on the Gulf coast.

Migration distance

Difference in migratory distance may account for the differences in fat stores across species. Gray-cheeked thrushes travel the longest migratory distance (average 6,200 km), and Veeries the

shortest (average 5,200 km) (Yong and Moore 1994). A tendency for longer-distance migrants to deposit more fat is consistent with our pattern of Gray-cheeked thrushes having among the largest fat deposits, and Veeries the lowest.

The consistency between the values of fat carried by Gray-cheeked and Swainson's thrushes suggest that our method of fat scoring is consistent and unbiased between these two species (Table 2). Veeries carried less fat than Swainson's and Gray-cheeked thrushes with the same fat score, indicating that Veeries may differ from the other two species in their pattern of fat deposition.

Experimental Procedure

Study Site

Data for this study came from the Shaw Woods Avian Monitoring Project (SWAMP), a migratory bird banding station located in the Shaw Woods portion of the Skokie River Nature Preserve in Lake County, Illinois (Gordon et al. 2002).

Data Set and Analyses

In 2002-2004, mist netting was conducted on from 13 to 21 days in May. Twelve 35 mm mesh, 12 m mist nets were opened at 0500 am or 0530 am, and kept open for six hours every morning. Nets were checked every hour. The captured birds were extracted from the nets and placed in separate cloth holding bags and labeled with the net number and the time of capture (Gordon et al. 2002). At the banding station, the birds were banded with an individually numbered leg band from the U.S. Federal Bird Banding Laboratory and then examined by a bander (Gordon et al. 2002).

Banders measured wing chord of each bird to the nearest millimeter and weighed the birds to the nearest gram with spring scales. They also rated external parasite load, flight feather molt, body molt, reproductive condition, flight feather wear, and subcutaneous fat deposits on qualitative scales with pre-defined written criteria (Gordon et al. 2002). To rate fat deposits of birds, banders examined the visible fat deposits in the furcular hollow, vent, wing pit, and abdominal region. Birds with no visible fat in those regions were given a fat score of 0. Individuals with some amount of fat in those areas were given a score of 1. Species whose furcular and abdominal regions were filled with fat were given a score of 2.

I used the data sets from 2002-2004 banding years. I eliminated outliers by plotting wing chord against weight and removing individuals that fell far above or below the range. I then calculated the mean \pm SE for the wing chord length, body weight, and the fat score of the remaining individuals of Swainson's thrush (n=236), Veery (n=133), and Gray-cheeked Thrush (n=49). I used wing chord as an index of body size for the within species analyses. The lean mass of the individuals was defined as the mass of birds with the fat score of 0 and used as a body size index for between species comparisons (Dunn 2000). I did not use the wing chord as an index of body size for between species comparisons because of possible morphological differences in wing shape between species.

I calculated the average mass of fat carried by birds with different fat scores by subtracting the average weight of birds with a fat score of 0 from the average weight of birds with fat scores of 1 and 2 for each species. To analyze the relationship between the wing chord and the fat stores of individuals within species, I performed a linear regression analysis and one-way ANOVA. For between species comparisons of fat condition, wing chord, and weight, I used student's *t*-tests.

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