

FAT SCORING: SOURCES OF VARIABILITY¹

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Abstract. Fat scoring is a widely used nondestructive method of assessing total body fat in birds. This method has not been rigorously investigated. We investigated inter- and intraobserver variability in scoring as well as the predictive ability of fat scoring using five species of passerines. Between-observer variation in scoring was variable and great at times. Observers did not consistently score species higher or lower relative to other observers nor did they always score birds with more total body fat higher. We found that within-observer variation was acceptable but was dependent on the species being scored. The precision of fat scoring was species-specific and for most species, fat scores accounted for less than 50% of the variation in true total body fat. Overall, we would describe fat scoring as a fairly precise method of indexing total body fat but with limited reliability among observers.

Key words: Fat scoring; lipid.

INTRODUCTION

Fat scoring is a widely used nondestructive method of assessing fat reserves in birds. This method takes advantage of a bird's thin skin through which subdermal fat deposits can be observed and assessed. Fat scores have been used for a variety of investigations including the relationship between estimated fat levels and (1) survival rates of birds (Blem 1980, Nolan and Ketterson 1983, Blem and Shelor 1986, Lima 1986, Lehtikoinen 1987, Rogers 1987), (2) breeding phenology or strategies (Hegner and Wingfield 1986, Barclay 1988), (3) the initiation or completion of migration (Wolfson 1954, Lawrence 1958, Connell et al. 1960, Helms and Drury 1960, Graber and Graber 1962, Moore and Kerlinger 1987), and (4) energetics (Helms 1963, Blem 1980).

Although this method has been used widely, few researchers have actually investigated the relationship between fat score and total body fat (TBF). Of the 13 studies investigating this relationship (see table V in Blem 1990), the most thorough study that we are aware of is by Rogers (1987). Using 11 species of passerines, he found that there was a significant positive correlation between fat score and TBF, but the coefficient of determination was only 0.58. To ask questions about survival rate or other characteristics and to use an index (fat score) that explains less than 60% of the variation in the parameter of interest

(TBF) seems questionable. Examination of Rogers' (1987) data revealed that much of the total variation about the regression line was due to only a few of the 11 species. This suggests that fat scoring may work well for some species but not for others. Already two sources of variation in Rogers' study have been noted, i.e., the precision of the relationship between fat score and TBF and species-specific variation. Other potential sources of variation are possible, including intra- and interobserver variation in scoring.

Because the reliability of fat scoring has never been rigorously tested, and because the method is widely used, we undertook this experiment to investigate the possible sources of error in fat scoring. Our objectives were to (1) determine the species-specific correlation between fat score and TBF for a variety of passerines, and (2) investigate the between- and within-observer variation in fat scoring.

METHODS

Twenty individuals of each of five species (House Finch *Carpodacus mexicanus*, Pine Siskin *Carduelis pinus*, Red-winged Blackbird *Agelaius phoeniceus*, Brown-headed Cowbird *Molothrus ater*, and House Sparrow *Passer domesticus*) were captured during February and March 1988. Birds were caught in both mist nets and Potter live traps and euthanized via CO₂ inhalation. The carcasses were weighed to the nearest gram, labelled, and double-bagged before freezing. We would have preferred to score fat on these birds while they were alive but it was logistically impossible to collect the necessary sample size and

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have the same observers present over the entire collection period.

After the entire sample was collected, carcasses were thawed at room temperature for 4 hr before they were scored for fat. This was done to allow the carcasses to be flexible enough for the observers to manipulate the carcass as they would a living bird. The observers were four experienced birders, each of whom had estimated fat scores on at least 100 birds of several different species, and who were familiar with the fat scoring scheme we selected. These observers were asked to score the fat of all carcasses into one of the six following categories: 0—no visible fat in either the furcular region or over the abdomen; 1—trace of fat in the interclavicular fossa or abdomen but neither completely lined; 2—interclavicular fossa lined, but not bulging, and little fat on the abdomen; 3—interclavicular fossa full, some fat on abdomen but not full; 4—interclavicular fossa and abdomen full to bulging; 5—interclavicular fossa and abdomen full with fat extending across the apex of the sternum. This scheme is a modification of the most commonly used fat scoring method developed by Helms and Drury (1960).

Each thawed carcass was scored by each observer then passed to the next observer. All 100 carcasses were scored at one sitting. This experiment was conducted to investigate the relationship between TBF and fat score and also inter-observer variation in fat scoring. After a short break to recover from scoring (scoring 100 birds is physically and mentally tiring), intraobserver variation in fat scoring was investigated. Pine Siskins were chosen for this experiment because it was thought, a priori, that they might exhibit a large amount of variation in TBF. All 20 carcasses were scored two additional times with renumbering between examinations to avoid the potential bias of observers recognizing previously scored carcasses. Thus, each Pine Siskin was scored a total of three times. One extra observer was included in this experiment (five observers total).

To determine whether fat scoring was affected by the status of the bird (alive or dead), 15 live House Sparrows were scored by an additional observer. They were then euthanized and handled just as the other carcasses were. Scores taken on the living birds were compared to the scores of their carcasses.

After all experiments were conducted, the car-

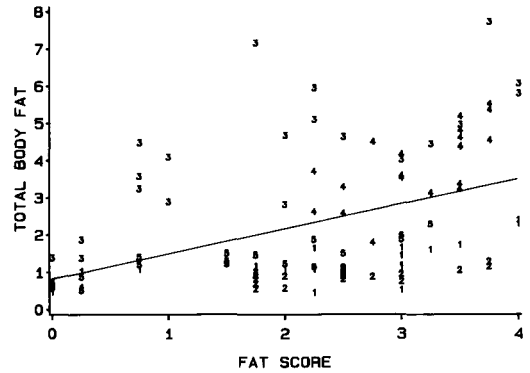


FIGURE 1. Relationship between total body fat (g) and mean fat score based on four observers for five species of songbirds. 1—House Finch, 2—Pine Siskin, 3—Red-winged Blackbird, 4—Brown-headed Cowbird, 5—House Sparrow. The overall equation is total body fat = $0.824 + 0.674$ (fat score) ($r^2 = 0.19$, $P < 0.001$).

casses were refrozen and TBF was determined at a later time. Carcasses were thawed and all gut contents were removed. Then, the carcasses were oven-dried to a constant weight at 90°C (Kerr et al. 1982), weighed, and ground into a homogenate. Soluble fats of the homogenate were extracted for 6 hr using petroleum ether in a Soxhlet extractor following the methods of Dobush et al. (1985).

The relationship between TBF and fat score or carcass wet weight for all species combined was estimated with simple linear regression by regressing TBF on the mean fat score for all observers combined or on carcass wet weight. The equality of regression lines among species was compared using analysis of covariance.

For each species-observer combination, one-way analysis of variance and Tukey's multiple comparison procedure were used to compare mean TBF for birds given different fat scores. In addition, TBF was regressed on fat score for each species-observer combination. We realize the fat scores are an ordinal variable with differences between categories arbitrarily set, but we find the regressions a useful way to summarize the results.

Comparability of scores among observers was assessed in two ways. For each species, the distribution of scores among observers was compared using contingency table analysis and the Pearson's chi-square statistic. Also, agreement indices (EPA 1988, p. 35–36) were calculated.

TABLE 1. Relationship between total body fat (Y) and mean fat score (X) determined by four observers.

Species	Intercept (SE)	P	Slope (SE)	P	r ²
House Finch	0.522 (0.330)	0.117	0.320 (0.130)	<0.001	0.49
Pine Siskin	0.483 (0.572)	0.400	0.183 (0.228)	0.002	0.43
Red-winged Blackbird	2.427 (0.278)	<0.001	0.980 (0.119)	<0.001	0.54
Brown-headed Cowbird	-0.214 (0.994)	0.830	1.320 (0.312)	<0.001	0.44
House Sparrow	0.711 (0.271)	0.010	0.327 (0.146)	<0.011	0.70

Unlike the contingency table, which compares the distribution of scores, the agreement index is based on differences between observers' scores for individual birds. The index has a range from 0 to 1 with 0 being maximum disagreement and 1 being perfect agreement. The hypothesis that agreement among scores was better than expected by chance was tested by generating random samples under the observed distribution of scores and computing the agreement index; this was repeated 1,000 times to yield an empirical distribution of the statistic. The probability (*P*-value) of obtaining by chance an agreement index at least as large as the observed index was used to test the hypothesis of better-than-random agreement.

Intraobserver scoring consistency was assessed (for Pine Siskins) by calculating the proportion of birds scored identically on each of the three examinations. These proportions were compared among observers using a contingency table analysis. An agreement index was also generated using the within-observer differences for the repeated measurements from the Pine Siskins.

RESULTS

Using the data from all five species and all four observers, we found a significant relationship between mean fat score and TBF (Fig. 1, $F = 22.4$, $df = 1, 98$, $P < 0.001$, $r^2 = 0.19$). These results compare with a similar analysis by Rogers (1987), but our coefficient of determination was consid-

erably lower than his ($r^2 = 0.58$). Also similar to Rogers' (1987) finding was the species-specific variation in the ability to index TBF using fat scores (Table 1). Analysis of covariance indicated that slopes ($F = 6.48$, $df = 4, 90$, $P < 0.001$) and intercepts ($F = 7.65$, $df = 4, 90$, $P < 0.001$) differed among species. This is not surprising because of the size range of the birds used in the study; larger birds, such as Red-winged Blackbirds, have substantially more body fat by weight than smaller birds, such as Pine Siskins. Thus, one would expect both the intercept and the slope to vary by species because the same fat scores are assigned regardless of the species. House Sparrow TBF showed the most precise relationship to fat score, whereas, Pine Siskin TBF had the least precise relationship (Table 1). Except for the House Sparrows, the proportion of variability in TBF explained by fat score was less than 0.55, which is marginal at best for most purposes.

One difference between our study and Rogers' (1987) is our use of the average fat score among four observers. A comparison of the regressions based on the mean score with those based on individual observers' scores (Table 2) shows that the coefficient of determination using the average was above the median coefficient of determination based on individual scores for all species. Further, the average coefficient of determination was higher than any individual r^2 for two species. The difference in precision in our study and Rog-

TABLE 2. Coefficients of determination for linear regressions between total body fat (Y) and fat score (X).

Species	Mean fat score r ²	Observer 1 r ²	Observer 2 r ²	Observer 3 r ²	Observer 4 r ²
House Finch	0.489	0.421	0.504	0.485	0.328
Pine Siskin	0.429	0.385	0.506	0.271	0.263
Red-winged Blackbird	0.543	0.676	0.312	0.583	0.370
Brown-headed Cowbird	0.443	0.115	0.387	0.319	0.296
House Sparrow	0.697	0.475	0.653	0.604	0.668

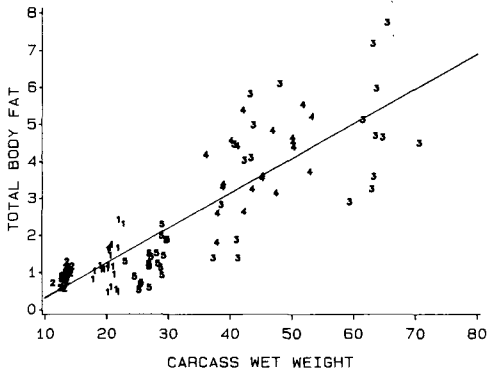


FIGURE 2. Relationship between total body fat (g) and carcass wet weight (g) of five species of songbirds. 1—House Finch, 2—Pine Siskin, 3—Red-winged Blackbird, 4—Brown-headed Cowbird, 5—House Sparrow. The overall equation is total body fat = $-0.630 + 0.094$ (carcass wet weight) ($r^2 = 0.73$, $P < 0.001$).

ers' (1987) cannot be attributed to our use of average fat score among observers.

Not unexpectedly, there was a significant relationship between carcass wet weight and TBF (Fig. 2, $F = 266.1$, $df = 1$, $98 P < 0.001$). For all species combined, the relationship between carcass wet weight and TBF was much stronger ($r^2 = 0.73$) than the relationship between mean fat score and TBF ($r^2 = 0.19$). Except for the House Finch, all individual species relationships between carcass wet weight and TBF were also significant (Table 3). Oddly, the species-specific relationships between TBF and carcass wet weight were much poorer than the corresponding relationships based on fat score (Table 3). Analysis of covariance indicated that neither slopes ($F = 0.31$, $df = 4$, 90 , $P = 0.87$) nor intercepts ($F = 0.48$, $df = 4$, 90 , $P = 0.75$) differed among species. Pine Siskin TBF showed the most precise relationship to carcass wet weight whereas House Finch TBF had the least precise relationship (Table 3). In no case was the amount of variation in TBF explained by carcass wet weight greater

than 0.40. Clearly, on an individual species basis, mean fat score indexed TBF better than did carcass wet weight. However, if comparisons among species are of interest then carcass wet weight might be a more appropriate measurement to use.

In 15 of the 20 analyses of variance, the mean TBF differed ($P < 0.05$) between at least the highest and lowest scores given; in five analyses no significant differences were detected (Table 4). The highest score always had the highest mean TBF and the lowest score always had the lowest mean TBF. However, in six of the 20 species-observer combinations, the order of the mean TBF was not the same as the order of the scores, i.e., a category with a lower score had a higher mean TBF than a category with a higher score (Table 4). Means for the reversed scores were never significantly different ($P > 0.05$), but this indicates that most observers had difficulty in distinguishing scores, especially the intermediate ones. For example, observer 4 gave nine House Finches a score of 3, but the mean TBF for that group was less than the mean TBF for the three House Finches given a score of 1 (Table 4).

According to the analyses of variance and the regressions, observers differed in their ability to assign appropriate fat scores. This is exemplified by the range in average TBF levels for score 4 in House Finches (Table 4); there is 20% difference between the highest average level (observer 3) and the lowest average level (observer 2). More extreme ranges were found in other species. Also, precision differed among observers and among species (Table 2). For one species, House Sparrows, the ascending pattern of mean TBF paralleled scores for all observers. Coefficients of determination were also relatively large for all observers for House Sparrows (Table 2). However, for Red-winged Blackbirds there was more variability among observers (Table 2). Two observers had no significant ($P > 0.05$) differences among score means, and three of the four ob-

TABLE 3. Relationship between total body fat (Y) and carcass wet weight (X).

Species	Intercept (SE)	P	Slope (SE)	P	r^2
House Finch	-2.008 (1.900)	0.305	0.159 (0.093)	0.104	0.14
Pine Siskin	-1.360 (0.681)	0.061	0.173 (0.051)	0.004	0.39
Red-winged Blackbird	0.501 (1.700)	0.772	0.073 (0.032)	0.033	0.23
Brown-headed Cowbird	-0.192 (1.654)	0.909	0.093 (0.037)	0.021	0.26
House Sparrow	-3.028 (1.324)	0.035	0.158 (0.048)	0.004	0.37

TABLE 4. Frequency of occurrence, mean total body fat, and Pearson's chi-square statistics for each fat score by species and observer. \bar{x} TBF = mean total body fat.

Observer	Score					Total
	0	1	2	3	4	Row χ^2
House Finch						
1 Frequency	4	2	4	7	3	20
\bar{x} TBF	0.82	1.04	1.06	1.25	2.17	
Cell χ^2	0.568	0.205	0.015	0.009	0.000	0.806
2 Frequency	1	4	6	5	4	20
\bar{x} TBF	0.49	0.90	1.09	1.27	1.96	
Cell χ^2	1.114	0.568	0.721	0.698	0.333	3.434
3 Frequency	3	2	5	8	2	20
\bar{x} TBF	0.72	1.15	0.90	1.39	2.38	
Cell χ^2	0.023	0.205	0.132	0.078	0.333	0.771
4 Frequency	3	3	2	9	3	20
\bar{x} TBF	0.72	1.20	1.08	1.16	2.17	
Cell χ^2	0.023	0.023	1.191	0.422	0.000	1.659
Total	11	11	17	29	12	80
					χ^2	6.660
					df	12
					P	0.879
Pine Siskin						
1 Frequency	0	0	13	4	3	20
\bar{x} TBF	—	—	0.86	0.96	1.19	
Cell χ^2	—	2.500	1.778	0.667	0.100	5.045
2 Frequency	0	0	9	8	3	20
\bar{x} TBF	—	—	0.80	0.97	1.19	
Cell χ^2	—	2.500	0.000	0.667	0.100	3.267
3 Frequency	0	10	6	4	0	20
\bar{x} TBF	—	0.84	0.97	1.09	—	
Cell χ^2	—	22.500	1.00	0.667	2.500	26.667
4 Frequency	0	0	8	8	4	20
\bar{x} TBF	—	—	0.83	0.94	1.10	
Cell χ^2	—	2.500	0.111	0.667	0.900	4.178
Total	0	10	36	24	10	80
					χ^2	39.16
					df	9
					P	0.001
Red-winged Blackbird						
1 Frequency	5	3	1	6	5	20
\bar{x} TBF	2.56	3.43	2.84	4.83	6.37	
Cell χ^2	0.013	0.000	2.722	1.000	0.417	4.852
2 Frequency	6	3	4	2	5	20
\bar{x} TBF	3.33	3.43	4.66	4.35	5.83	
Cell χ^2	0.329	0.000	0.056	1.000	0.417	1.801
3 Frequency	1	3	9	5	2	20
\bar{x} TBF	1.40	2.18	4.27	5.69	5.97	
Cell χ^2	2.961	0.000	4.500	0.250	0.817	8.527
4 Frequency	7	3	4	3	3	20
\bar{x} TBF	3.17	4.27	4.65	4.50	6.56	
Cell χ^2	1.066	0.000	0.056	0.250	0.150	1.521
Total	19	12	18	16	15	80
					χ^2	16.00
					df	12
					P	0.191
Brown-headed Cowbird						
1 Frequency	0	0	0	9	11	20
\bar{x} TBF	—	—	—	3.58	4.24	
Cell χ^2	—	—	4.000	0.000	2.286	6.286

TABLE 4. Continued.

Observer	Score					Total
	0	1	2	3	4	Row χ^2
2 Frequency	0	0	4	6	10	20
\bar{x} TBF	—	—	3.38	3.12	4.66	
Cell χ^2	—	—	0.000	1.000	1.286	2.286
3 Frequency	0	0	9	11	0	20
\bar{x} TBF	—	—	3.34	4.44	—	
Cell χ^2	—	—	6.250	0.444	7.000	13.694
4 Frequency	0	0	3	10	7	20
\bar{x} TBF	—	—	3.24	3.65	4.67	
Cell χ^2	—	—	0.250	0.111	0.000	0.361
Total	0	0	16	36	28	80
					χ^2	22.63
					df	6
					P	0.001
House Sparrow						
1 Frequency	3	5	5	7	0	20
\bar{x} TBF	0.67	1.12	1.33	1.65	—	
Cell χ^2	0.964	0.417	0.454	3.500	0.750	6.085
2 Frequency	6	4	7	1	2	20
\bar{x} TBF	0.82	1.30	1.35	2.00	2.11	
Cell χ^2	0.107	0.017	0.009	1.786	2.083	4.007
3 Frequency	6	5	8	1	0	20
\bar{x} TBF	0.78	1.29	1.59	2.00	—	
Cell χ^2	0.107	0.417	0.232	1.786	0.750	3.291
4 Frequency	6	1	7	5	1	20
\bar{x} TBF	0.82	1.23	1.27	1.69	2.31	
Cell χ^2	0.107	2.017	0.009	0.643	0.083	2.857
Total	21	15	27	14	3	80
					χ^2	16.24
					df	12
					P	0.181

servers had reversals of score means (Table 4). Pine Siskins, House Finches, and Brown-headed Cowbirds were difficult to score, as determined by the linear regressions, but results were more consistent among observers (Tables 2, 4).

Not only do observers differ in their ability to assign fat scores that index TBF, but they seemingly assign scores differently (although all observers were given the same set of instructions prior to the study) (Table 4). This is exemplified by the House Sparrow where observers 1 and 3 assigned no birds a score of 4 whereas observers 2 and 4 gave three birds a score of 4. This point is also demonstrated by the wide variation in chi-square row (observer) totals, e.g., Pine Siskin row totals varied from 3.267 to 26.667. In the latter case, observer 3 appears to be categorizing birds as one score lower than the other observers. Interestingly, observer 3 did not consistently score birds of other species lower relative to other observers (Table 4), indicating that observers are not consistent in how they score across species.

This was borne out by the overall chi-square values for the five species, i.e., Pine Siskins and Brown-headed Cowbirds were not consistently scored across observers while the remaining three species were more consistently scored (Table 4).

Agreement indices, which take into account differences in observers' scores for individual birds, also indicate poorer agreement for cowbirds (Table 5). Conditional on the observed cowbird scores, agreement among observers' scores was no better than expected by chance ($P = 0.12$). More-consistent-than-random scores ($P < 0.001$) were obtained for all other species.

The proportion of Pine Siskins scored consistently (all three scores the same) did not differ among observers ($\chi^2 = 5.142$, $df = 4$, $P = 0.162$). Only in two cases out of a possible 100 did an observer assign three different scores to the same bird. More than half of the time though, observers assigned the same bird two different scores. Usually the change in score was to an adjacent category. The intraobserver agreement index for

TABLE 5. Indices of between-observer agreement for fat scores from five species of songbirds. The probability is of obtaining, by chance, an agreement index at least as large as the observed index.

Species	Agreement index	Probability
House Finch	0.831	<0.001
Pine Siskin	0.656	<0.001
Red-winged Blackbird	0.763	<0.001
Brown-headed Cowbird	0.488	0.120
House Sparrow	0.803	<0.001

Pine Siskins was 0.79, compared with 0.67 for interobserver comparisons, indicating that a single observer yields more consistent results than multiple observers.

The data from the 15 House Sparrows scored while alive were compared with the data from the same birds when dead. These results should be interpreted with caution, because the status of the bird is confounded with observer effects (different observers scored the birds when alive and dead). The distribution of scores for the live birds did not differ significantly from that of the dead birds ($\chi^2 = 20.70$, $df = 16$, $P = 0.19$). The slope of the regression of TBF on fat score, 0.32, was also similar to that of dead birds (range = 0.30–0.40). However, the precision of the regression, as measured by the coefficient of determination, was lower for the live birds (0.38 vs. a range of 0.43–0.70). Working with living birds may be more difficult, indicating that our evaluation of the reliability of fat scoring may be optimistic.

We also investigated the effect of the number of possible scores on the accuracy of the method and on observer variability. In no case did reducing the number of possible scores from six to three influence either the precision of the method or inter- or intraobserver variability (unpubl. data).

DISCUSSION

Fat scoring, to the best of our knowledge, was first described by McCabe (1943). McCabe (1943) discussed several problems with fat scoring including interobserver variability in scoring and observers potentially scoring species differently despite using the same scoring scheme. Regardless of McCabe's (1943) initial concerns, fat scoring has not been rigorously examined until now.

The only thorough investigation of the method was Hailman's (1965), in which he described the nature of the fat score data, the appropriate measurements to use, and the appropriate statistical tests to use.

Despite these problems and lack of follow-up studies, researchers continue to use the method widely for what we believe are two reasons. First, the method is nondestructive and to date no real alternatives have been discovered, although other nondestructive methods have been investigated (see Baldassarre et al. 1980, Walsberg 1988). Second, the method is fast and easy to use.

When we first began to investigate the reliability of fat scoring, we interviewed a number of birders who have used the method extensively. We were intrigued to learn several attributes of the use of the method. We learned that observers were (1) using the same scoring categories but applying them differently dependent on the species, (2) using fat scoring to address hypotheses which required relatively accurate predictors of TBF, and (3) often were recording fat scores for no a priori purpose.

Our findings corroborate that fat scoring is only a fair index of TBF. We found that the precision of fat scoring was species-specific. House Sparrow TBF was indexed most precisely while Pine Siskin and Brown-headed Cowbird TBF were indexed least precisely. As well, we found that on average, observers were able to assign scores explaining only about half of the variation in TBF. Between-observer variation in fat scoring was inconsistent and great at times. Observers did not always score fatter birds higher. We were surprised to find that within-observer variation was at an acceptable level. Overall, we would describe fat scoring as a fairly precise index of TBF, but with limited reliability among observers.

We were quite surprised to learn that carcass wet weight did not explain as much of the variation in TBF as did fat scores for individual species. The relationship of carcass wet weight to TBF is more consistent among species and may provide a useful measure for interspecies comparison.

RECOMMENDATIONS

Fat scoring is a valuable tool that we encourage use of but with the following recommendations. (1) Be sure that the hypothesis being tested is one that can be answered with an index of moderate

precision. Do not, for example, try to investigate the relationship between the number of hours a bird can survive without food and fat score. (2) If there are no means of investigating a hypothesis other than fat scores, and that hypothesis requires a relatively precise index, then determine the relationship between fat score and TBF for the species in question and the appropriate time of year. (3) Try to avoid having more than one observer score birds during the study. This is especially important if the study lasts more than 1 year and it is possible that different observers will be used among years. (4) Have the observer practice on the species in question and be sure that the observer is exposed to the full range of fat scores before the study begins. (5) Do not overcategorize the scoring system; it adds no additional information. No more than five scores are necessary. (6) If the hypothesis being tested involves among-species comparisons, consider using carcass wet weight as an index of total body fat rather than fat scoring. (7) Be especially cautious of comparing and contrasting results of separate studies based on fat scores of the same species.

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