Nutrient Reserve Models for Post-breeding Lesser Prairie-chicken

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Abstract: We developed and evaluated 7 least-squares regression models to estimate body fat and protein reserves from external measurements of post-breeding male and female lesser prairie-chickens (*Tympanuchus pallidicinctus*). For males, protein was adequately modeled (R^2 = 0.60), but attempts to model body fat were unsuccessful. For females useful fat (R^2 = 0.92), log fat (R^2 = 0.74), condition index (R^2 = 0.58), and protein (R^2 = 0.74) models were derived. These models can be used to compare post-breeding lesser prairie-chicken nutrient reserves among populations and habitats, without sacrificing the birds sampled.

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Protein and fat reserves are considered important limiting factors in birds (Ankney and MacInnes 1978, Johnson et al. 1985). However, techniques and models for nondestructive field assessment of bird fat and protein levels are limited primarily to waterfowl (Whyte and Bolen 1984, Johnson et al. 1985, Ringleman and Szymczak 1985, Miller 1989). Body fat indices for upland game birds have been developed, but usually require sacrificing birds (Warren et al. 1984, Servello and Kirkpatrick 1987, Koerth and Guthery 1988).

Fat and protein reserves may be limiting in lekking species such as lesser prairie-chicken during post-breeding periods. Sage grouse (*Centrocercus urophasianus*) males expend substantial energy during the breeding season for territorial defense and pre-copulatory display (Hupp and Braun 1989, Vehrehcomp et al. 1989). Nutrient reserves are important to females during post-breeding periods because of energy needs

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for nest site selection, nest construction, egg laying, egg incubation, and brood rearing (Scott 1973, Kendeigh et al. 1977). Our objective was to develop and evaluate regression models based on nondestructive samples to predict body fat and protein reserves of post-breeding male and female lesser prairie-chickens.

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Methods

Field work was conducted in Cochran and Yoakum counties, Texas, and Lea County, New Mexico. Mean annual precipitation is 41 cm, >80% of which occurs between May and October (Newman 1960). Cattle production is the major land use. The area is characterized by the Brownfield-Tivoli fine sand soil association and a gently undulating, duned topography. Sand shinnery oak (*Quercus havardii*) dominates the area, with less frequent occurrences of sand sagebrush (*Artemisia filifolia*), sand dropseed (*Sporobolus cryptandrus*), purple threeawn (*Aristida purpurea*), and broom snakeweed (*Xanthocephalum sarothrae*) (Dittemore and Hyde 1960, Pettit 1979).

Lesser prairie-chickens ($N = 52$) were collected from 27 May to 3 July during 1984 and 1985. Sex and age were determined according to Copelin (1963) and Jones (1963). Wing chord length (WL) was measured to the tip of the eighth primary. Body length (BL) and body weight (BW) were measured and the carcasses were frozen for further analyses.

The feathered carcass (minus ingesta) was sectioned and ground twice in an electric meat grinder. The resulting homogenate was dried in a forced-air oven (60° C) or freeze-dried to a constant weight. The homogenate was reweighed to calculate water content by difference and reground. Fat was extracted from 5- to 9-g samples of the dried homogenate using Soxhlet apparatus and petroleum ether for 40–41 hours (Horwitz 1980), after which the ether was evaporated and the sample reweighed as a measure of fat extracted. Ash was determined by combusting duplicate 1- to 5-g samples of the dried homogenate in a muffle furnace at 600° C. Ash-free lean dry weight, a measure of protein, was obtained by subtracting ash, water, and fat from body weight (Olawsky 1987).

We used least squares multiple regression to develop and compare 3 models for 4 dependent variables: grams of fat (FAT), logarithm of grams of fat (LFAT), a lipid index (LI), and ash-free lean dry weight (AFLD). Morphological variables (BL and WL) were used as scalers with body weight (BW) to account for differences in body structure among individuals (Johnson et al. 1985, Ringleman and Szymczak 1985).

The LI (fat/fat-free dry weight) scales fat content by a measure of structural size (Johnson et al. 1985). Fat-free dry weight was calculated by subtracting water and lipid from body weight. Johnson et al. (1985) suggested a condition index (CI) transformation, CI = log(LI + 1) because of the allometric nature of the variables and logarithms are generally suited for linearizing ratios. All independent variables were log transformed in the CI and LFAT models (Johnson et al. 1985).

A dummy variable for sex (DSEX) was used in predictive equations for fat (FAT, LFAT, CI), and in those cases where DSEX interacted with a class variable, predictive models were developed for each sex. Sex-specific AFLD models were developed without dummy variables because of differing protein use that is likely occurring between sexes during the post-breeding period. Preliminary plots were used to determine independent variable relationships with the dependent variables, possible independent variable transformations, and for examination of possible interactions.

Variables (WL, BL, BW, BW^2, BL^2, WL^2, and respective non-squared interactions) were subjected to PROC RSQUARE for model selection (SAS Instit. 1985). Three models for each of the 4 dependent variables were selected by evaluating Mallows C(p), adjusted R^2 ($\overline{R}^2$), and R^2 generated by PROC RSQUARE. A model for each dependent variable was selected from the 3 models generated based on the individual model's *F*-statistic and independent variable coefficients and their standard errors. Prediction error sums of squares (PRESS) statistic was used as a measure of variance and bias for models generated within each dependent variable (Montgomery and Peck 1982). Multicollinearity was assessed by determining a condition number (K) based on eigenvalue analysis (Montgomery and Peck 1982).

Model assumptions were tested in the following manner: (1) linearity by partial residual plots; (2) constant variance by residual plots with corroboration by Spearman's rank correlation of actual versus predicted values; and (3) normality by residual error versus predicted Z value plots and corroboration by the Shapiro-Wilk W test on residual error values. The independent error assumption was assumed to be satisfied a priori, because of the lack of temporal, spatial, or contemporaneous correlations.

Results and Discussion

Body weight, BL, and AFLD differed between sexes ($P < 0.05$, Table 1). Differences in AFLD between sexes might be related to body weight differences, because AFLD is an important component of body weight.

Preliminary diagnostic plots indicated that interaction terms should be included in model building. The dummy variable (DSEX) interacted with a class variable in all fat predictive models for which male and female data were combined; therefore, models of body fat were developed for each sex separately. Based on $\overline{R}^2$ and Mallows C(p) values, 3 models for each dependent variable were evaluated for females and for FAT, LFAT, and AFLD for males (Tables 2 and 3). None of the models explained

Table 1. Male and female lesser prairie-chicken morphology and nutrient reserves from 52 birds collected in June 1984 and 1985 from Cochran and Yoakum counties, Texas, and Lea County, New Mexico.

	Male (N = 37)			Female (N = 15)		
Variable	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
Body weight (g)	741.74[a]	59.42	618.00–897.00	627.61[a]	56.99	517.48–714.01
Wing length (cm)	20.94	0.68	19.10– 22.10	20.62	0.59	19.40– 21.40
Body length (cm)	40.07[a]	1.05	37.80– 42.10	37.45[a]	1.18	35.30– 40.00
Fat (g)	19.03	6.96	6.12– 31.20	18.55	10.41	3.04– 36.61
Ash-free lean dry (g)	174.71[a]	14.38	132.73–193.35	151.45[a]	12.83	126.86–167.78

[a] $P < 0.05$ between males and females (Student's *t*-test).

>5% of the variation in CI for males. Assumptions were satisfied in all selected models. Multicollinearity was judged to be a problem in the male and female models of FAT (Table 3). No model satisfactorily predicted body fat for males. Models for fat (FAT and LFAT) in males had low $\bar{R}^2$ values (<20% of the variation explained). Models predicting AFLD had higher $\bar{R}^2$ values than did the lipid models.

Hupp and Braun (1989) found that male sage grouse used lipid reserves during courtship. For male sage grouse, Vehrehcamp et al. (1989) estimated courtship energetic costs ranged from 2 times standard metabolic rate (SMR) for males that did not display on leks to 4 times SMR for males displaying and mating on leks. This reflects the structural social hierarchy and differential breeding success found in a lekking species such as lesser prairie-chicken. However, Hupp and Braun (1989) concluded that male sage grouse did not use protein reserves during courtship. Thus, protein reserves may be a better indicator of male lesser prairie-chicken condition than body fat during the post-breeding period. However, bias and variance for AFLD was higher than for the fat models.

Lipid models were better predictors of body fat for females than for males. Models for predicting female body fat were good estimators of lipid reserves, which may reflect similar behavioral activities (mating, nest site selection, egg laying, incubation, and brood rearing) and energetic demands on all females. The $\bar{R}^2$ value was highest for models of female body fat (FAT) and lowest for models of the lipid index (CI). However, model variance and bias were lowest for the CI models. Models of female AFLD had higher $\bar{R}^2$ and lower model variance and bias than did male protein models.

Lesser prairie-chicken nutrient reserves can be estimated during the post-breeding period for both sexes with only a few body measurements taken during trapping (Haukos et al. 1989). We feel the models are simple and will aid in the management of lesser prairie-chickens by providing a nondestructive method of evaluating fat and protein reserves, which may be useful for comparing different prairie-chicken populations or habitats.

Table 2. Recommended nutrient reserve models, model F-statistic probability, regression coefficients (± SE), and independent variable t-statistic probability generated with least squares regression for post-breeding male and female lesser prairie-chickens collected in Cochran and Yoakum counties, Texas, and Lea County, New Mexico, during June 1984 and 1985.

Dependent variable and t-probability	Model	$P > F$
	MALE	
FAT	$-2143.33 + 4\times10^{-5}\ (\pm1\times10^{-5})\ BW^2 - 1.52\ (\pm1.64)\ WL + 110.27\ (\pm66.72)\ BL - 1.40\ (\pm0.84)\ BL^2$	0.10
$P > t$	(0.01) (0.36) (0.10) (0.10)	
LFAT	$-11.27 + 4.42\ (\pm2.11)\ LBW - 1.43\ (\pm1.96)\ LWL - 0.44\ (\pm0.41)\ LBLLBW$	0.03
$P > t$	(0.04) (0.47) (0.30)	
AFLD	$-104.28 + 0.27\ (\pm0.11)\ BW + 7.17\ (\pm2.34)\ WL - 0.0025\ (\pm0.002)\ BLBW$	0.0001
$P > t$	(0.02) (0.004) (0.30)	
	FEMALE	
FAT	$-6287.99 + 0.70\ (\pm0.31)\ BW - 4\times10^{-4}\ (\pm2\times10^{-4})\ BW^2 + 595.36\ (\pm97.37)\ WL - 14.65\ (\pm2.39)\ WL^2$	0.0001
$P > t$	(0.05) (0.12) (0.0001) (0.0001)	
LFAT	$-33.95 + 6.62\ (\pm1.14)\ LBW - 1.96\ (\pm3.64)\ LWL$	0.0003
$P > t$	(0.0001) (0.60)	
CI	$-1.09 + 0.28\ (\pm0.10)\ LBW - 0.44\ (\pm0.50)\ LWL + 0.06\ (\pm0.10)\ LBLLWL$	0.02
$P > t$	(0.02) (0.40) (0.56)	
AFLD	$31.02 + 0.43\ (\pm2.65)\ BL + 0.0024\ (\pm0.005)\ WLBW + 0.003\ 1/(\pm0.003)\ BLBW$	0.001
$P > t$	(0.87) (0.65) (0.27)	

Table 3. Descriptive and diagnostic statistics for the 7 recommended nutrient reserve models of post-breeding male and female lesser prairie-chickens collected in Cochran and Yoakum counties, Texas, and Lea County, New Mexico, during June 1984 and 1985.

Sex and dependent variable	R^2	$\bar{R}^2$	$C(p)$	PRESS		Bounds on K
				$\lvert P \rvert$	P^2	
Male						
FAT	0.21	0.11	2.70	5.74	46.29	4,131–32,954
LFAT	0.23	0.16	1.32	0.34	0.16	7–46
AFLD	0.60	0.57	9.13	8.13	106.56	18–113
Female						
FAT	0.92	0.90	3.64	2.20	17.64	4,347–38,074
LFAT	0.74	0.71	−0.28	0.38	0.20	1–4
CI	0.58	0.46	4.24	0.03	0.001	3–25
AFLD	0.74	0.67	8.17	6.98	72.84	13–76

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