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RELATIONSHIP BETWEEN AGE AND MASS AMONG FEMALE WHITE-TAILED DEER DURING WINTER AND SPRING

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Mautz et al. (1976) and Moen (1978) recognized a need for data on mass rhythms of wild deer (*Odocoileus virginianus*) before realistic maintenance requirements could be calculated. However, most literature on mass of white-tailed deer is based on captive deer or on dressed weights of animals collected during fall hunting seasons (Fuller et al., 1989) and with ages determined by the tooth-wear method (Severinghaus, 1949), known to be imprecise (Ryel et al., 1961). Overwinter loss of mass in wild deer was examined by use of a combination of dressed and whole weights (Severinghaus, 1981), and equations were developed for expressing the annual mass cycle of deer (Moen and Severinghaus, 1981). Nevertheless, information about whole-body mass and age in free-ranging white-tailed deer during winter is minimal.

Herein, we describe the relationship between age and mass of female white-tailed deer livetrapped during late winter and spring in the Superior National Forest of northeastern Minnesota (48°N, 92°W). The area is characterized by 5 months of winter weather, with an annual average of >150 cm of snowfall (Hovde, 1941). Most deer in the area spend winter in a few scattered yards that support densities of 16–45 deer/km^2 (Nelson and Mech, 1981). The major natural mortality factor of deer in the study area is the wolf (*Canis lupus*—Mech and Karns, 1977; Nelson and Mech, 1981, 1986).

Deer were captured on winter ranges from January–April, 1973–1985, by rocket nets, clover traps, and drug-loaded darts. Most were anesthetized and weighed with a spring scale, and their age determined by counts of annuli in the incisors (Gilbert, 1966).

Hypotheses considered as the basis for developing a model for the relationship between mass of adult females and age were that annual change in mass depends on current mass, annual change in mass depends on current age, and that annual change in mass depends on both current mass and age. These hypotheses were tested by creating a mathematical model for change in mass based on each hypothesis, expressing the model in mathematical differential form, mathematically integrating the expression to obtain a model for mass at a particular time, then fitting the model to the data separately for each month of capture. The four separate models were analyzed to determine further if they could be combined into a single model.

Ninety-six adult females >1 year old were captured and weighed a total of 123 times (Table 1). Of the 96 deer, 80 were weighed once, 12 twice, 2 three times, 1 six times, and 1 seven times. The biasing effect of these multiple observations was analyzed and found to be insufficient to alter estimates or inferences substantially based on an assumption of independent data.

For all 4 months of capture, the models based on the hypothesis that annual change in mass depends on current age fit the data much better than models based on the hypothesis that current mass determines annual change in mass. Also, the models based on combined effects of current mass and current age did not significantly improve the quality of fit. Therefore, the hypothesis that annual change in mass depends only on current age was accepted, and the form of the model for current mass as a function of current age was:

$$E(M) = b_1 - b_2\exp(-b_3A). \quad (1)$$

where $E(M)$ is the statistical expectation of mass in kilograms, b_1 is the maximum mass and is approached asymptotically as female deer increase in age, b_2 is the mass gained between the first summer and adulthood, b_3 is a term related to the rate at which female deer approach their maximum mass, and A is age in years. Observed masses for two female deer 13–15 years of age were substantially below their predicted values and below predicted weights for those 8–12 years of age, suggesting a decrease in mass after 12 years of age. Model 1 was modified to permit the possibility of decreasing mass for older deer, but the modification

TABLE 1.—*Mean mass (kg) of female deer of various ages livetrapped in the Superior National Forest, Minnesota.*

	Month of capture							
	January		February		March		April	
Age	Mass	n	Mass	n	Mass	n	Mass	n
1	61	1	53	8	53	12	47	4
2	64	1	65	5	59	12	55	4
3	70	3	62	4	62	5	56	2
4	68	1	70	5	59	5	57	2
5	75	3	72	1	65	8	59	1
6	75	1	65	3	65	3	69	1
7			63	2	79	1	61	4
8			72	3				
9	77	1	73	1				
10	81	1	73	1	76	1	73	2
11	73	1	73	1	73	1	67	1
12					65	5		
13					54	1		
14								
15							61	1

did not improve the quality of fit significantly ($P > 0.20$). The two observations for the 13–15-year-old deer were excluded from subsequent analyses.

For the 4 separate months of capture, the four estimates of each variable of model 1 were sufficiently close to suggest that a single, overall model might be possible. However, combining the four individual models into a single model requires consideration of the rate at which mass is lost during winter months. We considered the hypotheses that monthly loss of mass was constant regardless of age and mass, and that monthly loss of mass was proportional to mass at the beginning of winter. The two combined models, based on these two hypotheses, were virtually indistinguishable with respect to quality of fit, indicating that the data did not provide sufficient evidence to distinguish between the two hypotheses. The model based on the proportional hypothesis was selected because it was thought to be more biologically sound. Modifications of this model were developed to test if proportion of loss of mass per month changed with month of capture, age, or varying winter severity. No significant ($P > 0.20$) improvement was detected with any of these modifications.

Thus, the final model is based on the hypotheses that annual change in mass depends on age, that monthly loss of mass over winter is proportional to mass at the beginning of winter, and that monthly proportion of loss of mass is constant throughout winter and for all ages. The model based on these hypotheses is formulated as

$$E(M) = [b_1 - b_2\exp(b_3A)](1 - b_4C) \quad (2)$$

where $E(M)$, b_1, b_2, b_3, and A are as described for model 1, b_4 is the monthly proportion of mass lost during winter and c is month of capture (1 = January, 2 = February, 3 = March, 4 = April).

Estimates for the variables and their standard errors, based on model 2, are: $b_1 = 80.50 \pm 2.29$, $b_2 = 28.12 \pm 3.14$, $b_3 = 0.40 \pm 0.11$, and $b_4 = 0.05 \pm 0.01$. This model exhibited no significant lack of fit ($P > 0.25$), and there was a highly significant ($P < 0.001$) relationship between the dependent variable, mass of female deer, and the independent variables, age and month of capture (Fig. 1).

We could find no other report of relationships between mass of live, wild white-tailed deer and age determined from counts of incisor annuli. Based on either captive deer, or ages based on tooth wear, Severinghaus and Cheatum (1956) stated that mass of deer (sex not specified) increases to 5.5, and possibly 6.5 years, and Roseberry and Klimstra (1975) concluded that females achieved maximum mass in autumn by 4.5 years of age. Woolf and Harder (1979) found that dressed weights of wild females in autumn peaked at 4.5–5.5 years, based on tooth wear, and Fuller et al. (1989) concluded that mass of female deer in Minnesota maximized at 4 years based on dressed weights in autumn and on ages from incisor annuli. Our data are in accord with these reports in that our deer achieved 95% of maximum mass at age 5.0–7.5 years.

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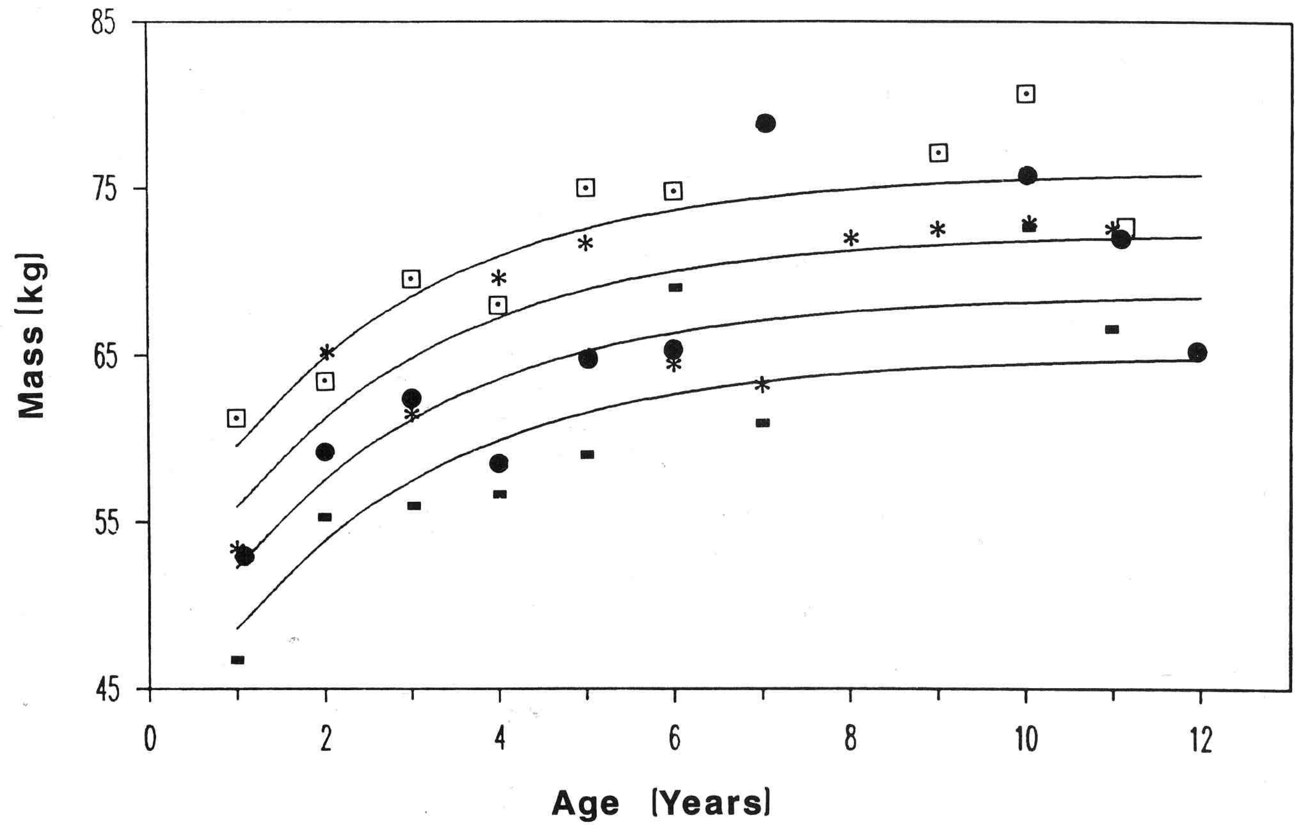

FIG. 1.—Relationship between mean mass and ages of live female white-tailed deer captured in northeastern Minnesota by month. Upper curve (squares) represents January data, next lower (asterisks), February; next lower (dots), March; and lowest (bars) April. R^2 = 0.59 for observations ($P < 0.01$) and 0.82 for means ($P < 0.01$). Mass estimate = [80.50 − 28.12exp(−0.40 age)](1 − 0.05 month). The 13 and 15-year-old deer were excluded from the analysis.

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