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Bone Marrow Fat as an Indicator of Condition in Roe Deer

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A method for the estimation of bone marrow fat levels described by Neiland (1970) gave high correlations with results obtained by an organic solvent extraction. The method was used to indicate body condition in roe deer *(Capreolus capreolus)* culled from two populations over four winters and from animals considered to be in poor condition at the time of death. Results suggest that healthy animals have femur fat levels during winter in the 75—85% range. Animals suffering a decline in condition exhibit a progressive proximal to distal decline in marrow fat along the limbs. Femur marrow fat in an animal which died from starvation was 11%, the lowest level determined in the study. The estimation of bone marrow fat levels using Neiland's method may be useful in detecting population densities which are higher than the habitat can adequately support.

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INTRODUCTION

Indices describing the extent of body fat deposits in deer are considered to reflect body condition (Harris, 1945; Cheatum, 1949; Riney, 1955 and Caughley, 1970). Ransom (1965), Bear (1971) and Anderson *et al.* (1972) compared measurements of various fat deposits and concluded that an index of kidney fat *(e.g.* Riney, 1955) and the amount of bone marrow fat (Harris, 1945; Cheatum, 1949) were the most useful. Fat reserves are generally utilised sequentially starting with the subcutaneous deposits, followed by the mesenteric, kidney and finally bone marrow fat (Ransom, 1965; Bear, 1971). These authors suggested that fat levels covering the range of utilisation could be determined by using the measurements of both kidney and the bone marrow fat.

The detection in female roe deer *Capreolus capreolus* (Linnaeus, 1758) shot in winter and early spring, of body condition lowered to a level at which recovery is likely to be slow or unlikely, might provide an indication of over-population in relation to available food and shelter. This assumes that, in the absence of disease, body condition will be

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density-dependent for a given habitat. In this context a measurement of condition at the lower end of the scale is required, and for this reason bone marrow fat levels alone were examined. If bone marrow fat measurements are to be useful, some rapid, simple method of estimation is required. I therefore examined alternatives to classical quantitative fat extraction procedures.

MATERIAL

Samples were obtained from 83 female deer shot as part of the routine winter cull in Alice Holt Forest, Hampshire from 1970/1 to 1973/4. Bias in the selection of animals was restricted because of a »shoot-on-sight« policy. Due to the good condition of animals at Alice Holt Forest samples were later collected from 23 female deer from Kielder Forest, Northumberland, an area pedologically and botanically much poorer, to investigate changes in bone marrow fat levels in animals which might be in poorer condition.

Additional samples were obtained from 3 roe deer, 4 fallow deer, *Dama dama* (Linnaeus, 1758) and 6 red deer (*Cervus elaphus* Linnaeus, 1758) at the Animal Virus Research Institute, Pirbright, Surrey which had been experimentally infected with foot and mouth disease.

Five roe deer which were found dead or dying or were shot because of their apparent poor condition were also sampled.

METHODS

Estimates of the fat content of roe deer bone marrow using techniques described by Greer (1968) and Neiland (1970) were compared with an organic solvent fat extraction technique similar to that described in Horwitz (1960).

Initially, legs were removed from the carcasse by cutting through the femurs and humeri near the joint with pelvis or scapula. In many cases this led to a deterioration of the sample in storage, rendering it unfit for use. Subsequently all long bones were removed intact and stored in polythene bags at —5°C for periods up to 3 months or until used. This appeared to prevent deterioration.

A 40 mm section of marrow was removed from mid-way along each bone, weighed and stood on end in a plastic jig, made from rigid plastic tubing, with 10 equal calibrations inscribed on it (Greer, 1968). After 15 minutes the degree of compression (vertical shrinkage) was read off in tenths and expressed as a percentage. The weighed sample was then ovendried at 60°C to constant weight (± 0.02 gm) and the dry weight expressed as a percentage of the original wet weight (Neiland, 1970).

An organic solvent extraction using 1,1,1-trichloroethane in standard Soxhlet apparatus was then employed to remove all the fat. The solvent was evaporated off and the fat residue dried, weighed and expressed as a percentage of the fresh weight.

Samples other than the 1970—71 group from Alice Holt Forest, the roe deer infected with foot and mouth disease, and those from animals considered to be in poor condition, were not subjected to an organic solvent extraction since I had obtained high correlations using Neiland's method.

Fat levels determined by Neiland's method for right and left femur marrow from each deer were tested using the range-standard deviation test (D a v i d *et al.* 1954) and the Grubb-type test (T i e t j e n & M o o r e, 1972) to determine whether the mean value of left and right femurs could be used and if discrepancies between left and right femurs suggested the exclusion of any data from analysis.

Juvenile and adult animals were identified by examination of tooth eruption in the lower jaw. Jaws with all permanent pre-molars present and molar 3 erupted clear of the gum were considered to be adult. This occurs at approximately 15 months of age in the roe deer. Assuming a birth date of 1st June, all winter culled adults would be at least 17 months old. (Shooting commences on 1st November.)

RESULTS

Compared with values obtained by organic solvent extraction the compression method (G r e e r, 1968) accounted for only 0.2% of the variability ($r=0.015$). In practice, the method was difficult to execute due to the small diameter of roe deer marrow and to the sample adhering to the jig and preventing compression.

Neiland's method accounted for 78.87% of variability ($r=0.888$) in the Alice Holt Forest data for 1970—71 ($n=26$; $p=0.1$). All these deer were considered to be in good health when shot and 95% had fat levels in the 80—95% range. This method accounted for 87.89% of the variability in the roe deer infected with foot and mouth disease ($r=0.937$; $p=0.1$), though larger differences between results using the two methods were evident at fat levels below 50%. No allowance was made for the relatively higher proportion of mineral residue at low fat levels (N e i l a n d, 1970).

The range standard deviation test and Grubb-type test suggested that data from one animal with a determined difference of 22% between the fat levels in left and right femur marrow should be excluded from further analysis.

Significant upward trends in fat content were detected with the progression of winter ($p=0.05$) in juveniles from Alice Holt Forest in 1971—72 ($n=10$), and adults from Kielder Forest in 1971—72 ($n=7$) and 1972—73 ($n=14$). The significant upward trend in juveniles from Alice Holt Forest (1971—72) was due to one very low observation in early winter and is thus suspect. The remainder showed no differences in fat levels throughout the winter ($p=0.5$). A quadratic regression using all the data failed to demonstrate any decrease in the rate of increase with the progression of winter ($p=0.05$).

No differences were found between Kielder and Alice Holt Forests ($p=0.05$). Differences were demonstrated between adults and juveniles ($p=0.1$) (Table 1). 1970—71 produced higher fat levels than any of the other years using age groups combined ($p=0.05$), but did not do so for adults alone (Table 2).

Fallow and red deer subjected to foot and mouth disease did not appear to decline in condition (Foreman & Gibbs, 1974), and this was supported by the high fat level (89—97%) recorded in these animals. Only one fallow deer had lower levels in femur and humerus fat (84% and 79% respectively).

Bone marrow fat levels for roe deer in good and poor condition are shown in Fig. 1. One roe deer with foot and mouth disease was slaughtered during the active phase of disease, and had a femur fat level of 46% while the other two, which were convalescing, had 25% and 28%.

Table 1
Mean femur fat percentages and standard errors for different age groups using all years combined.

	Adult	Juveniles
Mean fat percentage	80.11	68.66
Standard error	1.23	2.27

Table 2
Mean femur fat percentages and standard errors for adults and juveniles for each year.

Year	1970/71	1971/72	1972/73	1973/74	Age group (averaged over yrs)
Adults	84.3 (3.13) N=13	77.0 (2.47) N=17	77.7 (1.75) N=31	81.4 (2.27) N=20	80.11 (1.23) N=81
Juveniles	78.6 (2.98) N=11	67.6 (4.04) N=16	63.5 (4.94) N=5	65.0 (5.71) N=3	68.67 (2.27) N=25
Year effect (averaged over age group)	81.45 (1.08) N=24	72.35 (1.18) N=23	70.59 (1.31) N=36	73.19 (1.54) N=23	N=106

The data on the former animal indicated a progressive utilisation of fat from proximal to distal bones with values of 70—80% fat in the metacarpals and metatarsals and 46% in the femurs and humeri while the latter had 20—45% fat in all bones.

A male animal from Chedington Woods, Dorset, which was shot because of symptoms suggesting blindness, deafness and general ill-health, showed visually an apparent progressive loss of fat from proximal to distal bones. In this case the marrows of the femurs and humeri were dark red and flaccid and the metacarpal and metatarsal marrows were pink and firm. The tibias and radii showed this proximal to distal change in fat content within the length of the bone and for this reason more than one marrow sample was taken from each bone. The marrow fat levels ranged from 75—80% in metacarpals and metatarsals to approximately 20% in femurs and humeri.

Another male shot at Abinger Forest, Surrey, because of its obvious poor condition also showed a progressive utilisation of fat from nearly 90% in metacarpals and radii to 61% in the humerus. The hind limbs were not available for sampling.

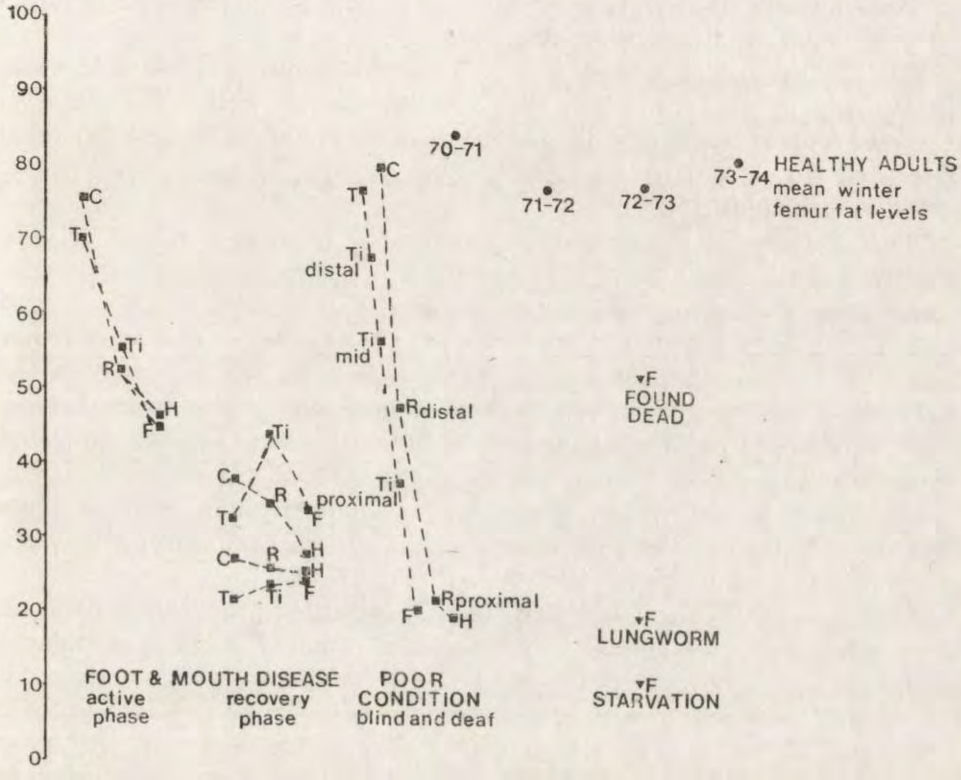

Fig. 1. Bone marrow fat percentages from roe deer in good and poor condition. T — metatarsal, Ti — tibia, F — femur, C — metacarpal, R — radius, H — humerus.

An emaciated female at Alice Holt Forest was observed walking aimlessly about and was found dead the following day. She had died from starvation due to an abcess which blocked the posterior naso-pharynx thus preventing ingestion and rumination. Mean femur fat level was 11%.

A young sick deer found at Chedington Woods, Dorset, died the following day. Post-mortem examination revealed an advanced state of parasitic pneumonia involving lung worm (*Dictyocaulus* sp.) infestation. Mean femur fat level was 19%.

An adult female found dead from unknown causes at Alice Holt Forest had a mean femur fat level of 52%.

DISCUSSION

Neiland's method is a useful practical technique for the determination of bone marrow fat levels in roe deer. It is simple to use and requires only a balance and a drying oven.

Healthy deer during winter have 75—80% femur marrow fat, while in animals in poor condition this sometimes falls well below 50% as Cheatum (1949) found in white-tailed deer (*Odocoileus virginianus*) and Hornocker (1970) found for mule deer (*O. hemionus*) and wapiti (*Cervus canadensis*).

No satisfactory explanation for increasing fat levels from early to late winter (the opposite to that expected) is apparent. The deer populations studied evidently did not experience any serious decline in food abundance or quality and there was no prolonged severe weather during the study. Apparently the habitat could adequately support the prevailing deer density. Further work should investigate bone marrow fat levels in populations which are not culled by man and are subjected to severe climatic conditions.

Bone marrow may not function as a fat depot in juveniles. This limits the use of the method for juveniles and makes comparisons between juveniles and adults difficult to interpret.

All the animals considered to be in poor condition prior to examination had much lower fat levels than those of the culled animals considered to be in good condition at the time of death. The deer with active foot and mouth disease appeared to be experiencing a progressive drop in condition while the two which were convalescing were in very poor condition, possibly due to the pressure on fat reserves in order to promote recovery. The only animal known to die naturally, due to malnutrition, demonstrated the lowest value obtained.

A progressive proximal to distal utilisation of marrow fat reserves occurs in the limbs, and metatarsal and metacarpal fat is not affected until a very poor condition prevails. The early detection of a decline in condition in roe deer populations must therefore be restricted to an examination of femur or humerus marrow. This is consistent with the findings of Brooks *et al.* (1977) for some African ungulates.

The assessment of femur marrow fat levels in culled roe deer may provide a useful management tool for detecting population densities higher than the habitat can support. If femur and humerus fat levels of deer shot in winter and early spring are consistently below 70—75% it seems likely that food and/or shelter are below the requirements for optimum growth and performance. Assuming therefore that body condition may be density-dependent over a period of several years, then culling levels and habitat may be manipulated accordingly.

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REFERENCES

1. Anderson A. E., Medin D. E. & Bowden D. C., 1972: Indices of carcase fat in a Colorado Mule deer population. J. Wildl. Manage., *36:* 579—594.
2. Bear G. D., 1971: Seasonal trends in fat levels of pronghorns, *Antilocapra americana,* in Colorado. J. Mammal., *52:* 583—589.
3. Brooks P. M., Hanks J. & Ludbrook J. V. 1977: Bone marrow as an index of condition in African ungulates. S. Afr. J. Wildl. Res., *7:* 61—66.
4. Caughley G., 1970: Fat reserves of Himalayan thar in New Zealand by season, sex, area and age. New Zealand J. Sci., *13:* 209—219.
5. Cheatum E. L., 1949: Bone marrow as an index of malnutrition in deer. N. Y. State Conservationist, *3:* 19—22.
6. David H. A., Hartley H. O. & Pearson F. S., 1954: The distribution of the ratio, in a single normal sample, of range to standard deviation. Biometrika, *41:* 482—493.
7. Forman A. J. & Gibbs E. P. J., 1974: Studies with foot and mouth disease virus in British deer (red, fallow and roe). 1. Clinical disease. J. Comp. Path., *84:* 215—220.
8. Greer K. R., 1968: A compression method indicates fat content of elk (wapiti) femur marrows. J. Wildl. Manage., *32:* 747—751.
9. Harris D., 1945: Symptoms of malnutrition in deer. J. Wildl. Manage., *9:* 319—322.
10. Hornocker M. G., 1970: An analysis of Mountain Lion predation upon Mule Deer and Elk in the Idaho primitive area. Wildlife Monographs, *21.*
11. Horwitz W. (ed.) 1965: Official methods of analysis. 10th ed. Association of Official Agricultural Chemists, Washington, D. C.
12. Neiland K. A., 1970: Weight of dried marrow as indicator of fat in caribou femurs. J. Wildl. Manage., *34*: 1904—1907.
13. Ransom A. B., 1965: Kidney and marrow fat as indicators of white tailed deer condition. J. Wildl. Manage., *29*: 397—398.
14. Riney T., 1955: Evaluating condition of free ranging red deer *(Cervus elaphus)*, with special reference to New Zealand. New Zealand J. Sci. Tech., Sec. B,. *36:* 429—463.

15. Tietjen G. L. & Moore R. H., 1972: Some Grubb-type Statistics for the detection of several outliers. Technometrics, *14:* 583—597.

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ZAWARTOŚĆ TŁUSZCZU W SZPIKU KOSTNYM JAKO WSKAŹNIK KONDYCJI SARNY

Streszczenie

Badania prowadzono na 83 samicach sarn, strzelonych w regionie Hampshire w latach od 1970/71 do 1973/4, 23 sarnach z Northumberland oraz 5 sarnach padłych, będących w złej kondycji. Dla porównania pobrano próby od 3 sarn, 4 danieli i 6 jeleni z Instytutu Badań Wirusów Zwierząt. Jako wskaźnika kondycji ciała u *Capreolus capreolus* wybranych z dwóch populacji w ciągu 4 zim i spośród zwierząt będących w złej kondycji w czasie śmierci, użyto metody oznaczania tłuszczu w szpiku kostnym. Wyniki sugerują, że u zdrowych zwierząt poziom tłuszczu w kości udowej w ciągu zimy wynosi 75—85%. Zwierzęta będące w spadku kondycji wykazywały progresywne obniżanie zawartości szpiku w kościach kończyn poczynając od części proksymalnych do dystalnych (Rycina 1). Zawartość szpiku w kościach udowych u zwierząt padłych z głodu wynosi 11%. Jest to najniższa wartość ustalona w tych badaniach. Szacowanie zawartości tłuszczu w szpiku kostnym może być użyteczne w stwierdzaniu czy zagęszczenia populacji przewyższają pojemność środowiska.