ALCES VOL. 23, 1987

POST-MORTEM TEMPERATURES OF MOOSE CARCASSES

E.M. Addison

Wildlife Research, Ontario Ministry of Natural Resources
P.O. Box 50, Maple, Ontario L0J 1E0

N.A. Fish

Department of Veterinary Microbiology
University of Guelph
Guelph, Ontario N1G 2W1

D.J.H. Fraser

Wildlife Research, Ontario Ministry of Natural Resources
P.O. Box 50, Maple, Ontario L0J 1E0

and

T.J. O'Shaughnessy

Ontario Ministry of Natural Resources
190-192 Cherry St.
Chapleau, Ontario P0M 1K0

Abstract: Temperature was recorded hourly for up to 24 h post-mortem for forequarters and/or hindquarters of 18 moose (*Alces alces*) killed at approximately 11 months of age. Hindquarters cooled more slowly than forequarters. A hindquarter with the hide on cooled more slowly than a hindquarter with the hide off which was held under otherwise comparable conditions. Quarters of moose which were skinned on snow cooled more rapidly than quarters skinned on wood.

Alces 23 (1987)

Conservation officers often wish to know the post-mortem interval (PMI) of wildlife (Beattie and Giles 1977). They most frequently want to know if an animal was shot prior to the opening of a season or if an animal was shot after sunset or before sunrise.

Rectal, thigh muscle, and naso-pharyngeal temperatures have been used to estimate the PMI in white-tailed deer (*Odocoileus virginianus*) (Gill and O'Meara 1965). Gill and O'Meara (1965) also studied changes in the appearance of the eye, including pupil diameter, and the extent of rigor mortis in the carcass. However, they considered carcass temperature to be the best single estimator of PMI. Woolf *et al*. (1983) provided predictive values for PMI based on comparisons of nasal and thigh temperatures of white-tailed deer. Although other techniques such as potassium levels in vitreous humor have been used (Johnson *et al*. 1980), carcass temperature remains the most widely used predictor of PMI.

A number of unpublished internal government reports from Quebec provide estimates of the PMI of moose (Alces alces). Data from these reports are particularly valuable because they describe cooling of carcasses under "normal" field conditions. Data from controlled experiments are also useful and identify effects of various weather and handling factors on rate of cooling of carcasses. In the present study, we were able to document changes in temperature of carcasses of moose collected and handled under somewhat controlled conditions.

The objectives of the present study were (1) to produce "cooling curves" for forequarters and hindquarters of young moose killed, eviscerated and handled under known and somewhat constant conditons and (2) to determine if removal of hide or processing of a moose on snow as compared to wood or bare ground affect the rate of cooling.

METHODS

Eighteen neonatal moose were raised in captivity (Addison et al. 1983) for studies on parasites, behaviour, and physiology. Temperature data were collected from one 7 month old moose in February and from all other moose at about 11 months of age from April 16 to April 29. Rectal temperature was recorded before moose were killed. Two moose were killed with an overdose of 20 mg of succinylcholine chloride (Anectine, Burroughs Wellcome and Co. Ind., Tuckahoe, N.Y.). Sixteen moose were immobilized with 300 mg of xylazine hydrochloride (Rompun, Haver-Lockhart Laboratories, Mississauga, Ont.) and killed with injection of T-61 (N-[2-(methoxyphenyl)-2-ethylbutyl-(1)]-γ-hydroxy-

butyramide and 4,4′-methylene-bis-(cyclohexyl-trimethylammonium iodide), Hoechst Canada Inc., Montreal, P.Q.) into the jugular vein. In 15 of 18 cases, the carcass was lifted by use of a tractor onto a plywood table in a large garage before further processing. Two moose were eviscerated and quartered on bare ground and one moose was skinned on snow. The moose skinned on snow lay in contact with the snow for 20 minutes on one side with the hide on and 20 minutes on the other side with the hide removed. The carcass was then lifted onto the wood necropsy table and treated similarly to the other moose. Lateral temperatures of two hindquarters from one moose, one with the hide on and one with the hide removed were recorded at hourly intervals for 24 h to determine the effect of the hide on rate of cooling. The hide was removed from the remaining 16 moose. Skinning usually took 1-3 h because many skin samples were being preserved for other studies. Evisceration was completed, moose were quartered and the first post-mortem temperatures were read 2.5-4.25 h after death ($\bar{x}$=3.1, S.D.=0.81). The first two moose were quartered in a standard manner with the cervical and lumbar vertebrae remaining attached to the quarters. The cervical and lumbar vertebrae were removed from the quarters for the remaining 16 moose. Distal portions of the legs were removed at the carpal and tarsal joints. Weights were obtained for quarters of 11 moose which were killed, skinned and quartered in a uniform manner.

Doors of the garage were kept closed to minimize fluctuations in ambient temperature. Ambient temperature within the garage was measured using standard mercury thermometers. Relative humidity was measured in a Stevenson screen outside the garage. Meat temperatures were taken using Sybron Taylor meat thermometers. Temperatures were recorded approximately half way through the area of greatest muscle mass of each quarter when skinned and about 1/3 of the way through the muscle mass from the side of the hide in the quarter which was not skinned. This was done in order to measure each quarter where it cooled most slowly. For lateral placement in the forequarters, the thermometer was inserted to a depth of 6.5-8 cm through the triceps muscle to measure an area close to but posterior to the humerus. A second reading on the forequarter was made by inserting the thermometer to the same depth toward the humerus from the posterior aspect of the triceps. In the hindquarters, the thermometer was inserted laterally 8.5-11 cm through the vastus lateralis muscle immediately posterior to the femur. The site of entry was midway between the patella (kneecap) and anus. Temperature of the hindquarters was also recorded by inserting a thermometer 8.5-11 cm anteriorly through the semimembranosus muscle.

Thermometers were left in the muscle mass until a constant temperature was obtained and then removed to reduce any effect the thermometer might have in drawing heat away from the meat. A wooden plug was inserted into each site to mark its location. Temperatures were recorded hourly from all quarters of 16 moose from approximately 3 h until 14-18 h post-mortem and then again at 23-26 h post-mortem. Relative humidity and ambient temperature was recorded at the same time as were temperatures of the meat.

The Student's T-test for paired data (SPSS-11, 2nd ed., Chicago, Illinois) was used to compare differences between meat temperatures taken from lateral and posterior positions and temperatures between right and left forequarters and hindquarters. Multiple regression analysis was used to identify relative effects of parameters on variation in the rate of cooling of moose and to develop predictive equations to estimate the PMI. The multiple regression was applied to $\log_{10}$ transformations of temperatures taken laterally from hindquarters but not forequarters. Each hindquarter was treated as a separate case. Data for the regressions were weighted by dividing the number of moose by the number of cases. Data for 7 moose were excluded from the initial regression analysis because of incomplete data on weights of quarters or because they were handled differently for determining the effects of removal of hide and skinning on snow. Variations around mean values are expressed as standard deviations.

We have followed the example and designation of Woolf et al. (1983) in using the post-mortem interval (PMI) as the dependent variable since it is calculation of the PMI which is desired by enforcement officers. This is done in spite of the fact that realistically it is the temperature which is dependent on the PMI.

RESULTS

Moose weighed 216 ± 26 kg on the day of death. Rectal temperatures of moose prior to death were 38.1 ± 0.4°C. The average ambient temperature within the garage was 6.5 ± 3.6°C and in different experiments ranged from 2.4°C to 13.3°C. The relative humidity averaged 70% and varied from 100% in the mornings to 34% in late afternoon.

Hindquarters weighed 22.3 ± 3.1 kg. Right and left hindquarters differed by 1 kg or less in 10 of 12 moose and by 1.5 and 4 kg in the other two moose. Forequarters weighed 27.4 ± 4.4 kg and ranged in weight from 19.5 to 35 kg. Right and left forequarters differed in weight by as much as 7 kg and by an average of 2.6 ± 3.4 kg.

Temperatures were similar ($P>0.05$) for right and left quarters comparing either lateral or posterior points of insertion of thermometers in either the forequarters or the hindquarters (Table 1). Temperatures from a lateral insertion were higher ($P<0.001$) than temperatures from a posterior insertion in the same quarter (Table 1). This was true for 91% of 694 paired sets of lateral and posterior measurements. Lateral and posterior measurements were the same in an additional 5% of the cases.

Forequarters cooled more rapidly than hindquarters (Fig. 1). Hindquarters were warmer than forequarters in 96% of 778 paired cases where the moose, PMI, and thermometer location were the same. The 4% of cases when forequarters were warmer than hindquarters were distributed at the start of the experiments shortly following evisceration and butchering or at the end of the experiments when temperatures of all quarters were approaching the ambient. However, even at 23-26 h post-mortem, hindquarters were slightly warmer than forequarters in 84% of 58 cases.

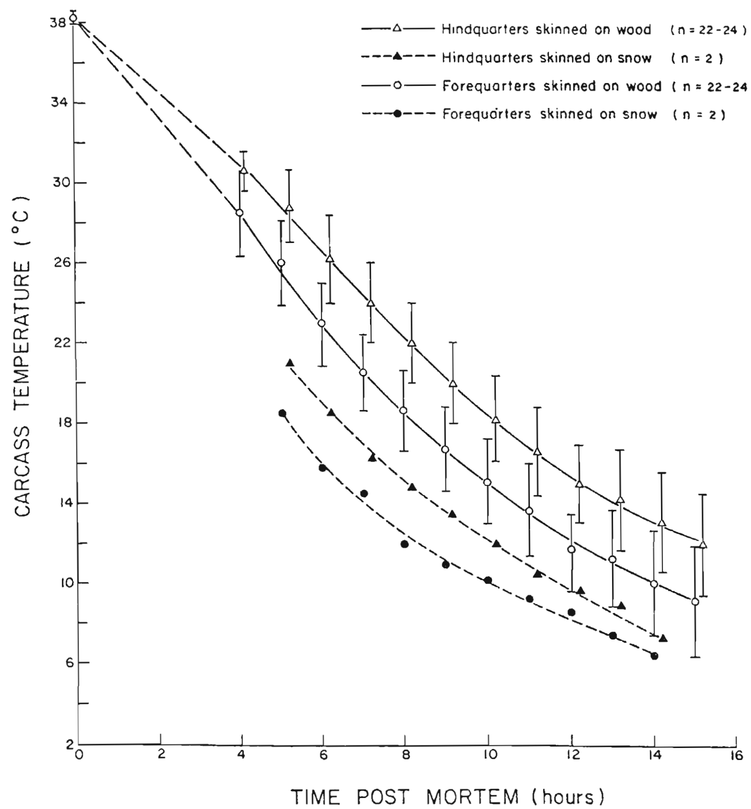

Figure 1. Post-mortem temperatures of forequarters and hindquarters of moose. The mean ± standard deviation are given for moose skinned on wood.

Table 1. Comparison of temperatures recorded from lateral and posterior insertion of thermometers into hindquarters of moose.

Quarter	Number of cases	Position of thermometer	Temperature Mean	S.D.	Difference
Right front	189	lateral	16.1	9.58	1.71±1.37[1]
		posterior	14.4	9.54	
Left front	189	lateral	16.4	9.37	1.75±1.24
		posterior	14.6	9.29	
Right hind	189	lateral	18.7	9.24	1.61±1.55
		posterior	17.1	9.34	
Left hind	189	lateral	19.3	8.76	1.35±1.31
		posterior	17.9	8.83	

[1]mean difference ± 1 standard deviation (S.D.)

In general, both forequarters and hindquarters cooled 1-2°C/h from 4-10 h post-mortem (Fig. 1). However, the rate of cooling was much slower when the hide was left on the quarter (Fig. 2). Cooling was more rapid in a moose which was skinned on snow than in moose which had no contact with snow (Fig. 1).

Temperature of hindquarters as measured from lateral insertion of the thermometer was chosen for the multiple regression analysis since these data represented the warmest part of the quarters. The formula for weighting data was 11/304 (# of moose/# of cases).

Factors thought to have a possible pronounced effect on estimates of the PMI were the extent to which the carcass had already cooled at the

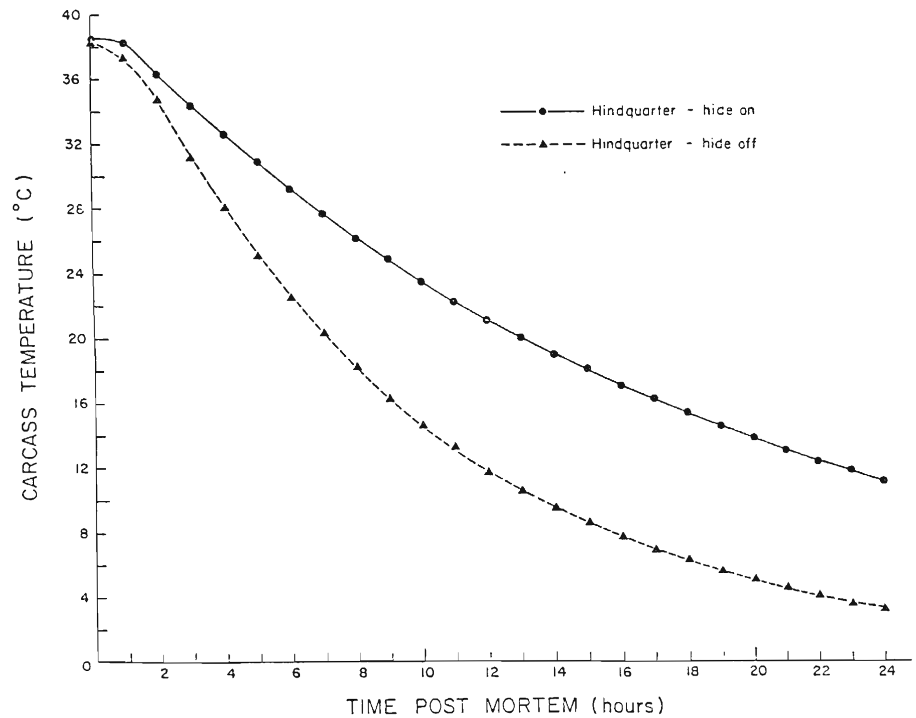

Figure 2. Effect of removal of hide on post-mortem cooling of hindquarters of one moose.

outset of that time (K-M), the difference in temperature between the ambient and the carcass (M-A), and the weight of the quarter (W),

where PMI = post-mortem interval (h)

A = ambient temperature (°C)

K = estimated muscle temperature at death (40°C)

M = lateral temperature of hindquarter (°C)

W = weight of hindquarter (kg).

Estimation of the PMI was considered initially to be predicted from the following formula:

$$\log_{10}PMI = a \log_{10}(K-M) + b \log_{10}(M-A) + c \log_{10} W + d$$

The regression model was:

$$\log PMI = 1.12 \log(K-M) - 0.16 \log(M-A) + 0.66 \log W - 1.19$$

and it accounted for 91% of the variance (R^2). The only significant factor explaining the variance was the decrease in muscle temperature since death (K-M)($0.002<p<0.005$).

The regression model was refined to exclude weight since there was little variation in the weight of hindquarters. Data were now available from 16 moose. Each case was weighted (16/438) as previously described. The regression model was now: $\log PMI = 1.10 \log(K-M) - 0.15 \log(M-A) - 0.29$ and it accounted for 86% of the variance (R^2) in the data. Changes in muscle temperature since death (K-M) were significant in explaining variance in the model ($P<0.001$) but differences in temperature between the meat and the ambient temperatures did not explain much of the variance ($P>0.05$).

The model was further refined to exclude the effects of differences

between meat and ambient temperatures. The resulting model was: $\log PMI = 1.24 \log (K-M) - 0.65$ and it accounted for 85% of variance in the data.

DISCUSSION

Results of the present study should only be used to estimate the PMI of moose which are of approximately the same size, exposed to similar ambient temperatures, and handled in a manner comparable to moose in this study. Differences in the abovementioned variables would alter the character of the cooling curves and regression models developed in this study.

Weight of animal and time of evisceration after death strongly influence the rate of cooling of carcasses of white-tailed deer (Gill and O'Meara 1965, Woolf et al. 1983). They undoubtedly do the same with moose although it is not demonstrated using the data set from the present study. The decrease in muscle temperature probably explains such a high proportion of the variance in the present data because techniques used provided relatively uniform values for weight of quarters and methods of handling moose following death.

Contact of the carcass with snow and whether or not the hide had been removed from the carcass were two variables which significantly influenced estimates of the PMI. The pronounced cooling of the carcass when on snow was surprising since the moose lay on the snow for such a short period of time. These results and those of previous studies emphasize the need for conservation officers to obtain a detailed knowledge of how a carcass was handled before taking temperature readings from a carcass.

Ambient temperature will often have a pronounced effect on estimates of a PMI under field conditions (see Woolf et al. 1983). Similarly, wind could considerably influence the rate of cooling. Knowing this, officers could prepare to make accurate estimates of a PMI by recording ambient temperature and general wind conditions for 24h prior to an anticipated period of concern.

Officers should ensure that meat thermometers are working well in advance of their use. Some meat thermometers may have separations in the column of mercury because of rough treatment during transport in the field. Reestablishing a continuous column of mercury with some thermometers may require submersing the bulb into dry ice. Ambient temperatures on meat thermometers should be compared with readings from a second thermometer immediately before taking temperatures of moose meat. This information may be particularly useful if the accuracy of carcass temperature readings are subsequently questioned.

Both forequarters and hindquarters in this study cooled in a predictable way and may be used to estimate PMI. However, we recommend using a lateral insertion of the thermometer in the hindquarters as the first choice of location for taking temperatures. The hindquarters cooled more gradually and the lateral position of the thermometer gave better access to the core temperature of the muscle mass than did a reading from the posterior. It was also easier to find the preferred location for inserting the thermometer by using the lateral position of

the hindquarter. The femur can be located by probing when inserting the thermometer halfway along a line between the knee and the anus.

Forequarters cooled more rapidly than hindquarters even though they were considerably heavier. The distribution of the weight on the quarters is more important in influencing the rate of cooling than is the total weight. Much of the extra weight on the forequarters is distributed along the area of the ribs and in the case of a quarter butchered in a normal fashion, also in the area of the cervical and lumbar vertebrae. While these areas contribute considerable weight to the quarter they contribute little to slowing the rate of cooling of the major muscle mass high on the leg because they are remote from the major muscle mass.

ACKNOWLEDGEMENTS

We thank the many people who assisted with the capture and husbandry of moose. We also thank R. McLaughlin, D. Joachim, D. Kristensen, L. Barr, P. Methner and other staff in research who assisted in the collection of temperature data. Thanks are extended to R. Parsons, R. Maw, B. van Wout, B. Ramsbottom, G. Oram, B. Stewart, B. Simpson, M. Kilby and other conservation officers and biologists who also assisted in the project. The enthusiastic participation of District Manager Don White and fish and wildlife staff of the Minden District of the Ministry of Natural Resources is also appreciated. Special thanks is extended to D.J.T. Hussell who developed the regression model, to R. McLaughlin and J.D. Smith who assisted with analysis and review of the manuscript, to

B. Wilkinson who assisted in preparation of the manuscript and to A. Chui who prepared the illustrations. The field work was conducted at the Wildlife Research Station in Algonquin Provincial Park.

Ontario Ministry of Natural Resources, Wildlife Research Section Contribution No. 87-06.

REFERENCES

ADDISON, E.M., R.F. MCLAUGHLIN, and D.J.H. FRASER. 1983. Raising moose calves in Ontario. Alces 19: 246-270.

BEATTIE, K.H., and R.H. GILES, Jr. 1979. A survey of the wildlife law enforcement research needs and current research. Wildl. Soc. Bull. 7: 185-188.

GILL, J.D., and D.C. O'MEARA. 1965. Estimating time of death in white-tailed deer. J. Wildl. Manage. 29: 471-486.

JOHNSON, B.C., L.A. MAGUIRE, and D.R. ANDERSON. 1980. Determining time of death in mule deer by potassium levels in the vitreous humor. Wildl. Soc. Bull. 8: 249-252.

WOOLF, A., J.L. ROSEBERRY, and J. WILL. 1983. Estimating time of death of deer in Illinois. Wildl. Soc. Bull. 11: 47-51.