THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER SIXTEEN

THERMAL ENERGY BALANCE CALCULATIONS

by

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CHAPTER 16: THERMAL ENERGY BALANCE CALCULATIONS

The illustrations of heat transfer given in CHAPTER 15 provided introductions to the four modes of thermal energy exchange. The roles of these four modes will now be considered for the organism as an ecological unit within the basic concept of homeothermy.

Homeothermic animals are usually described as "animals which maintain a constant body temperature." This very simple idea is often presented to students in elementary grades, and it is commonly said that the body temperature of humans is 98.6°F. All humans do not have the same body temperature though, and all parts of the human body are not at the same temperature.

Careful consideration of the basic concept of homeothermy leads one to a conclusion that is much more basic than the simple statement that the body temperature remains "constant." Metabolic processes are exothermic, so heat energy is released when food is oxidized, and heat energy is dissipated to the environment when the environment is colder than the animal. Homeotherms maintain a balance between the amount of heat energy released from food and the heat energy dissipated to the environment, and the effect of this balance is a constant body temperature.

Animals that maintain a balance between the heat produced and the heat lost are constantly solving a very complex heat transfer equation.

The effects of weather are manifested in the animal-range relationship through the medium of thermal or heat exchange. Meteorological parameters alone may be quite meaningless when used in interpreting animal responses because weather instruments do not respond to the thermal regime of the atmosphere in the same way that a living organism does. Further, weather instruments are often placed in standard weather shelters at standard heights so as many variables as possible are eliminated. A living organism, however, is exposed to the changing weather conditions and it also has its own physiological and behavioral variables. Knowledge of the four basic modes of heat exchange enables the biologist to understand the functional relationships between weather and the living organism.

The four modes of heat transfer interact. Radiation and convection are mutually dependent, for example, as convection losses reduce surface temperature and radiant heat loss. The rapidity of these changes--80% of the radiant temperature change occurred in a few seconds when wind velocities increased from 45 to 447 cm per second (1-10 mph)--are described in Moen and Jacobsen (1974). Arithmetic summations of net radiation and convection losses, as if radiation occurred in a vacuum and convection acted alone, are unrealistic because wind generally reduces the surface temperatures, and surface temperatures are a part of DLTA T in calculations of both convection and radiation exchange.

Absorbed radiant energy increases surface temperatures, again affecting the DLTA T in convection and radiation exchange. A logarithmic increase was described by Moen and Jacobsen (1974) for data published in Parker and Harlan (1972). Radiation and convection are clearly not independent processes.

An organism is coupled to the energy exchange processes by certain specific properties of its own (Gates 1968; 2). The amount of heat exchanged by radiation, convection, conduction, and evaporation depends on the thermal characteristics of the atmosphere and substrate, such as soil, rock, or snow, and the thermal characteristics of the object or organism. If a surface is highly reflective to radiant energy, then there can be little thermal effect from radiation. A cylinder with a very small diameter is a very efficient convector and slight air movement can result in a large amount of heat loss. Conversely, a large cylinder is a poor convector. An object covered with a layer of good insulation loses little heat by conduction, and an object with no water or other fluid that can be vaporized can have no heat loss by evaporation.

The exchange of heat between an organism and its environment is a dynamic process that includes the simultaneous exchange by each of the four modes of heat transfer.

The complexities of radiation and convection exchange at the surface of an animal are increased by the fibrous characteristics of the hair coat and the rough aerodynamic features of the animal's geometry. These complexities increase further as animals may change their posture and orientation as part of thermoregulatory behavior. Homeothermic animals, while they do not precisely maintain a set body temperature, do maintain an overall energy balance by regulating both behavior and metabolism in relation to the thermal environment. The total calculated heat loss can then be compared with estimates of ecological energy metabolism (ELMD) that were described in CHAPTER 7, with the annual patterns of ecological metabolism per day expressed as multiples of base-line metabolism. Comparisons of ecological metabolism with predicted heat loss provides opportunities for ecological accounting; the total calculated heat lost should be approximately equal to ELMD, and if they are not, the estimates of total daily heat loss are likely to be wrong.

Two ways of calculating energy balances are given in this CHAPTER 16. The summation approach in TOPIC 1 illustrates the individual heat transfer processes in energy balance calculations. The multilayered systems approach in TOPIC 2 emphasizes thermal boundary region conditions. The latter is a more useful and applicable approach for evaluating the combined effects of variations in thermal and geometric parameters in wild ruminants.

LITERATURE CITED

Moen, A. N. and F. L. Jacobsen. 1974. Changes in radiant temperatures of animal surfaces with wind and radiation. J. Wildl. Manage. 38(2):366-368.

Parker, H. D. and J. C. Harlan. 1972. Solar radiation affects radiant temperature of a deer surface. U. S. For. Serv. Res. Note RM-215. Rocky Mt. For. and Range Exp. Sta., Fort Collins, CO. 4 p.

REFERENCES, CHAPTER 16

THERMAL ENERGY BALANCE CALCULATIONS

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS----------------	AUTHORS/EDITORS----	YEAR
aubo	lefe	phpa	308	----	introd to environ physiol	folk,ge,jr	1966
aubo	pepr	oxen	1144	----	biometeorology, volume 2	tromp,sw; weike,wh	1967
edbo	usup	lout	155	----	ecolog energetics, homeot	gessaman,ga	1973
aubo	whfr	sfca	458	----	wildlife ecology	moen,an	1973
aubo	whfr	sfca	488	----	intro to biophys plant ec	nobel,ps	1974
edbo	spve	nyny	609	odvi	biopysicl ecol, perspe of	gates,dm; schmerl,r	1975
aubo	jwis	nyny	273	----	intro physiol plant ecolo	bannister,p	1976

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	enrgy exchng, western minn	moen,an	1968
JWMAA	38--2	366	368	odvi	odhe, eff wnd, rad, rd tmp	moen,an; jacobsen	1974
NAWTA	33---	224	236	odvi	energy balance in winter	moen,an	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
XARRA	215--	1	4	odhe	sol rad affct rad surf tmp	parker,hd; harla,	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				alal			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				rata			

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CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

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CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIOJA	16--6	561	569	----	heat transfer,animal forms	mitchell,jw	1976
ECMOA	39--3	227	244	----	thermodynmc equilbria,anim	porter,wp; gates,	1969