TOPIC 1: SUMMATIONS

Summations of energy flux involve the algebraic addition of net radiation, convection, conduction, and evaporation to determine total heat loss when an animal is exposed to a given set of circumstances. The summation approach is useful for illustrating the roles of each of the four modes of heat transfer, but its use is limited to calculations describing stable conditions only.

The amount of heat lost is affected by changes in habitat, posture, and other factors contributing to the overall thermal environment. New summations must be made each time a new situation is evaluated, such as an animal in more protective cover, in more heat-conserving postures, or in different activities. Comparisons of animals in different thermal conditions provide insights into benefits derived from different responses to weather factors, and into the relative benefits of physiological and behavioral responses.

Homeothermy involves more than the maintenance of a fairly stable body temperature; it involves the maintenance of a thermal energy balance within the framework allowed by nutritive conditions. Food is the source of the metabolic energy dissipated. Evaluations of energy balances resulting from different responses in relation to nutritive conditions provides another opportunity for ecological accounting discussed in the introduction to PART IV. The energy in must equal the energy out; all of it must be accounted for if we are to understand the role of energy in natural systems.

Calculations of thermal exchange have been described in relatively simple terms up to now. As the number of interactions increases, the need for clear, deliberate, and logical thinking increases. The WORKSHEETS in the UNITS that follow should help keep things in order.

UNIT 1.1: NIGHT-TIME RADIATION CALCULATIONS; INFRARED WAVELENGTHS ONLY

Summations of heat loss from animals that are exposed to night-time conditions, with infrared radiation only, are the simplest possible while yet retaining the correct conceptual approach. Four modes of heat transfer have been discussed, and three of them--radiation, convection, and conduction--will be used in the first summations to illustrate the effects of postural and cover changes on heat loss.

A cloud-filled sky has a radiant temperature that is very close to measured atmosphere temperature. The radiation flux is uniform in all directions, and is the simplest of situations for calculating radiation exchange. The first WORKSHEET uses this simplified situation.

Postural changes. An animal may greatly alter its surface area exposed to the environment and the extent of participation in the different modes of heat transfer by altering its posture. Maximum surface areas are exposed when standing, and minimum when bedded in a tightly-curled position. More area is exposed to radiation and convection in a standing posture than in a bedded posture, and more to conduction in bedded than in standing posture. These differences may be evaluated by summing the net heat loss by these modes of heat transfer from the surface areas involved.

Standing posture. An animal in a standing posture exposes nearly all of its surface area to heat exchange with the atmosphere. Radiation exchange occurs between its surface exposed to the surrounding environment. Convection occurs wherever the air can move freely over the animal's surface. In a standing posture, the animal is a collection of convectors, mostly somewhat spherical in shape, that participate in free and forced convection. The hooves in contact with the substrate provide the only pathway for heat loss by conduction, and their surface area is very small compared to the total surface area of the animal.

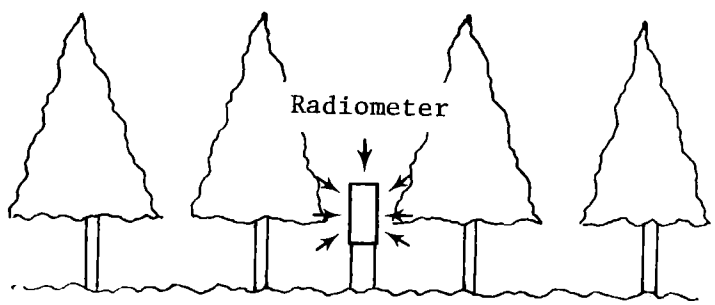
Bedding posture. When an animal beds down, the portions of its surface area participating in radiation, convection, and conduction change markedly. The portion participating in conduction increases very much as parts of the trunk and legs are in contact with the substrate. Portions of surface areas of the legs, tucked under the animal, are in contact with the trunk, reducing the surface area exposed to the external environment. The bedded posture results in much more compact geometry to the whole animal, a somewhat rounded protrusion above the ground surface, rather than a collection of several (four legs, a trunk, neck, head, and two ears) convectors. Even the possible angles for radiation exchange are much reduced when in a bedded posture compared to a standing one.

Cover changes. The preceding paragraphs dealt with the effects of postural changes on the energy balance of animals. Such changes "in place" are also accompanied by changes "in location" by free-ranging animals.

Canopy effects. There is a greater amount of downward infrared radiation from a conifer canopy than from a leafless hardwood canopy, and a greater amount from a leafless hardwood canopy than from a clear sky. Measured values are given in Moen (1968) for these three conditions. At 0° C, the downward flux in KCAL PSQM PHOU from a white cedar canopy was about 275, from the hardwood canopy 255, and from the open sky, 235.

Upward flux. Upward flux is calculated with the same formula for QREE or downward flux, but the radiant temperatures of snow, soil and vegetative cover are used rather than the canopy temperature. While there are differences between their temperatures and atmospheric temperature, the use of atmospheric temperature to represent the surface temperatures of the snow is a reasonable first approximation, and is used in the calculations of energy balance here.

Horizontal flux. There is horizontal infrared radiation flux within a plant community as well as the vertical flux calculated with the equations given thus far. The density of the cover and the snow or ground surface temperatures are the major determinants of the amount of horizontal flux. The cover density determines how much of the sky is visible to a radiometer oriented to measure horizontal flux, and the snow or ground surface



contributes to the flux also. In general, the horizontal flux is about midway between the downward and upward flux since each contributes about equally to the field of view; that is a sufficiently good approximation within a canopy.

Thermal characteristics of the animal's surface. Thermal characteristics of the animal's surface must be known before calculations of heat exchange can be made. Radiant surface temperatures are used to calculate radiant heat loss, which may be compared to the radiant heat absorbed and net radiation exchange calculated.

Radiant surface temperatures. The surface temperatures of an animal are dependent on both external and internal factors. At night, infrared but not visible wavelengths of radiation are a source of heat energy for the hair. Differences in blood flow and internal anatomy contribute to differences in surface temperatures, too. An equation for surface temperatures of the trunk of white-tailed deer is given in Moen (1968), and several equations in Moen (1973) are used for predicting surface temperatures over

different body surfaces. Surface temperatures of well-insulated animals are often very cold. At -30° C air temperature, for example, the radiant surface temperature of the trunk of a white-tailed deer may be -22° C, just 8° above air temperature. At 0°, the difference is about 6.5°, based on the equation in Moen (1968).

Radiant heat loss. The radiant heat loss from the surface of an animal may be easily calculated with the equations for radiant surface temperatures referenced in the paragraph above. Deer with a radiant surface temperature of 0° emit about 300 KCAL PSQM PHOU, and at -30°, about 197. Note that less radiant energy is emitted from the animal's surface when it is cold than when it is warm. Radiant heat loss is only part of radiation exchange; amounts emitted are to be compared to the amounts absorbed from the environment to determine the net radiation exchange.

Words of caution. The calculations of net radiation exchange described thus far are not appropriate for surfaces existing in a vacuum, or in constant convection conditions. Canopy and deer surface temperatures have been measured while being influenced by atmospheric conditions, of course, so the temperatures used in the equations reflect the effects of the atmosphere.

General discussions of heat loss differences between standing and bedded postures in different cover types are mere displays of ideas. It is necessary to test our understanding by completing the calculations in the WORKSHEETS that follow. The problems on the worksheets incorporate postural changes with the effects of open fields, herbaceous vegetation, deciduous forest, and coniferous cover.

LITERATURE CITED

Moen, A. N. 1968. Surface temperatures and radiant heat loss from white-tailed deer. J. Wildl. Manage. 32(2): 338-344.

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman Co., San Francisco. 458 p.

REFERENCES, UNIT 1.1

NIGHT-TIME RADIATION CALCULATIONS; INFRARED WAVELENGTHS ONLY

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	energy exchange, minnesota	moen,an	1968
ECOLA	57--1	192	198	odvi	energy conser, wtd, winter	moen,an	1976
JWMAA	32--2	338	344	odvi	surf temp, radian heat los	moen,an	1968
NAWTA	33---	224	236	odvi	energy balance, wtd, winte	moen,an	1968

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

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
JTBIA	47--2	413	420	rata	wind chill, solar rad inde	oritsland,na	1974

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

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

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

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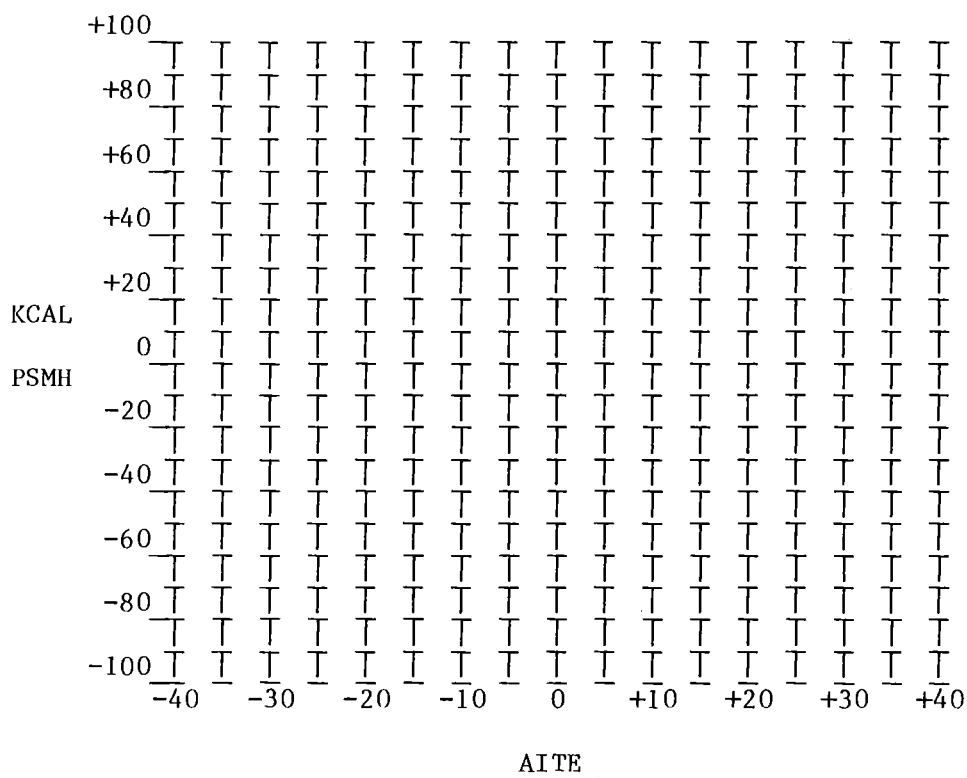
CODEN VO-NU BEPA ENPA ANIM KEY WORDS---------- AUTHORS---------- YEAR

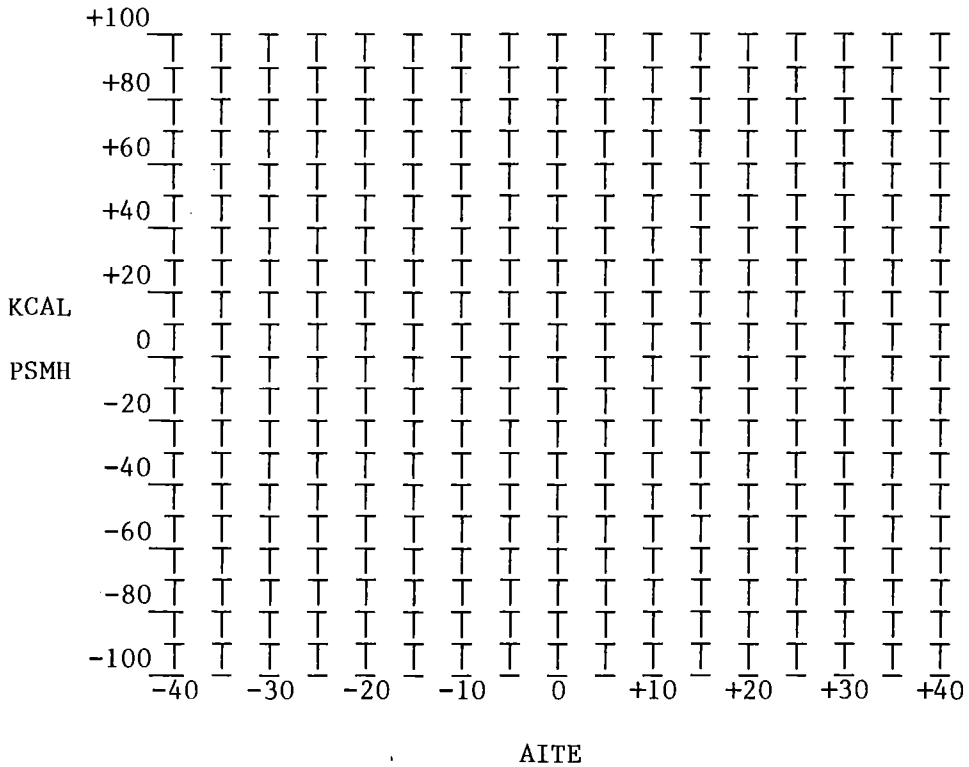
JAPYA 35--5 751 754 dosh measurem, local heat balan clark,ja; cena,k/ 1973

CHAPTER 16, WORKSHEET 1.1a

Radiant energy exchange under a cloudy sky at night

The radiant energy exchange between an animal and its thermal environment with a cloudy sky may be calculated as a net radiation exchange with formulas given previously. Determine surface area (CHAPTER 1, UNIT 2.3), radiant temperature and infrared radiation from deer and from different cover types (CHAPTER 15, UNIT 1.3), subtract radiant energy emitted from the radiant energy received by the deer. The result is the net radiation exchange for the deer. Plot your results in kcal per square meter per hour (KCAL PSMH) below. Additional grids are provided on the next page for more results.

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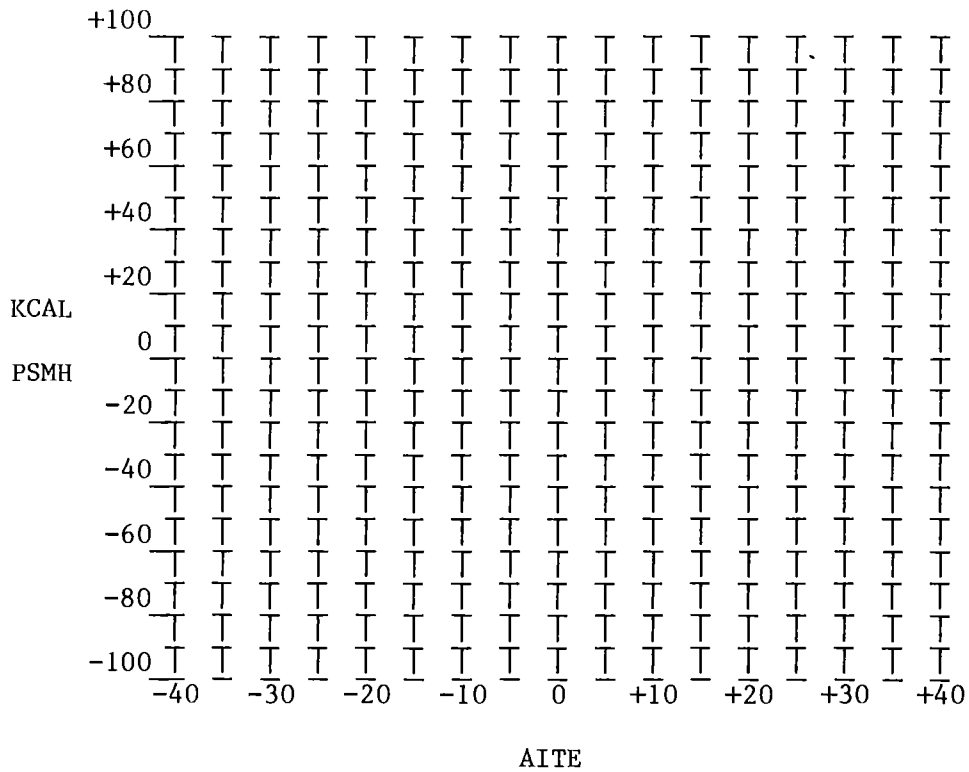
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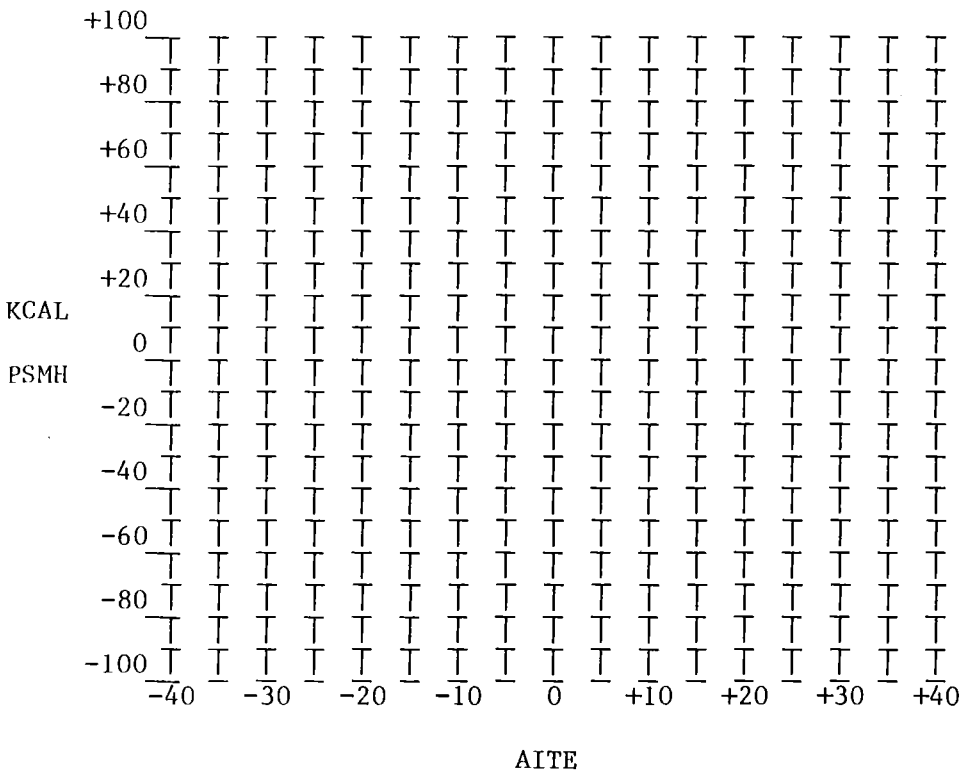
CHAPTER 16, WORKSHEET 1.1b

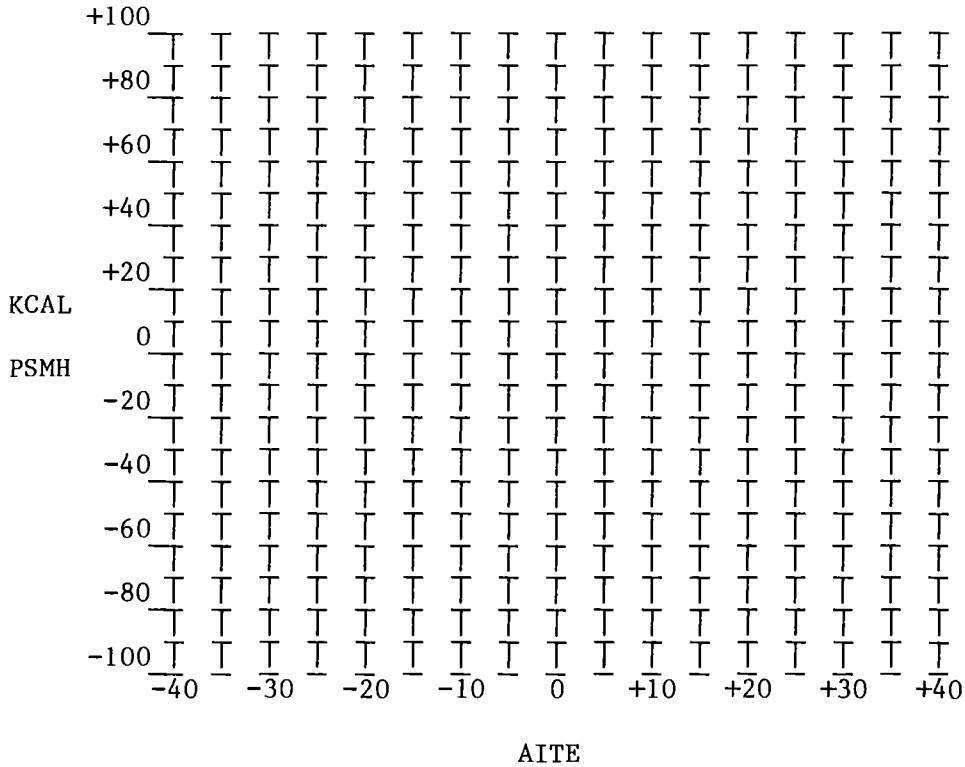
Radiant energy exchange of deer under different canopy types

Using the same procedures as in the previous WORKSHEET, calculate the net radiant energy exchange form deer under different canopy types, such as a conifer canopy, deciduous hardwood canopy, and no canopy under a clear sky. Since the radiant energy flux is not uniform in all directions, a "radiation profile" of the deer should be considered. This consideration was discussed in CHAPTER 15, UNIT 1.1. The half above: half below profile will be a sufficiently good approximation for these calculations.

Plot the net radiation energy exchange for different canopy types below. As you do, keep in mind that radiation is affected by wind, and that the calculation of net radiant energy exchange is a good exercise, but energy balances as a result of all modes of heat transfer are best calculated with overall heat transfer coefficients.



Additional grids are provided on the next page.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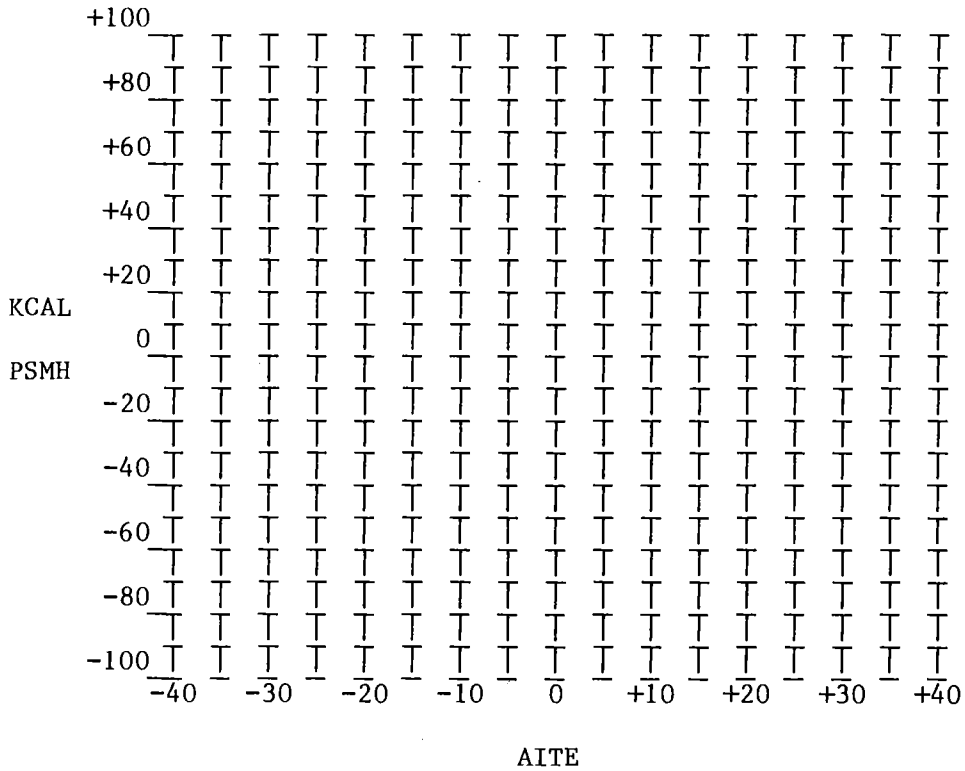
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UNIT 1.2: DAY-TIME RADIATION CALCULATIONS; INFRARED AND VISIBLE WAVELENGTHS

Consideration of visible wavelengths in calculations of radiation exchange adds to the complexity of the summations because of the direct and diffuse components of the visible, in addition to the all-directional infrared flux. The geometry of the animal becomes an important consideration when evaluating the effects of direct solar radiation as the angles affect the amounts of direct solar radiation received by different parts of the animal. This consideration was introduced in CHAPTER 15, UNIT 1.1, RADIATION PROFILES. Now, profile geometry is considered in calculations of radiation exchange for the whole animal.

There is almost a total lack of data on surface temperatures of hair coats of wild ruminants exposed to solar radiation. Parker and Harlan (1972) demonstrated a drop of 18° C when a tanned mule deer pelt exposed to the sun was shaded. This change occurred in 120 seconds. Equations expressing the change from shaded to exposed and exposed to shaded are given in Moen and Jacobsen (1974). Experiments completed at the Wildlife Ecology Laboratory, Cornell University, show that the radiant temperatures of deer hair exposed to the direct rays of the sun are several degrees higher than hair exposed to diffuse and infrared radiation only. These data are currently being analyzed and prepared for publication.

The absorption of direct solar radiation by the hair coat raises the radiant surface temperature and radiation emitted. Simple arithmetic subtraction of radiation emitted from radiation absorbed gives the net radiation exchange. The answer, however, is again characteristic only of exchange at the radiant surface of the animal, without consideration of interactions with the effects of the atmosphere.

Another word of caution. Since wild ruminants are surrounded by an atmosphere rather than living in a vacuum, arithmetic summations of radiation gained and lost from the surface of an animal are inadequate. Further, pyranometers, pyrheliometers, and other kinds of radiometers used for measuring solar and infrared radiation have shields or domes that protect the sensing elements from atmospheric effects, or else they have fans that provide a constant air flow that stabilizes atmospheric effects. Wild ruminants do not have domes or fans, nor are the hairs similar to the sensors of such instruments. Consequently, animals absorb different amounts of radiation than such instruments do, and instrument results must be applied to animals' surfaces with caution when estimating heat loss.

A WORKSHEET follows that illustrates geometric considerations when quantifying radiation exchange. Then, some basic convection considerations are made in UNITS 1.3 and 1.4, followed by conduction analyses in UNIT 1.5 and evaporation considerations in UNIT 1.6. All of these UNITS describe separate modes of basic heat transfer in relation to the geometry of the animal. Summations are made in UNIT 1.7. The summation approach does not allow for adequate physical integration of interactions at the hairy surface of a wild ruminant; that is discussed in TOPIC 2: OVERALL HEAT TRANSFER COEFFICIENTS.

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. J. 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, UNIT 1.2

DAY-TIME RADIATION CALCULATIONS; INFRARED AND VISIBLE WAVELENGTHS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	energy exchange,minnesota	moen,an	1968
ECOLA	57--1	192	198	odvi	energy conser, wtd,winter	moen,an	1976
JWMAA	38--2	366	368	odvi	chang, rad temp, wind, rad	moen,an;jacobsen,	1974

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

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

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

JTBIA 47--2 413 420 rata wind chill, solar rad inde oritsland,na 1974

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CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	50--2	328	332	----	bioclimat,summer,microenv,	dowson,tj; denny	1969
JAPYA	35--5	751	754	----	measurem, local heat balan	clark,ja; cena,k/	1973
AGMYA	8-4/5	353	359	doca	energy balance,climate,nig	ojo,o	1971
COPMB	4----	214	218	dosh	model heat flow,high solar	vera,rr;koong,lj/	1975

CHAPTER 16, WORKSHEET 1.2a

Solar radiation distribution over an animal's surface

Animals sometimes orient with the sun. Calculations of heat exchange involving solar radiation are very complex; the angles at which the sun's rays strike the animal's surface are important considerations when quantifying the effects of solar radiation.

Solar radiation angles may be estimated in the following way. Find a garden-type model of a deer that has realistic body proportions. Place it in different orientations with the sun throughout the day and record the angles (slopes and aspects) with which the sun strikes the surface. Then estimate the surface area exposed to the different angles. Mounted animals in standing and bedding postures provide even better estimates, but they may not be readily available.

UNIT 1.3: NATURAL CONVECTION CALCULATIONS

The concept of natural convection was discussed in CHAPTER 15, UNIT 2.1, and illustrations of the effects of variations in the geometry of the convector and wind velocities given. Patterns were clear, and the relationships relatively easy to understand.

The application of the concept to the real animal is difficult for several reasons. One difficulty is due to the complex geometry of an animal, with a body that is composed of imperfect cylinders and other geometries that are clearly not well-designed convectors. Further, the body is covered with hair, so not only are there several large convective geometries, but there are also a very large number of very small-diameter convectors--hairs--over the surface of the animal's body. These small-diameter convectors respond very quickly to air flow; they are efficient convectors. Convection is really a two-stage process then as (1), the hairs respond, and (2), the body parts respond to atmospheric movements. This idea is discussed in Moen (1973), with the concept of a "theoretical convective diameter" introduced there.

A second difficulty in applying the concept of free convection to an animal is due to the complex temperature variations over the animal's surface, making DLTA T in the convection formula a highly variable parameter. Not only are there temperature variations over the animal's surface, but also along each hair shaft. The total convection loss may be considered as a sum of all of the local convection losses, and any number of local areas could be considered separately.

Calculations can be made for two geometric extremes. One, the surface of an animal is considered to be the sum of the surface of the individual hairs, and two, the surface of an animal is considered to be the sum of the surface areas of different smooth-surfaced body parts. The former approach results in extremely large surface areas for convective heat loss from many thousands of tiny convectors or hairs. Convective losses are astronomical when each hair is considered an independent and separate little convector. It is not practical to treat the hair coat in that manner, even though the hairs function as convectors. The latter approach is at least possible with current measurement capabilities, and is the approach used in Moen (1973) to calculate convective heat loss.

Natural convection may be calculated for each body part by considering the areas involved, the temperature differences between the atmosphere and body surface, and the geometries of the body parts as convectors. Summation of natural convection from each of these parts results in an estimate of the total convection loss from the animal, which may be added to the estimates of radiation loss to get the sum of these two modes of heat transfer. WORKSHEETS provide opportunities for making such calculations.

LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Co., San Francisco. 458 p.

REFERENCES, UNIT 1.3

NATURAL CONVECTION CALCULATIONS

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS----------	AUTHORS/EDITORS---	YEAR
edbo	spve	nene	609	odvi	therml exchng,physio,behv	moen,an; jacobsen,	1975

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	enrgy echng, western minne	moen,an	1968
ECOLA	57--1	192	198	odvi	energy conser, wtd, winter	moen,an	1976
JWMAA	32--2	338	344	odvi	surf temp, radian heat los	moen,an	1968
NAWTA	33---	224	236	odvi	energy balance, winter,wtd	moen,an	1968

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

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

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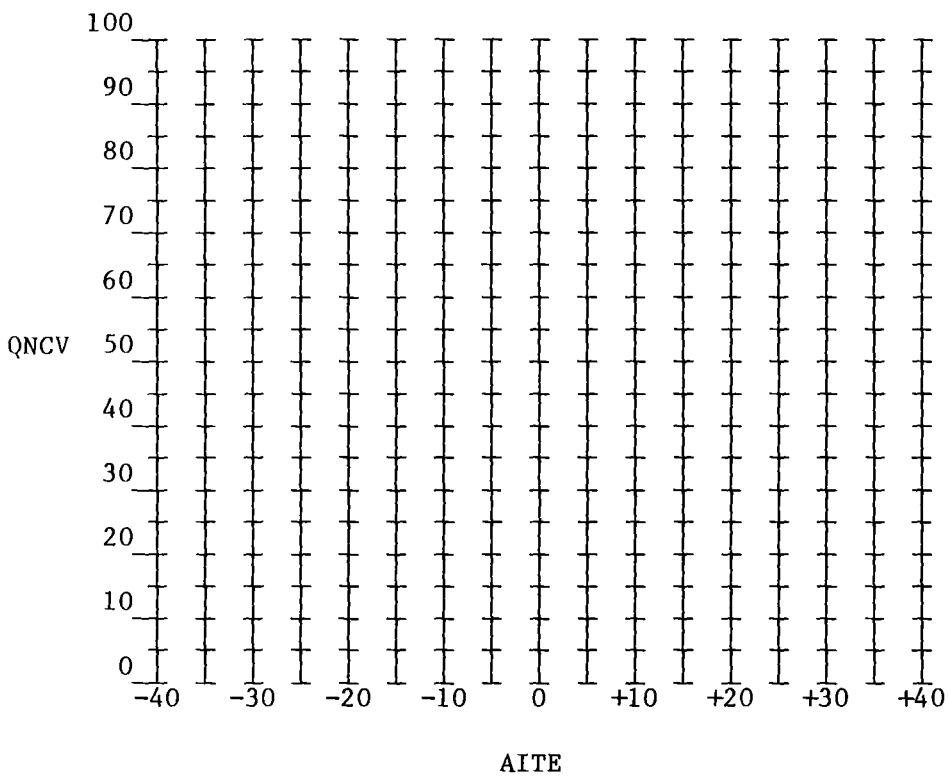
CHAPTER 16, WORKSHEET 1.3a

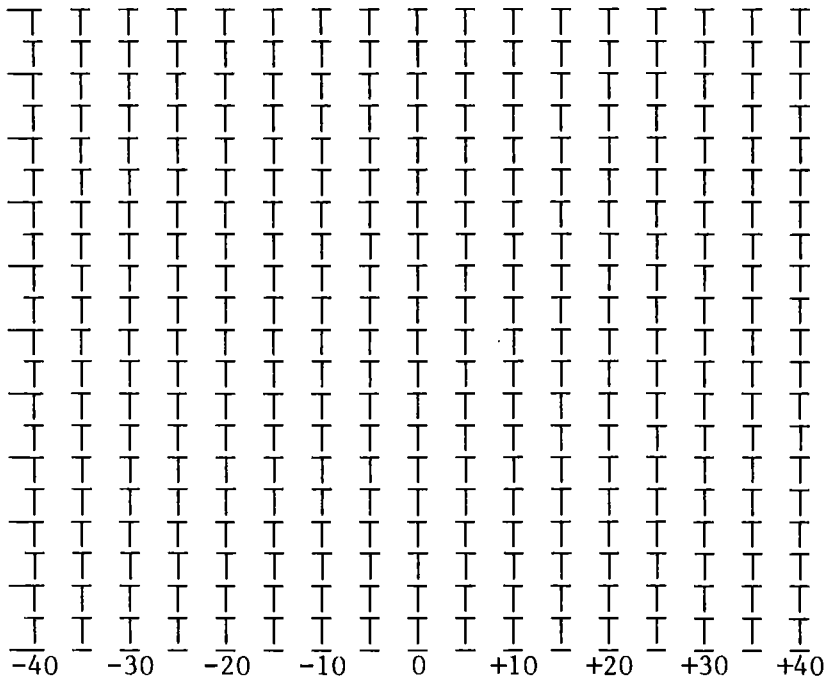
Natural convection from white-tailed deer

Natural convection may be calculated for white-tailed deer if the diameters of different body parts, surface areas of different body parts,and temperature differences between animal surface and air are known. Use PART I, CHAPTER 1, TOPIC 2 to estimate body geometry and CHAPTER 15, UNIT 1.3 to estimate surface temperatures. Use these in the formula for natural convection discussed in CHAPTER 15, UNIT 2.1.

$$QNCV = 3.516\ (DLTT/DCYC)^{1/4} SANC$$

Complete a series of calculations for different body parts and air temperature, and plot the results below and on the next page. Note that the y-axes of the grids on the next page need to be labeled according to the scale used.





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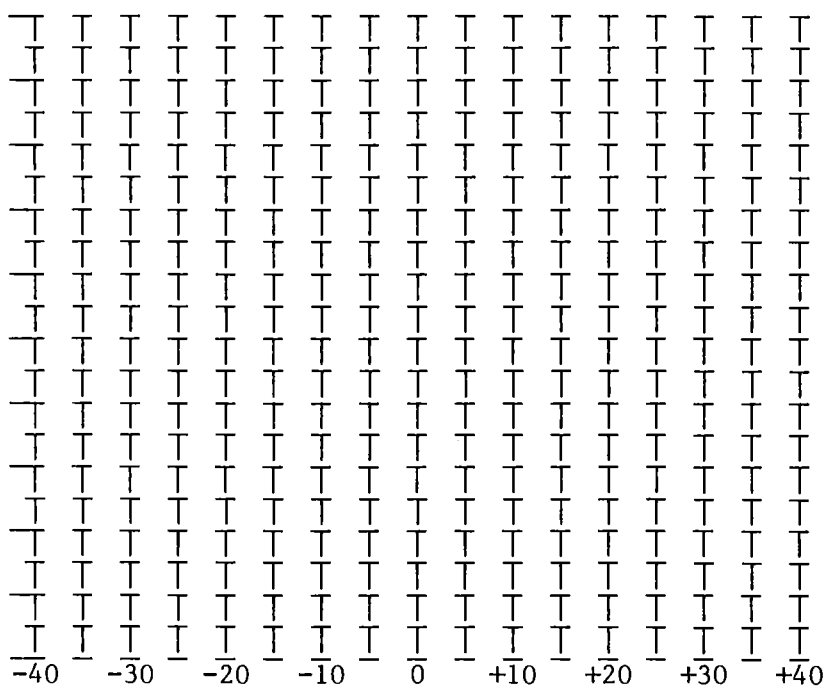

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UNIT 1.4: FORCED CONVECTION CALCULATIONS

All of the considerations discussed in UNIT 1.3: NATURAL CONVECTION CALCULATIONS apply here, with additional considerations of velocity distributions, both horizontal and vertical, in different habitats and over different parts of the animal's surface. Vertical wind profiles were discussed in CHAPTER 14, UNIT 3.2, and these are considered here in relation to geometric considerations in CHAPTER 1, UNITS 2.2 and 2.3.

An animal in a standing posture is exposed to a range of wind velocities, with the vertical velocity profile dependent on wind and cover characteristics. The velocity profile over a smooth snow surface has higher velocities near the snow surface than the velocity profile of a surface covered with vegetation. An animal standing over the snow surface has its legs exposed to higher velocities than if it were standing in vegetation reaching up to its trunk. Thus the lengths of the legs, belly heights, trunk diameter, position of the head, and vegetation densities and heights all become important simultaneous geometric considerations when evaluating forced convection losses. Surface temperature distributions must also be considered, of course, for the DLTA T part of the convection equation.

The effects of difference in geometry velocity profiles, and surface temperature distributions for different convective parts of white-tailed deer are evaluated in the WORKSHEETS that follow.

REFERENCES, UNIT 1.4

FORCED CONVECTION CALCULATIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	enrgy echng, western minne	moen,an	1968
ECOLA	57--1	192	198	odvi	energy conser, wtd, winter	moen,an	1976
JWMAA	32--2	339	344	odvi	surf temp, radian heat los	moen,an	1968
NAWTA	33---	224	236	odvi	energy balance, wtd, winte	moen,an	1968

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

NAWTA 35--- 106 114 wind as ecol and thrm forc stevens,ds; moen, 1970

CHAPTER 16, WORKSHEET 1.4a

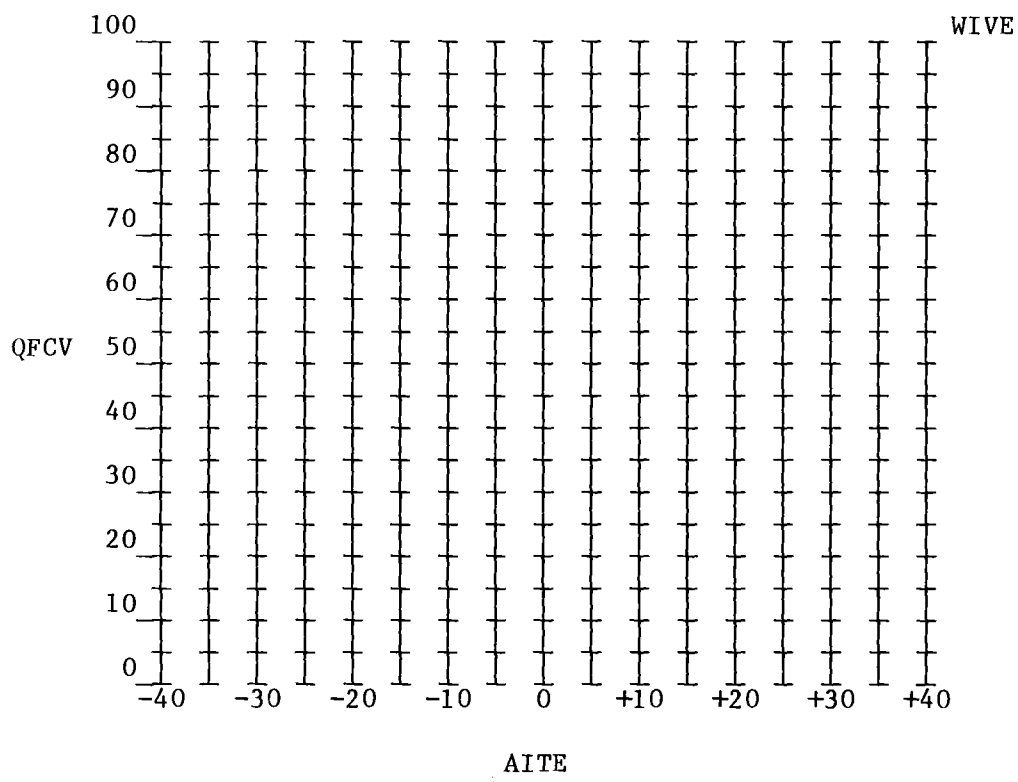
Forced convection from white-tailed deer

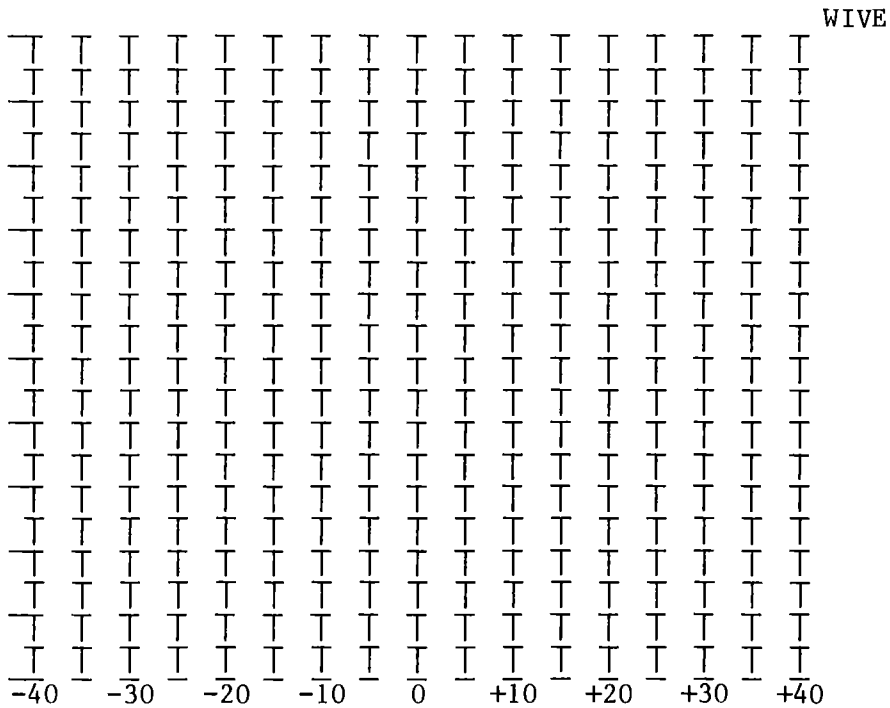
This WORKSHEET is similar to WORKSHEET 1.3a, with the addition of wind velocity as a factor in determining radiant surface temperature, and a different formula for the convection coefficient. Refer to CHAPTER 15, UNIT 2.2 for the formula:

$$QFCV = 3.702\ [(WIVE^{1/3})/(DCYC^{2/3})][(DLTT)(SAFC)]$$

Using geometry and surface temperature calculations discussed in WORKSHEET 1.3a, estimate heat loss by forced convection for different body parts, air temperatures, and wind velocities. Note that wind velocities past an animal are not equal at all heights; here is an opportunity to apply vertical wind velocity profile calculations (CHAPTER 14, UNIT 3.2) to a more complex problem.

Complete the calculations and plot the effects of wind velocity as a family of curves. Additional grids are provided on the next page.

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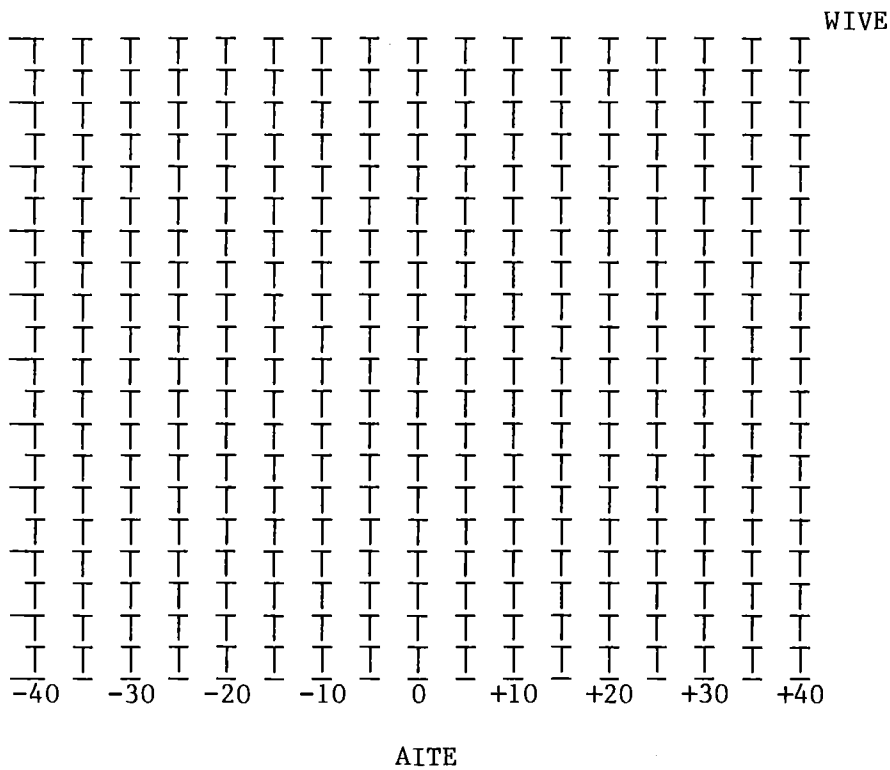
AITE


WIVE
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-20
-10
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+10
+20
+30
+40
AITE

UNIT 1.5: CONDUCTION CALCULATIONS

The simplest mode of heat transfer to consider in summations is that of conduction. An animal bedded on the ground or snow loses heat to the substrate by conduction through its hair. Conductivity coefficients determined in a closed system are applicable because there is no atmospheric disturbance in this interface. Depths of the hair, temperature differences, and bed areas are needed in addition to the conductivity coefficients in order to make these calculations for different wild ruminants.

Bed areas were given in CHAPTER 1, UNIT 2.4, hair depths in CHAPTER 2, UNIT 1.3, and conductivity coefficients in CHAPTER 15, UNIT 3.1 The temperature differences, or DLTA, is the only parameter left to quantify for conduction calculations.

The idea of a temperature gradient is simple, but the measurement of temperature gradients between animal and environment is difficult. How does one measure the temperatures at the base of the hairs (skin) and of the snow surface under bedded deer, caribou, moose, and other wild ruminants? Not easily done, unless implanted temperature transducers transmit by radio from the skin, and the animals bed down on temperature transducers on the snow.

Fortunately, temperature gradients from the skin to the snow surface can be approximated with some logic. The skin temperature cannot be higher than the internal body temperature, about 39°C. It could be less, but measurements of skin temperature on the trunk of white-tailed deer approach the internal body temperature (Moen unpublished data). The legs, curled up under the animal, could be several degrees cooler, but are likely not too different from the trunk when in that position.

Snow surface temperatures are often close to air temperatures. When an animal beds on the snow, heat transmitted from the animal to the snow can raise the temperature of the snow to no more than 0 °C, as melting begins to occur at that temperature. The heat energy then goes into the change of state of snow from solid to liquid, and the latent heat of fusion absorbs energy while the snow temperature remains at 0°C. Thus DLTA T = 39°C. As melting occurs, liquid water percolates into the snow. When the animal arises from the snow on a cold day, ice forms in the bed as the liquid water freezes, a common observation in the northern regions of the United States and in Canada.

These approximations may be used to calculate the conduction of heat to the snow by a bedded animal with the formula for static conduction. Opportunities for calculations are given in the WORKSHEET at the end of this UNIT, with the values per unit area used in computing conductive heat loss for animals with different surface areas and bed areas that were given in CHAPTER 1.

REFERENCES, UNIT 1.5

CONDUCTION CALCULATIONS

SERIALS

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

odvi

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

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

SSEBA 18--- 31 48 vert insula, metabol adap, cold hart,js 1964

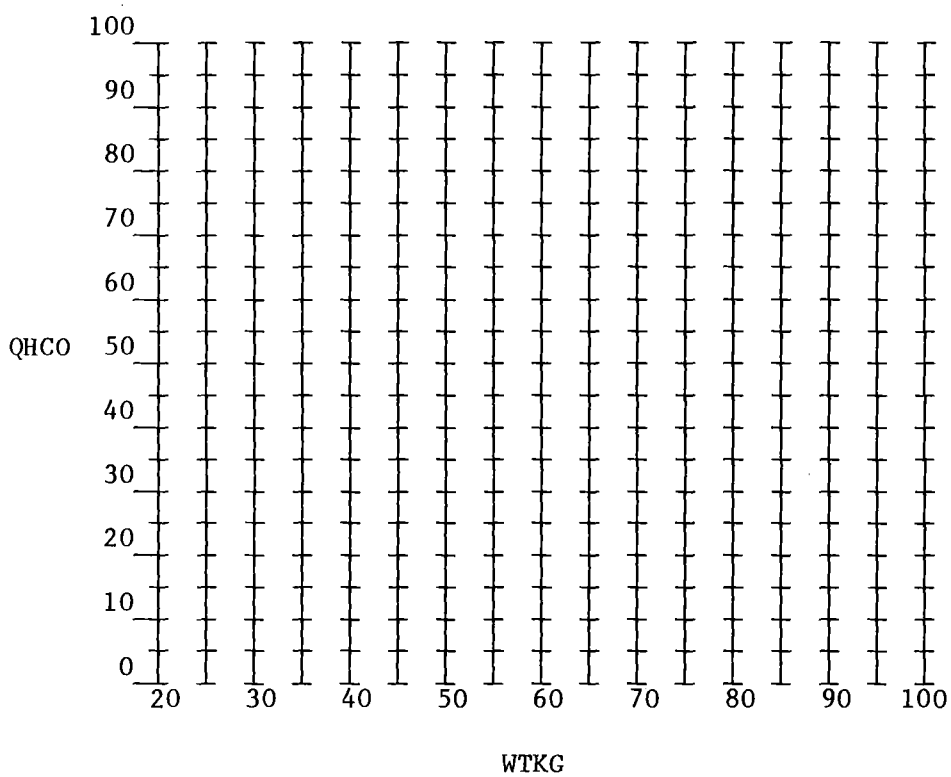
CODEN VO-NU BEPA ENPA ANIM KEY WORDS---------- AUTHORS---------- YEAR

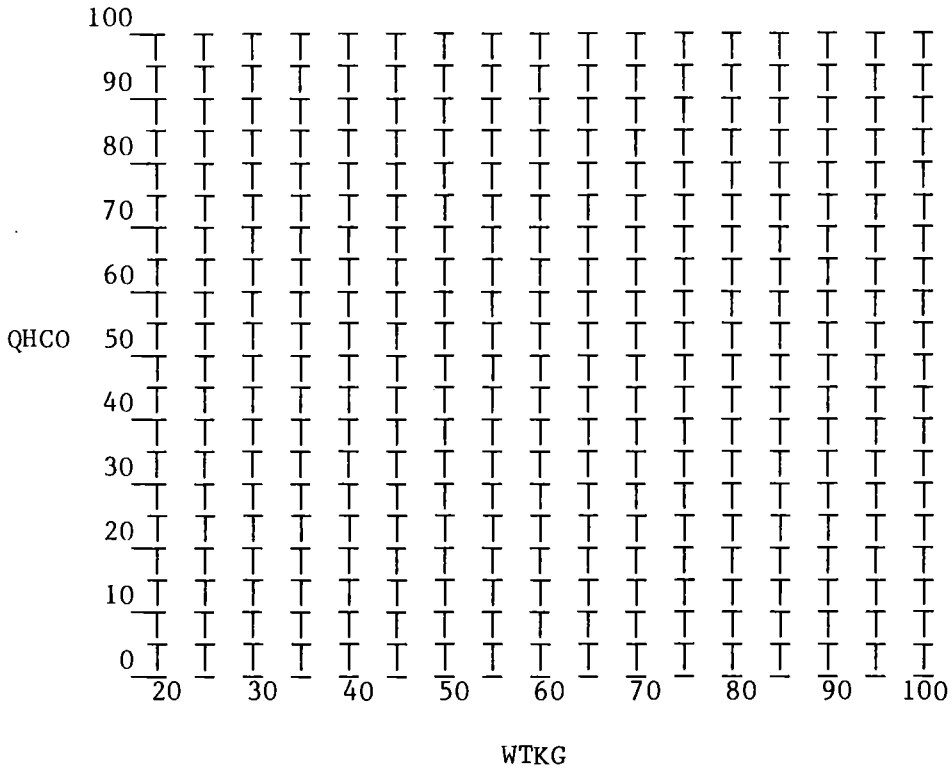
TRJOA 25-10 832 837 rata therm insulation of pelts moote,i 1955

CHAPTER 16, WORKSHEET 1.5a

Conduction calculations from white-tailed deer

Conduction calculations may be made by refering to the surface areas of beds of deer in different postures (CHAPTER 1, UNIT 2.4), hair depths and conductivities (CHAPTER 15, UNIT 3.1). Complete the calculations of bedded heat loss for deer of different weights in kg (WTKG) and plot in the grid below. A DLTA T of 39° for deer on a snow substrate is a good maximum to use. DLTA T could be different on other substrates. Additional grids are available on the next page.

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QHCO 50
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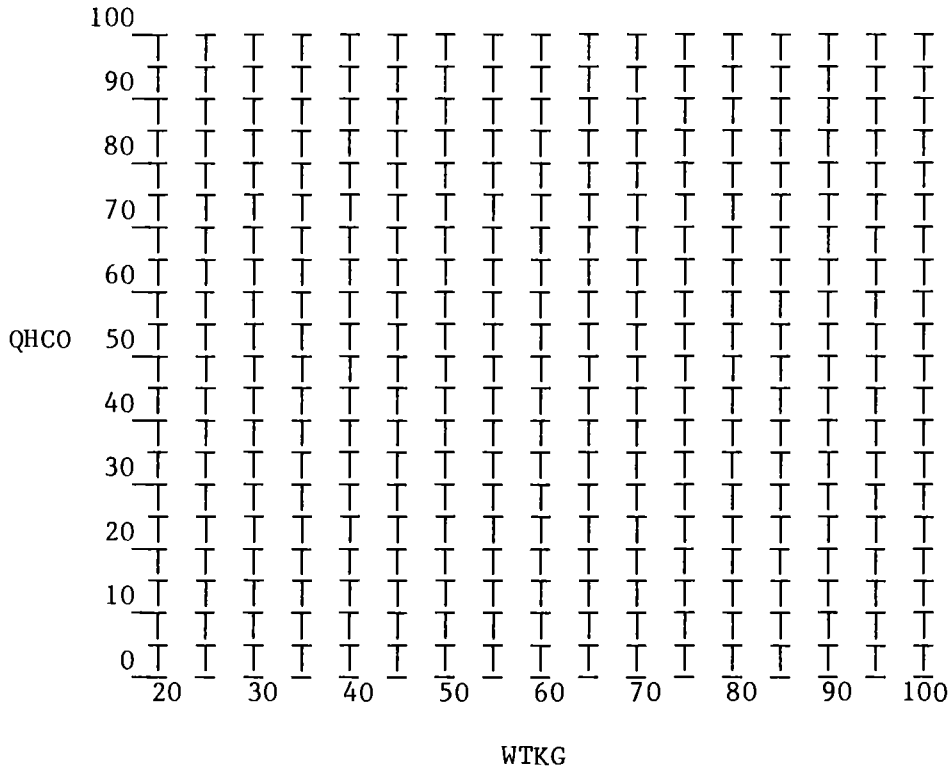
100
WTKG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QHCO 50
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50
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70
80
90
100
WTKG

UNIT 1.6: EVAPORATION CALCULATIONS

Evaporative heat exchange is the one form of heat loss over which an animal has some physiological control, and it is an especially important consideration for animals in hot environments. When the atmospheric temperature equals internal body temperature, it is the only avenue for additional heat loss. In cold environments, evaporation may be low due to the small vapor pressure deficits, but when there is a wind, even air with a low vapor pressure deficit, moving and thus never coming into equilibrium with the animal, can be an important evaporative heat sink. Caribou have anatomical charateristics in their nasal passages that act as heat exchangers, minimizing heat loss (Langman 1979). Infant caribou have been observed to lose relatively large amounts of heat when their coats are wet and they are exposed to cold wind (Lentz and Hart 1960).

Evaporation calculations are different because one is dealing not only with heat transfer but with mass transfer as well. Water is being changed from a liquid to a gas, and its distribution affects evaporative heat loss. Since the heat of vaporization is known (see CHAPTER 15, UNIT 4.1, WORKSHEET 4.1b), the amount of water evaporated from an organism, regardless of the transport mechanism involved, and the amount of energy removed by vaporization can be determined. Subjects are weighed before and after a period of time, and the difference between the first and second weights, minus the weight loss due to urine and feces, is the approximate weight of water lost for use in estimating evaporative heat loss. Evaporative heat loss is quite a small part of the total heat loss of animals in cold environments, so major errors are not introduced by treating this source of heat loss as rough estimates only. A constant rate of heat loss (10.83 KCAL PSQM PHOU) was used in calculations by Moen (1968).

This unit completes the evaluations used in arithmetic summation. A different approach to estimating total heat loss, OVERALL HEAT TRANSFER COEFFICIENTS, is introduced in TOPIC 2.

LITERATURE CITED

Langman, V. A. 1979. Nasal heat exchange in northern ungulates. Second International Reindeer/Caribou Symposium, Roros, Norway p. 30.

Lentz, C. P. and J. S. Hart. 1960. The effect of wind and moisture on heat loss through the fur of newborn caribou. Can. J. Zool. 38(4):679-688.

Moen, A. N. 1968. Energy exchange of white-tailed deer, western Minnesota. Ecology 49(4):676-682.

REFERENCES, UNIT 1.6

EVAPORATION CALCULATIONS

SERIALS

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

odvi

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

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

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alal

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

CJZOA 38--4 679 688 rata wind, moist, hea los, newb lentz,cp;hart,js 1960

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

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oram

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

BVJOA 124-2 83 88 doca evapor loss, new born calf hales,jrs; findl/ 1968

JASIA 74--2 247 258 doca moisture, evapor, coats sw allen,te; bennet/ 1970

JDSCA 51-10 1693 1697 doca body surf evap, lo, hi tem joshi,bc; mcdowe/ 1968
JDSCA 54--3 458 459 doca evap cool, comfor, lactati fuquay,jw; brown/ 1971

ZOTCA 24... 233 240 doca cutaneous heat loss bovine de tena andreu,s 1975

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

JAPYA 40--4 514 520 dogo thermosensit, hypothalamus jessen,c 1976
JPHYA 284-- 162p 163p dogo core temp, resp loss, exer jessen,c; mercer, 1978

PYSOA 21--4 100 100 dogo sweat gland secre, black b robertshaw,d; dm/ 1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS	AUTHORS	YEAR
FEPRA	30--2	319	319	dosh	resp evap cool, hyperventi	hofman,wf; riegl/	1971
IJLAA	46--8	459	460	dosh	evaporation, colorat effec	singh,m; acharya,	1976
IJLAA	47--6	367	368	dosh	heat dissip, different typ	singh,m; acharya,	1977
IJMDA	12-10	1223	1223	dosh	met rate, evap, conductanc	degen,aa	1976
JAPYA	26--5	517	523	dosh	temp, wool, surf, resp eva	hofmeyr,hs; guid/	1969
RSPYA	30--3	327	338	dosh	thermoresp, shorn, unshorn	hofman,wf; riegle	1977
RSPYA	30--3	339	348	dosh	resp evapo, shorn, unshorn	hofman,wf; riegle	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS	AUTHORS	YEAR
AJPHA	219-4	1131	1135	ungu	temp regul, evaporation	taylor,cr	1970
SZSLA	25...	345	356	ungu	evap temp regulation	jenkinson,dm	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS	AUTHORS	YEAR
EAFJA	37--4	325	330	afri	environ physiol, semideser	schoen,a	1972
SZSLA	25...	215	227	afri	heat load,watr req,gazelle	taylor,cr	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS	AUTHORS	YEAR
JDSCA	51-10	1689	1692	----	body surf evap, lo, hi tem	joshi,bc; mcdowe/	1968
SZSLA	25...	357	369	----	evap heat loss,arid env,ma	bligh,j	1972

UNIT 1.7: TOTAL HEAT LOSS SUMMATIONS

Results of calculations of heat losses by the four modes of heat transfer--radiation, convection, conduction, and evaporation--may be added together and total heat loss determined. This procedure is fine if interactions between the different modes of heat transfer are considered. For example, wind reduces the radiant temperature of an animal's surface. The reduction is due to convection. Radiation losses may be correctly added to the convection losses only if the lower radiant temperature is used. If that is not considered, heat losses will be overestimated.

Another source of error is in the algebraic addition of radiant energy to the total heat exchange. The addition of radiant energy from a dense plant canopy, for example, may increase the summed heat load and appear to markedly reduce heat loss. Since any additional heat energy absorbed at the tips of the hairs is subject to natural and forced convection, the realized benefits are much less than the calculated ones. This was noted in relation to thesis data (Moen 1966) which I have not published; the explanation was not fully realized until experiments were conducted in the wind tunnel at the Wildlife Ecology Laboratory at Cornell University and the behavior of the thermal boundary region and temperature profile observed.

Total heat loss summations are useful because they call attention to the modes of heat transfer and interactions between them. A WORKSHEET provides a format for summations. If you do the clculations for deer, compare your results with those in Moen (1968a, 1968b, 1973, 1976) and Moen and Jacobsen (1975).

After gaining an understanding of summations, go to TOPIC 2: OVERALL HEAT TRANSFER COEFFICIENTS to evaluate interactions between the four modes of heat transfer and the relative contributions of the different layers in the thermal boundary region to heat transfer.

LITERATURE CITED

Moen, A. N. 1966. Factors affecting the thermal exchange of white-tailed deer, western Minnesota. Ph.D. Thesis, University of Minnesota. 166 p.

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Moen, A. N. 1968b. Energy balance of white-tailed deer in the winter. N. Am. Wildl. and Nat. Res. Conf. Trans. 33:224-236.

Moen, A. N. 1973. Wildlife Ecology: An analytical approach. W. H. Freeman and Co., San Francisco. 458 p.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1):192-198.

Moen, A. N. and N. K. Jacobsen. 1975. Thermal exchange, physiology, and behavior of white-tailed deer. Pages 509-524 In D. M. Gates and R. B. Schmerl (eds.), Perspectives of Biophysical Ecology. Springer-Verlag, Inc., N.Y. 609 p.

REFERENCES, UNIT 1.7

TOTAL HEAT LOSS SUMMATIONS

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS----------	AUTHORS/EDITORS--	YEAR
aubo	whfr	sfca	458	odvi	wildlife ecology: analyt a	moen,an	1973
edbo	spve	nyny	609		perspectvs of biophys ecol	gates,dm; schmerl	1975

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
ECOLA	49--4	676	682	odvi	energy exchange, minnesota	moen,an	1968
ECOLA	57--1	192	198	odvi	energy conservatn in wintr	moen,an	1976
JWMAA	32--2	338	344	odvi	surf temp, radian heat los	moen, an	1968
NAWTA	33---	224	236	odvi	energy balance, deer, wint	moen, an	1968

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------	AUTHORS----------	YEAR
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CHAPTER 16, WORKSHEET 1.7a

Summations of heat loss

The WORKSHEETS in the previous UNITS in this TOPIC have provided opportunities for calculating heat loss by the four modes of heat transfer from animals of different weights. If you have completed each of these WORKSHEETS, you can sum the heat losses by each of the modes to estimate a total heat loss. Complete the blanks below.

Weight = _____; Base-line metabolism = _____; Surface area = _____

AITE = _____; Sky/canopy condition = _____; WIVE = _____.

Net radiation loss _____

Convection loss _____

Conduction loss _____

Evaporation loss _____

Total heat loss _____

MBLM _____

An evaluation of how realistic the total heat loss is may be made by dividing the total by base-line metabolism for an animal of that weight. The resulting multiple of base-line metabolism (MBLM) should be between 1.5 and 2.0 for winter conditions if the animal is not in a critical thermal environment (see CHAPTER 7, TOPIC 6) since the heat dissipated must equal ecological metabolism if homeothermy is to be maintained. In some weather conditions, an animal must conserve heat, and in others, dissipate excess heat. Thermoregulation is discussed in TOPIC 3 of this CHAPTER.

Additional blanks for summations of heat loss are provided for different sets of conditions.

Weight = _____; Base-line metabolism = _____; Surface area = _____

AITE = _____; Sky/canopy condition = _____; WIVE = _____.

Net radiation loss _____

Convection loss _____

Conduction loss _____

Evaporation loss _____

Total heat loss _____

MBLM _____

Weight = _______; Base-line metabolism = _________; Surface area = _________
AITE = _______; Sky/canopy condition = _________; WIVE = ________.
Net radiation loss _____
Convection loss _____
Conduction loss _____
Evaporation loss _____
Total heat loss _____
MBLM _____

Weight = _______; Base-line metabolism = _________; Surface area = _________
AITE = _______; Sky/canopy condition = _________; WIVE = ________.
Net radiation loss _____
Convection loss _____
Conduction loss _____
Evaporation loss _____
Total heat loss _____
MBLM _____

Weight = _______; Base-line metabolism = _________; Surface area = _________
AITE = _______; Sky/canopy condition = _________; WIVE = ________.
Net radiation loss _____
Convection loss _____
Conduction loss _____
Evaporation loss _____
Total heat loss _____
MBLM _____

Weight = _______; Base-line metabolism = _________; Surface area = _________
AITE = _______; Sky/canopy condition = _________; WIVE = ________.
Net radiation loss _____
Convection loss _____
Conduction loss _____
Evaporation loss _____
Total heat loss _____
MBLM _____