TOPIC 2. OVERALL HEAT TRANSFER COEFFICIENTS

Insulation is resistance to heat flow. The more resistance provided, the better the insulation. A perfect insulation has infinite resistance, but such insulation does not exist.

Problems associated with estimating the benefits of different amounts of insulation used in building applications are relatively simple because the insulation is enclosed between two walls. The problem is one of temperature gradients, conductivity coefficients and depths. It is an ideal example of static conductivity. An overall heat transfer coefficient is the reciprocal of the sum of the resistance.



Hair is exposed to the atmosphere, and the exposure of such fibrous insulation poses a very different and much more complex problem than the static conductivity application described above. The main difference is that there is no defined outer surface; the fibrous insulation is rough and air, wind, and radiant energy penetrate to various depths.



The thermal boundary region, or layer of air with different densities and temperatures around the animal (see Moen 1973:248) described in CHAPTER 15 is divided into three layers of insulation: the hair, hair-air interface, and air. The outer limit of the thermal boundary region is defined as the point where 95% of the temperature difference from the base of the hair (skin) to the ambient atmosphere has occurred.



The depth of the thermal boundary region is dependent on the physical depth of the hair, wind velocity, and the amount of radiant energy absorbed by the hair. Infrared radiation is not a major factor in natural habitats, but solar radiation has an important effect on the depth of the thermal boundary region when the hair is exposed to sunlight.

Heat energy is transmitted through these layers of insulation, generally from the animal to the atmosphere since skin temperatures are usually the highest of any on the temperature profile.



Heat energy is transmitted successively through the three layers; the amount of heat energy transmitted through the first equals the amount transmitted through the second, and through the third layer. The sum of the depths of each of the layers provides the total depth through which the heat escapes. Because of the labile and porous nature of these layers, their depths change with changes in weather conditions, especially wind and solar radiation. Once their depths have been determined for different combinations of wind and solar radiation and thermal resistance calculated, heat transfer may be calculated for each layer.

The total resistance of all three layers is equal to the sum of their individual resistances. This simplifies the calculations when applying this approach to the whole animal because it is not necessary to know the temperature differences between layers, or the depths of each layer, but rather the overall temperature difference between the skin and ambient atmosphere and the overall depth of the thermal boundary region.

As the depth of the hair increases, the total depth of the thermal boundary region and thus thermal resistance increases. As wind velocities increase, the depth of the thermal boundary region and thus thermal resistance decreases. Hair depths do not change rapidly, unless they are being moved by the wind or by the animal's activity. Wind velocities may change very rapidly, of course. The sum of the resistance through each layer is the total resistance to heat flow. The heat transfer coefficient is the reciprocal of the resistance, and expresses the rate at which heat is transmitted through an insulation rather than the resistance of the insulation to heat transmission. Overall heat transfer coefficients (OHTC) are dependent on hair depths and wind velocities, and radiation absorbed, just as the resistances are, so an array of these must be generated for different combinations of hair depths, wind, and radiant energy for application to animals in the natural environment.

Thermal boundary region characteristics are presently being analyzed for white-tailed deer (Moen and Gustafson, In Preparation), but there are no data for other species of wild ruminants. It is likely that reasonable approximations can be made for other species by using the resistances determined for deer and the hair depths of the species being studied, since the thermal resistances <u>per unit depth</u> of the hair coats of other species are not greatly different from those of deer (See CHAPTER 15, UNIT 3.1).

The next two UNITS illustrate the patterns of changes in overall heat-transfer coefficients with changes in wind, hair depth, and radiant energy. The first analyses are for flat surfaces and cylinders, which, as simplifications of the real animals, illustrate the basic patterns of change at the hairy surface. Whole-body analyses involve the surface areas and hair depths of different body parts, the vertical geometry of the animal in relation to the vertical wind velocity profile, the habitat characteristics that determine the wind velocity profile, air temperatures, and wind velocities measured at a 2-meter reference height.

The use of overall heat transfer coefficients is divided into units on hair depth effects (UNIT 2.1), infrared radiation effects (UNIT 2.2), infrared and solar radiation effects (UNIT 2.3), and wind effects (UNIT 2.4). All of these variables may occur at the same time, so a unit on the combined effects of different variables (UNIT 2.5) is also included.

UNIT 2.1 HAIR DEPTH EFFECTS

Hair depth has a major effect on the resistances of the three layers in the thermal boundary region. The greater the hair depth, the greater the elevation in the temperature profile near the skin. This effect is illustrated below for increasing hair depths.



The temperature profile shown above shows a large gradient for the air layer and a small gradient for the hair layer.



Increasing temperature ->

The temperature profile above shows a smaller gradient for the air layer and a larger gradient for the hair layer than in the previous illustration. This illustrates the effect of good insulation on the temperature profile. Perfect insulation would result in a vertical line for the temperature profile in the air layer, since no heat is transferred through a perfect insulator. The hair layer does not meet that high standard, of course. One more illustration of the effects of hair depth on the temperature profile follows.



Increasing temperature ->

The temperature profile above shows the effects of an even greater hair depth than in the two previous illustrations. Note the temperature gradient in the air layer is very small because the greater depth of the hair layer makes the hair better insulation than the lesser depths.

The temperature gradients in the air and hair layers are reflections of the resistances of the layers. The large gradient in the hair layer indicates a high resistance to the transfer of heat energy, and the small gradient in the air layer a low resistance to heat energy. As the hair layer increases in depth, it makes up an increasingly large percentage of the total resistance of the thermal boundary region.

The insulation value of the hair is obviously an important consideration when analyzing heat flow and the thermal balance of animals, since heat that is lost from an animal must pass through this insulative layer. The gradient is also very steep. I have recorded skin temperatures at the base of the hair of white-tailed deer of about 37° C when the air temperature was -20° C, a difference of 57° over a depth of less than 5 cm.

Calculated values of overall heat transfer coefficients, resistances through each of the layers, and percentages of the total resistance of the thermal boundary region that can be attributed to each of the layers are being determined as data analyses for the white-tailed deer continue. The generalized description given for the effects of hair depth introduces the basic ideas, and sets the stage for the discussions of the effects of additional variables in the UNITS that follow.

REFERENCES, UNIT 2.1

HAIR DEPTH EFFECTS

SERIALS

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR VCSZA 33--4 300 312 cerv [course of molting, deer] dobroruka,1j 1969

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR JOMAA 47--1 154 155 odvi wooly-coated deer, new yor friend,m; hesselt 1966

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR CJZOA 50--5 639 647 odhe pelage and molt, b1-tld dr cowan, imt; raddi, 1972

CODEN VO-NU BEPA ENPA ANIM KEY WORDS------ AUTHORS------ YEARJZOOA 170-1 6977ceel coat struct, seasnl change ryder,ml; kay,rnb 1973JZOOA 181-2 137143ceel seas coat changes, grazing ryder,ml1977JZOOA 185-4 505510ceel coat grwth,day length cycl kay,rnb; ryder,ml1978

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

alal

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

rata

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

anam

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR ZETIA 49--1 71 76 bibi hair display loss, male bi lott, df 1979

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------ YEARBJLSB 6---2 127141 obmo wool shedding in muskoxen wilkinson,pf1974JZOOA 177-3 363375 obmo length, diamtr coat fibers wilkinson,pf1975

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

oram

UNIT 2.2: INFRARED WAVELENGTHS ONLY

A series of tests completed in the Thermal Environment Simulation Tunnel at the Wildlife Ecology Laboratory, Cornell University, have resulted in calculations of resistances and overall heat transfer coefficients (OHTC) for different hair depths and wind velocities. Such calculations have been made for no other wild ruminant, but they may be used for making first approximations for other species, provided the surface areas and hair depth distributions of the other species are known.

The effect of infrared energy on the thermal resistances is illustrated by the changing temperature profiles illustrated below. A constant hair depth is used, with three levels of infrared energy, including a negative flux characteristic of a clear, night sky.



The temperature profile illustrated above actually goes slightly to the left and below air temperature at the hair surface in the illustration above because the infrared flux is negative. A clear night sky is a heat sink, and has a cooling effect on the earth's surface as well as the surfaces of plants and animals. The effect was discussed in CHAPTER 14, UNIT 1.2, in relation to dew and frost formation at various distances from the base of a tree. Effects of an increased infrared flux follows.



The illustration on the previous page shows a temperature profile that results when infrared flux is neither unusually small or large, negative or positive. Such a profile occurs when environmental radiant temperature and atmospheric temperature are equal. The temperature profile is in equilibrium with its surroundings.

A different kind of a temperature profile occurs when the animal is exposed to a source of infrared radiation. This effect is illustrated below.



The infrared radiation that is absorbed at the hair surface causes an increase in the temperature gradient in the air layer. This effect is similar to the "elevated minimum" air temperature discussed in CHAPTER 14, UNIT 2.2. Energy is absorbed at the surface, warming the air next to the surface and changing the shape of the profile. Such a situation could occur when the animal beds down under a dense conifer canopy, which is a source of infrared energy, on a clear night when air temperature is low due to cooling of the air mass and earth's surface by outward radiation. Then, the conifer canopy may function as a source of heat energy that is greater than the radiation from the clear night sky.

The examples above illustrate the idealized effects of infrared radiation on the temperature profile and resistances of each of the layers in the thermal boundary region. The differences in infrared radiation flux under different canopy types are measurable and distinct. The effect of these differences on the temperature profiles is not particularly great because of the effect of wind. If the hairy surface of an animal were in a vacuum, then the effects of absorbed radiation would be very clear. Since the hair is exposed to the atmosphere, the effects are ameliorated by convection. This is a singularly important reason for not simply adding radiant energy to a calculated heat balance. Arithmetic summations do not account very well for the interactions between the four different modes of heat transfer.

The effects of wind are illustrated in UNIT 2.4. The next unit, UNIT 2.3, includes illustrations of the effects of both infrared and visible wavelengths on the temperature profile and thermal resistances.

REFERENCES, UNIT 2.2

INFRARED WAVELENGTHS ONLY

SERIALS

CODEN VO-NU BEPA ENPA ANIM KEY WORDS------ AUTHORS------ YEARJRMGA 27--5 401403 odvi radiant temp, hair surface moen,an1974JWMAA 32--2 338344 odvi surf temp, radiant heat lo moen,an1968JWMAA 38--2 366368 odvi radiant temp surface, wind moen,an; jacobsen 1974

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 NJZOA 19--1 89 91 rata surf tmps, heat los, summe wika,m; krog,j 1971 ZOLZA 53--5 747 755 rata [body surface heat emissi] segal,an; ignatov 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

 ovca

 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

 ovda

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

 obmo

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

 obmo

J.

UNIT 2.3: INFRARED AND VISIBLE WAVELENGTHS

Infrared radiation is always present, while visible wavelengths are naturally present only when the sun shines or in moonlight. Moonlight is of no consequence as a source of heat energy, so solar radiation, which includes both infrared and visible wavelenghts, and the background infrared radiation contribute to the radiant energy of interest in this UNIT.

Background infrared radiation was discussed in the previous unit (UNIT 2.2). Measurable differences in infrared flux under different plant canopies were discussed in CHAPTER 14, UNIT 1.3. Solar radiation, especially direct beam radiation from the sun, may be present in much larger quantities than infrared, and its effects are illustrated below.

Solar radiation that reaches the surface of an animal is either reflected or absorbed. Reflection and absorption characteristics were discussed earlier (CHAPTER 15, UNIT 1.2), where it was pointed out that the angles of the sun's rays are an important determinant of absorption coefficients. The angles depend on the sun's position in the sky and the orientation of the animal, resulting in an infinitely large amount of variability.

Consider the effects of increasing larger amounts of solar radiation on the temperature profiles and thermal resistances of the thermal boundary region. The sequence below shows the idealized effects of these changes.



Increasing temperature \rightarrow

The illustration above is for infared radiation only when environmental radiant temperature and atmospheric temperature are in equilibr-It is a duplicate of the second illustration in UNIT 2.2. ium. Note the smooth profile, and compare it to the effects of an increased radiation load in the next illustration.



An increased radiation load shifts the profile to the higher temperature side as heat energy is absorbed by the hair and the air between the hairs. This increases the steepness of the temperature gradient in the air, and also increases the depth of the air layer that is a part of the thermal boundary region. Thus the layer of insulating air has a greater depth. The temperature at the hair surface is also greater, reducing the temperature gradient through the hair layer. A small temperature gradient through a good insulator, such as hair, results in a very small amount of heat loss through that layer. The addition of solar radition to a animal's surface may greatly reduce heat loss. The next example illustrates the effects of an even greater solar radiation load.



The solar radiation load may be great enough to cause an inversion in the temperature profile, with a higher temperature at the tips of the hairs than at the skin beneath the hairs. When such a profile develops there is a heat gain by the animal rather than a heat loss. The animal would not sense that condition immediately, however, because the hair layer acts as insulation from the heat. As the heat energy moves through the hair layer to the skin where thermal sensors are located, the animal feels warmed. The inverted profile reverses the temperature gradient so heat loss through the entire layer simply cannot occur. This effect may be very important to deer on a south slope in later winter. It is important to point out, however, that the addition of thermal energy and the reduction of heat loss cannot drive the metabolic processes of the deer; input energy (food) is still needed, which is often gotten from newly-exposed vegetation from the previous year and from early new spring growth.

The temperature profiles with increasing radiant energy loads are dramatically altered by wind. The effects of wind are discussed next.

REFERENCES, UNIT 2.3

INFRARED AND VISABLE WAVELENGTHS

SERIALS

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR odvi 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 solar radiation, wind chil 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 ovca

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

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

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

CODEN VO-NU BEPA ENPA ANIM KEY WORDS------ AUTHORS------ YEAR ECOLA 58--6 1384 1392 doca cattle colors, solar radia finch,va; western 1977 JANSA 35--3 624 627 doca phys principl, energy exch morrison,sr 1972 JAPYA 26--4 454 464 doca penetrance coats by radiat hutchinson,jcd; / 1969 OJVRA 20--2 223 234 doca absorpt, solar rad, colour riemerschmid,g; e 1945

CODEN VO-NU BEPA ENPA ANIM KEY WORDS------ AUTHORS------ YEAR CBPAB 52--2 343 349 doru reflectance, sol rad, coat hutchinson,jcd; / 1975 IJBMA 20--2 139 156 doru meteorology in animal prod bianca,w 1976 JAPYA 37--3 443 446 doru heat flow meters, heat los mchinnis,sm; ingr 1974 PRLBA 188-- 377 393 doru radiati transf, anim coats cena,k; Monteith, 1975

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR AJZOA 20--1 17 22 dosh effec postu, heat loa, sum dawson,tj 1972 ECOLA 50--2 328 332 dosh bioclim compar, summer day dawson,tj; denny, 1969 JAPYA 35--5 751 754 dosh local heat balance, radiat clark,ja cena,k/ 1973

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----- AUTHORS----- YEAR ECOLA 45--3 646 649 sol rad char of tree leavs birkebak,r; birke 1964

UNIT 2.4: WIND EFFECTS

The effects of wind on the temperature profile through the thermal boundary region are illustrated most dramatically with the elevated maximum profiles (the third one) in the previous unit (UNIT 2.3) shown again below.



The profile above, with marked temperature gradients, results in natural convection from the hairy surface because of the density differences in the air of different temperatures. The warmer air rises, and a plume develops over the animal. In fact, every animal bedded in the sun on a warm spring day has such an invisible plume over it.



Chapter 16 - Page 53

As the wind velocity increases, the temperature profile is compressed. The gradient becomes greater in the hair layer and less in the air layer. The thickness of the entire thermal boundary region decreases as illustrated below.



An increase in the wind velocity may compress the temperature profile almost to the physical depth of the hair. Then, the temperature gradient through the air layer is very small, and the depth of the air layer is very small. The temperature gradient through the hair layer is larger, and the value of the overall heat transfer coefficient is larger than in either of the previous two situations.



The effects of wind on the depth of the thermal boundary region and the shape of the temperature profile are large because the wind physically moves the air, destroys density differences and hence temperature gradients. When the thermal boundary region is disturbed in such a way, it no longer functions as insulation, leaving only the hair depth as the layer of insulation. This explains why the hair depth is such an important determinant of the overall heat transfer coefficient. In fact, wind velocity, which affects the depth of the air layer, and hair depth are two of the most important characteristics in thermal exchange.

The distribution of wind velocity over the irregular sufaces of a bedded, standing, or moving animal is very complex, with turbulence added as a result of the animal's geometry. The pattern of thermal boundary region depths in relation to wind is shown below.



Such complexities, even for the simplest of cases, are more than can be precisely evaluated mathematically. Insights may be gained, however, by evaluating sets of conditions that result in estimated amounts of heat loss, and these amounts related to metabolic heat production. Concepts and insights are valuable even when empirical measurements are difficult to make.

REFERENCES UNIT 2.4

WIND EFFECTS

BOOKS

TYPE	PUBL	CITY	PAGE	AN IM	KEY	WORDS-				AUTHORS/	EDITORS	YEAR
aubo	gaul	loen	234	rata	the	wind a	ind t	the	caribou	munsterh	jelm,e	1953

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS AUTHORS	YEAR
JRMGA	275	401	403	odvi	radiant temps, hair surfac moen,an	1974
JWMAA JWMAA	322 382	338 366	344 368	odvi odvi	surf temp, radiant heat lo moen,an radiant temp surface, wind moen,an; jacobsen	1968 1974
NAWTA	35	106	114	odvi	func aspects wind, thermal stevens,ds; moen,	1970

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 CJZOA 38--4 679 688 rata eff wind, moist newb htlos lentz,cp; hart,js 1960 NJZOA 19--1 89 91 rata surf tmps, heat los condit wika,m; krog,j 1971 TRJOA 25-10 832 837 rata thermal insulation of pelt moote,i 1955 ZOLZA 53--5 747 755 rata [body surfac heat emissio] segal,an; ignatov 1974 JTBIA 47--2 413 420 rata wind chill, solar radiatio 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 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 JANSA 35--3 624 627 doca physic principl energ exch morrison, sr 1972 JASIA 74--2 247 258 doca accum, evap moist, sweatin allen, te; bennet/ 1970 IJBMA 20--2 139 156 doru meteorólogy in anim produc bianca,w 1976 JAPYA 37--3 443 446 doru heat flow meters, heat los mcginnis,sm; ingr 1974

CODEN VO-NU BEPA ENPA ANIM KEY WORDS------ AUTHORS------ YEAR JASIA 52--1 25 40 dosh partition heat los, clippe blaxter,kl; grah/ 1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS AUTHORS	YEAR
JAPYA	204	796	801	mamm	hair dens, wnd spd, h loss tregear,rt	1965
BIOJA	11-12	1030	1047		energy exch, cylind append wathen,p; mitche/	1971
JTBIA	351	119	127		convect resp syst, panting seymour,rs	1972
PRLBA	188	395	411		conductin, convectn, coats cena,k; monteith,	1975

UNIT 2.5: COMBINED EFFECTS OF DIFFERENT VARIABLES

Air temperatures, wind velocities, locations, postures, surface areas, and other characteristics of the animal-environment relationship change during a 24-hour period. Real-time analyses are impossible because changes are too numerous and too rapid. Calculated heat losses for the many different combinations of conditions are added together to give the total quantity of heat lost (QHLK) for a 24-hour period. The total is then compared to estimates of heat production. Using this approach, the benefits of different postures and locations can be demonstrated under different temperature and wind conditions and an understanding of some thermoregulatory behavioral responses gained.

The validity of the results of calculations for deer and the results of first approximations for other species may be checked by comparing the calculated heat loss to base-line metabolism (BLMD). Calculation of ecological metabolism (ELMD) of white-tailed deer in Chapter 7 show that ELMD, expressed as multiples of base-line metabolism MBLM [MBLM = (ELMD/BLMD)] is expected to range numerically from about 1.5 to 1.8. Total heat loss, espressed as MBLM, should also be in that range. Divide the quantity of heat lost in KCAL (QHLK) calculated in the worksheets by BLMD to determine the ratio, or MBLM. If it is greater than the multiple calculated for energy metabolism estimates, the animal is losing more heat energy than is being produced metabolically. This cannot go on for extended periods of time, of course, because body temperature will then drop. If QHLK is less than ELMD, then the animal must do something to dissipate the excess heat energy, or body temperature will rise.

REFERENCES UNIT 2.5

COMBINED EFFECTS OF DIFFERENT VARIABLES

SERIALS

C	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					odvi				
C	ODEN	vo-nu	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					odhe				
C	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					cee1				
C	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					ala1				
C	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					rata				
C	ODEN	vo-nu	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					anam				
C	ODEN	vo-nu	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					bibi				
C	ODEN	vo-nu	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					ovca				
C	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					ovda				
c	ODEN	VO-NU	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					obmo				
_	0.0.0.1.1								
C	ODEN	vo-nu	BEPA	ENPA	ANIM	KEY	WORDS	AUTHORS	YEAR
					oram				