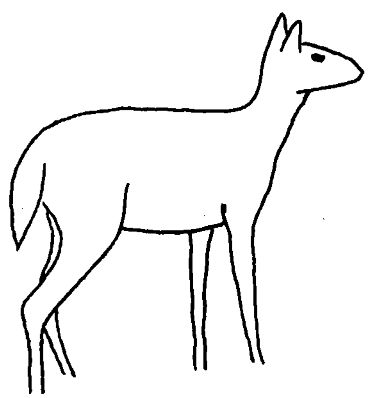
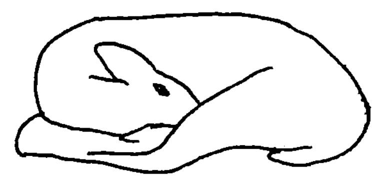
## TOPIC 2. GEOMETRY

The geometry of an animal is an important consideration in ecological analyses because it affects so many fundamental relationships, especially physical ones, between the animal and the characteristics of the range. For example, the amounts of accumulated snow affect animals of different sizes differently; a small fawn has shorter legs than a large buck, and this is an important consideration when evaluating the effects of snow on movements. Size differences affect the heights animals can reach for forage, and that determines the upper limit to the range for each individual. Vertical height profiles are of interest to biologists when evaluating thermal relationships in relation to vertical wind profiles in differrent habitats. Further, the amount of thermal exchange between animal and environment is related to the posture and surface areas of animals as illustrated below.



Maximum surface area, standing



Minimum surface area, bedded, curled

One might guess that the surface area of the standing animal on the left is considerably larger than the surface area of the bedded animal on the right. Further considerations of intermediate postures can be made; a bedded animal may have its head up, increasing its surface area exposed to the atmosphere, and it may extend its legs somewhat, increasing its surface area exposed to the substrate. These subtle changes in posture may have very important thermoregulatory functions; they can be evaluated when surface areas of body parts are considered in calculations of thermal exchange.

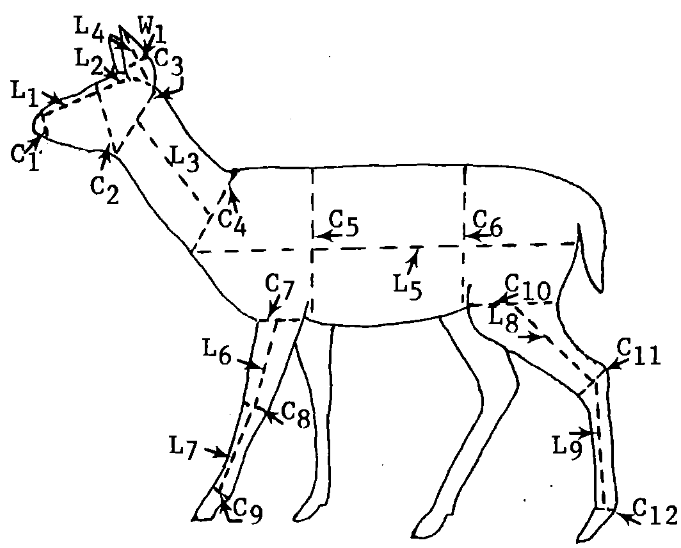
The effects of geometric differences are of distinct ecological significance when evaluating physical animal: range relationships. The geometric considerations discussed above are objective. Some geometric characteristics are subjective--postures of animals indicate whether an animal is a potential aggressor or a sub-dominant--but these are considered in Part II, Behavior of Wild Ruminants. Surface area and geometric considerations are discussed in the next four UNITS.

Linear measurements, relatively easy to make with inexpensive equipment, may be used for several purposes. Mammalogists often record a rather standard series of measurements, including the body length, tail length, hind foot length, and skeletal lengths. Such measurements have been useful in evaluating taxonomic relationships between populations in different areas. Subspecies are sometimes identified on the basis of linear measurements. Some of these measurements are made on internal skeletal characteristics; these are discussed in TOPIC 3, SYSTEMS CHARACTERISTICS. Linear measurements of fetuses have been made and related to age and sex. These are useful when estimating the time of breeding, and of fetal or maternal mortality.

The heart girth, or circumference of the chest just behind the front legs, may be used to estimate field-dressed and live weights. Then, heart girth in cm (HEGC) is the independent variable and field-dressed weight in kg (FDWK) or estimated live weight in kg (ELWK) the dependent variable. Linear measurements of lengths and diameters of body parts may be used to calculate vertical profiles when animals are in different postures. External linear measurements, easily made with a flexible tape, may be used in calculating surface areas of different parts of the body.

Regression equations for relationships between linear measurements and weights are useful for predicting geometric dimensions over a range of weights. Interspecies comparisons can also be made, and the lack of data may make it necessary to estimate geometric considerations of one species from data on another.

The linear measurements indicated on the silhouette below are used in calculating vertical profiles discussed in UNIT 2.2 and surface areas discussed in UNITS 2.3 and 2.4.



REFERENCES, UNIT 2.1

LINEAR MEASUREMENTS

SERIALS


| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 1---3 | 130 | 133 | od-- | skull measurem, northern d | phillips,jc | 1920 |
| JOMAA | 39--3 | 347 | 367 | od-- | mammals of mex state, guer | davis,wb; lukens, | 1958 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| AMNAA | 43--3 | 650 | 666 | odvi* | fetal developme, white-tai | armstrong,ra | 1950 |
| JOMAA | 9---1 | 57 | 59 | odvi | new white-tailed de, louis | miller,fw | 1928 |
| JOMAA | 17--1 | 67 | 68 | odvi | size, weight, adirond deer | schoonmaker,wj | 1936 |
| JOMAA | 25--4 | 370 | 403 | odvi | notes on mexican mammals | davis,wb | 1944 |
| JOMAA | 32--4 | 411 | 421 | odvi | analys reproduc patte, tex | illige,d | 1951 |
| JOMAA | 40--1 | 108 | 113 | odvi | breeding records, captive | haugen,ao | 1959 |
| JOMAA | 47--2 | 266 | 280 | odvi | endocrin glands, seas, sex | hoffman,ra; robin | 1966 |
| JWMAA | 5---2 | 182 | 190 | odvi | study, edwards plat, texas | sanders,e | 1941 |
| JWMAA | 5---3 | 333 | 336 | odvi | trends, kill of wisco buck | schunke,wh; buss, | 1941 |
| JWMAA | 20--3 | 286 | 292 | odvi | reg diff, size prod, w vir | gill,j | 1956 |
| JWMAA | 22--3 | 319 | 321 | odvi | determ age, young fawn whi | haugen,ao; speake | 1958 |
| JWMAA | 24--4 | 364 | 371 | odvi | shelter require, penned wt | robinson,wl | 1960 |
| JWMAA | 29--4 | 699 | 705 | odvi | antlers in female white-ta | donaldson,jc; dou | 1965 |
| JWMAA | 34--2 | 383 | 388 | odvi* | morphol develop, aging, fe | short,c | 1970 |
| JWMAA | 34--4 | 887 | 903 | odvi | repro, grow, resid, dieldr | murphy,da; korsch | 1970 |
| JWMAA | 37--4 | 553 | 555 | odvi | weight tape for w-td, virg | smart,cw; giles,/ | 1973 |
| JWMAA | 39--1 | 48 | 58 | odvi | morphol charact, crab orch | roseberry,jl; kli | 1975 |
| NAWTA | 28--- | 431 | 443 | odvi* | nutrition, fetal, fawn gro | verme,lj | 1963 |
| PCGFA | 19--- | 118 | 128 | odvi/ | meas, estima antler volume | rogers,ke; baker, | 1965 |
| TNWSD | 28--- | 91 | 108 | odvi | phys variables, condit, bg | dauphine,tc,jr | 1971 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| CJZOA | 48--1 | 123 | 132 | odhe* | development, fetal period | ommundsen,p; cowa | 1970 |
| JOMAA | 8---4 | 289 | 291 | odhe | horned does | dixon,j | 1927 |
| JOMAA | 30--1 | 76 | 77 | odhe | external measurements of m | halloran,af; kenn | 1949 |
| JOMAA | 45--1 | 48 | 53 | odhe | comp 3 morph attrib, n mex | anderson,ae; fra/ | 1964 |
| JWMAA | 15--2 | 129 | 157 | odhe* | mule deer, nebras nat fore | mohler,ll; wampo/ | 1951 |
| JWMAA | 23--3 | 295 | 304 | odhe | embryonic, fetal developme | hudson,pj; browma | 1959 |
| JWMAA | 34--2 | 383 | 388 | odhe* | morphol develop, aging, fe | short,c | 1970 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| ATRLA | 14--- | 141 | 151 | ceel | growth, developmen, calves | dzieciolowski,r | 1969 |
| ATRLA | 15-17 | 253 | 268 | ceel/ | relation age, size, poland | dzieciolowski,r | 1970 |
| CJZOA | 47--6 | 1418 | 1419 | ceel | sexual dimorphism, fetuses | retfalvi,l | 1968 |
| JOMAA | 36--1 | 145 | 145 | ceel | fetus in yearling cow elk | saunders,jk, jr | 1955 |
| JOMAA | 47--2 | 332 | 334 | ceel | fetus resorption in elk | haugen,ao | 1966 |
| JWMAA | 9---4 | 295 | 319 | ceel | roosev elk, olymp pen, was | schwartz,je,ii; m | 1945 |
| JWMAA | 15--1 | 57 | 62 | ceel | weights, measurem, rock mt | quimby,dc; johnso | 1951 |
| JWMAA | 15--4 | 396 | 410 | ceel | biology of the elk calf | johnson,de | 1951 |
| JWMAA | 23--1 | 27 | 34 | ceel | breed seas, known-age embr | morrison,ja; tra/ | 1959 |
| JWMAA | 30--1 | 135 | 140 | ceel | meas, weight relat, manito | blood,da; lovass, | 1966 |
| MAMLA | 35--3 | 369 | 383 | ceel | body size, fat, demography | caughley,g | 1971 |
| POASA | 47--- | 406 | 413 | ceel | size, wt, wichita mt, okla | halloran,af | 1966 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| CAFNA | 81--4 | 263 | 269 | alal | weights, measurem, alberta | blood,d; mcgilli/ | 1967 |
| CJZOA | 56--2 | 298 | 306 | alal* | measurements, weight relat | franzmann,aw; len | 1978 |
| JOMAA | 27--1 | 90 | 91 | alal | weights, measurem, minneso | breckinridge,wj | 1946 |
| JOMAA | 50--2 | 302 | 310 | alal* | odvi struct adapt for snow | kelsall,jp | 1969 |
| JOMAA | 51--2 | 403 | 405 | alal* | charact of captive, michig | verme,lg | 1970 |
| JOMAA | 51--4 | 808 | 808 | alal | weights, measurme of moose | doutt,jk | 1970 |
| JWMAA | 23--2 | 231 | 232 | alal | feeding, growth capti calf | dodds,dg | 1959 |
| JWMAA | 26--4 | 360 | 365 | alal | in gravelly, snowcrest mou | peek,jm | 1962 |
| VILTA | 4---1 | 1 | 42 | alal | captive, hand-reared calve | markgren,g | 1966 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| CAFNA | 90--4 | 449 | 463 | rata | annual antl cycle, newf ca | bergerud,at | 1976 |
| CJZOA | 44--3 | 401 | 411 | rata | growth, development bar-gr | mcewan,eh; wood,a | 1966 |
| JWMAA | 28--1 | 54 | 56 | rata | relat mandible leng to sex | bergerud,at | 1964 |
| JWMAA | 32--2 | 350 | 367 | rata | introduct, increase, crash | klein,dr | 1968 |
| NJZOA | 24--4 | 407 | 417 | rata* | morphol, fat stor, org wei | krog,j; wika,m; | 1976 |
| ZOLZA | 44--9 | 1396 | 1404 | rata | [morphol peculiar, taimyr] | michurin,ln | 1965 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JWMAA | 16--3 | 387 | 389 | anam | measurem, hart mt antelope | mason,e | 1952 |
| JWMAA | 35--1 | 76 | 85 | anam/ | meas, wts, carc yield, alb | mitchell,gj | 1971 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 45--4 | 630 | 632 | bibi | new data, bis bis athabasc | bayrock,la; hille | 1964 |
| POASA | 41--- | 212 | 218 | bibi | wts, meas, wichi mts, okla | halloran,af | 1960 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 44--1 | 116 | 118 | ov | growth, behav, captive lam | forrester,dj; hof | 1963 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 46--3 | 524 | 525 | ovca | fetal measurem, milk chara | forrester,dj; sen | 1965 |
| JWMAA | 22--4 | 444 | 445 | ovca | weight, measurem, deser bh | aldous,mc; craig/ | 1958 |
| JWMAA | 29--2 | 387 | 391 | ovca | growth, develop, desert bh | hansen,cg | 1965 |
| JWMAA | 34--2 | 451 | 455 | ovca | heights, growth, w alberta | blood,da; flook,/ | 1970 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | ovda | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | obmo | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JWMAA | 19--4 | 417 | 429 | oram | two-year study, crazy moun | lentfer,jw | 1955 |
| JWMAA | 39--4 | 705 | 708 | oram | girth, measurem, estim wei | rideout,cb; worth | 1975 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| CJZOA | 57-11 | 2153 | 2159 | many | morph param, locomot, snow | telfer,es; kelsa | 1979 |
| JOMAA | 27--4 | 308 | 327 | many | mammals of northern idaho | rust,hj | 1946 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JWMAA | 36--1 | 64 | 79 | caca | fact aff growth, body size | klein,dr; strandg | 1972 |

CHAPTER 1, WORKSHEET 2.1a

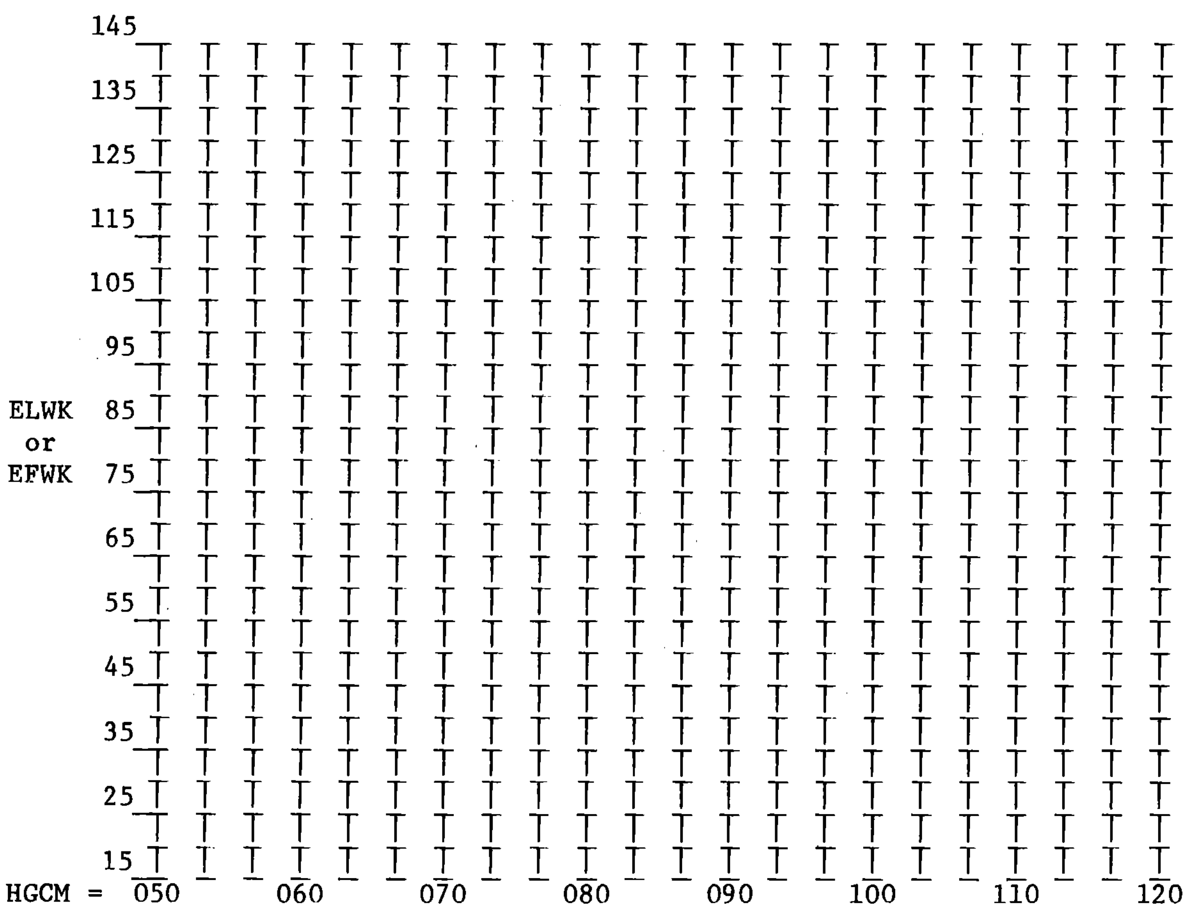
Heart girth: Live weight and field-dressed weight relationships of white-tailed deer (odvi)

Heart girth, the circumference of the chest just behind the forelegs, may be used to estimate live weight and field dressed weights of white-tailed deer based on data in Cowan et al. (1968). Thirteen animals, presumably all males, were measured and the results reported in inches and pounds. These have been converted to centimeters and kilograms and exponential equations for estimated live weight in kg (ELWK) and estimated field-dressed weight in kg (EFWK) derived. The equations are:

$$ELWK = 5.77231\ e^{(HGCM)(0.02664)}$$

$$EFWK = 3.81850\ e^{(HGCM)(0.02898)}$$

Verify the first equation with HGCM = 50.0, ELWK = 21.87 and the second equation with EFWK = 16.26. Then, complete calculations at 10 cm intervals and complete the graph below. How do ELWK and EFWK estimated here compare to earlier estimates of ELWK from EFWK?



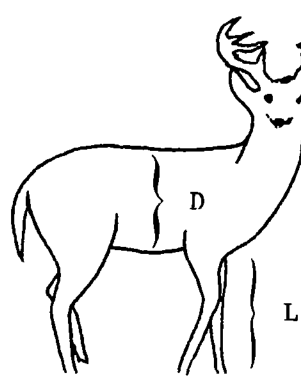
## LITERATURE CITED

Cowan, R. L., E. W. Hartsook, J. B. Whelan, J. L. Watkins, J. S. Lindzey, R. W. Wetzel, and S. A. Liscinsky. 1968. Weigh your deer with a string. Pennsylvania Game News 39(11):17-19.

## UNIT 2.2: VERTICAL PROFILES

The vertical dimensions of animals may be used to describe the distribution of body parts in relation to different mechanical characteristics of the range. For example, the vertical distribution of the legs, trunks, neck, and head may be related to the vertical distributions of wind velocities in different cover types. An animal in the open is exposed to a wide range of velocities from the ground up to the height of its head. The legs of an animal standing in vegetation that reaches up to its trunk are in a different range of wind velocities than the trunk, neck and head of the animal. How important are these considerations? Their importance can be evaluated in PART 5 where calculations of heat loss in different habitats are described.

Height profiles may be estimated from the measurements described in UNIT 2.1. Leg lengths, trunk diameters, and neck and head dimensions may be summed to determine the vertical height profiles of different species.




D + L = Height

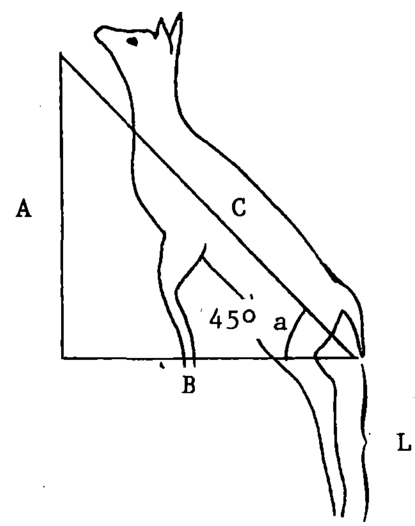
Belly heights are important considerations when snow becomes a barrier to movement, and are estimated from the linear measurements of the legs illustrated in UNIT 2.1. The sum of the upper and lower leg measurements, considered to be belly height, may be expressed in relation to weight be curve-fitting, with belly height as the depedent variable and weight as the independent variable.

Members of the family Cervidae are similar in body proportions, and equations for white-tailed deer may be used as first approximations for mule deer, elk, and moose if measurements on these species are unavailable. They probably also apply fairly well to caribou. Sheep, goats, muskox, and bison have different proportions--their legs seem to be somewhat shorter in relation to body weight--and the deer equation may result in overestimations of belly heights.

Belly heights may be quite easily determined photographically with captive animals. Simply place a clearly-marked measuring stick alongside the trunk of an animal of kown weight and photograph from a distance great enough to eliminate any need for corrections due to parallax. Belly heights may then be read and related to weight. This photographic technique illustrates how simply and inexpensively one can often get data on characteristics that are used in analyzing ecological relationships. Large numbers of animals are not required either; one animal raised from birth to maturity and weighed and photographed regularly provides the data needed for a first approximation. Two animals measured in the same way provide data for a test of differences in the intercepts and slopes for their weight ranges. It is unfortunate that such measurements have not been made on the many species of wild ruminants that have been raised in captivity.

Larger animals can reach higher for forage than smaller ones, so their range has a greater vertical dimension than that of the smaller animal. This is true within species--large deer can reach higher than small deer--and between species--moose can reach higher than deer for forage. This is an important consideration when quantifying the forage supply; the same forage quantities are not available to all animals in a population.

Estimates of the heights reached may be made from the linear measurements of the hind legs, neck, trunk, and head described in UNIT 2.1, with consideration of the angles of these body parts when an animal is in this height-extending posture. The length of the hypotenuse and angle a may




be used to estimate the length of side A with the formula A = (sin a)(C). The equation, if C = 2.0 m and angle a = 45°, is:

$$A = (\sin 45)(2.0) = (0.71)(2.0) = 1.42\text{m} = 142 \text{ cm}$$

Total height reached is determined by adding side A to the length l. The overall formula for determining the height of forage reached (HEFR) is then:

$$\text{HEFR} = (\sin a)(C) + [L]$$

HEFR is the determinant of the upper limit to the availability of forage, which is necessary for determining the total amount of forage on the range. It is much better to use this correct conceptual approach that recognizes differences between the heights reached by animals of different sizes than to use a single arbitrary value for the upper limit of the range. HEFR will be related to the vertical distribution of forage in PART IV.

REFERENCES, UNIT 2.2

VERTICAL PROFILES

BOOKS

| type | publ | city | page | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| aubo | whfr | sfca | 453 | odvi | wildlife ecology | moen,an | 1973 |

SERIALS

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | odvi | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 30--1 | 76 | 77 | odhe | external measurement, mule | halloran,af; kenn | 1949 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| ATRLA | 14--- | 141 | 151 | ceel | growth, devel, red deer ca | dzieciolowski,r | 1969 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| CJZOA | 56--2 | 298 | 306 | alal* | weights, measureme, alaska | franzmann,aw; le/ | 1978 |
| JOMAA | 50--2 | 302 | 310 | alal* | odvi,structura adapt, snow | kelsall,jp | 1969 |
| VILTA | 4---1 | 1 | 42 | alal | captiv, hand-reared calves | markgren,g | 1966 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| NJZOA | 24--4 | 407 | 417 | rata* | morphol, fat stor, or wei, | krog,j; wika,m; / | 1976 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | anam | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| POASA | 41--- | 212 | 218 | bibi | weights, measure, wich mo | halloran,af | 1961 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | ovca | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | ovda | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | obmo | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | oram | | | |

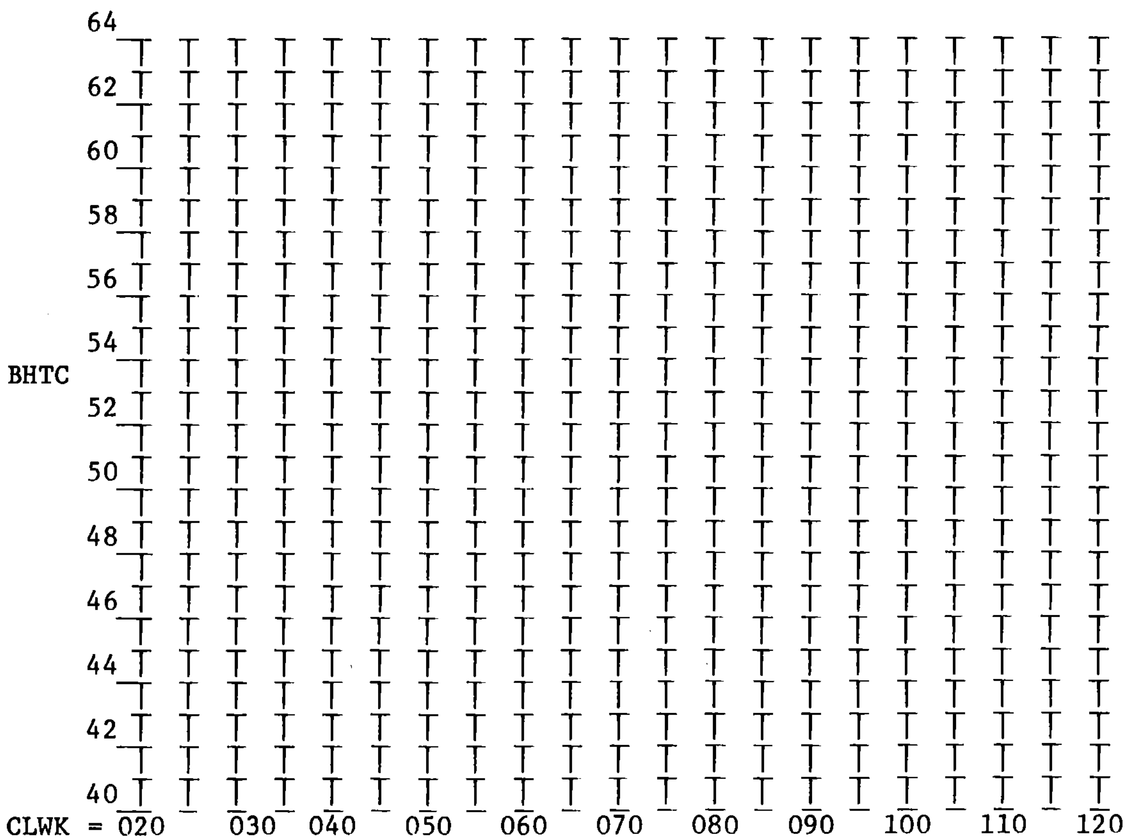
Vertical profiles; belly heights of white-tailed deer (odvi)

Belly heights of white-tailed deer of different weights can be calculated with an equation in Moen (1973; p. 399):

$$BHTC = 12.5\ CLWK^{0.21} + 8.0\ CLWK^{0.25}$$

where BHTC = belly height in cm and CLWK = calculated live weight in kg.

A 60 kg deer has a predicted belly height of 51.8 cm (just over 20 inches). Results for weights from 20 to 120 kg at intervals of 10 kg should be plotted below.




LITERATURE CITED

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

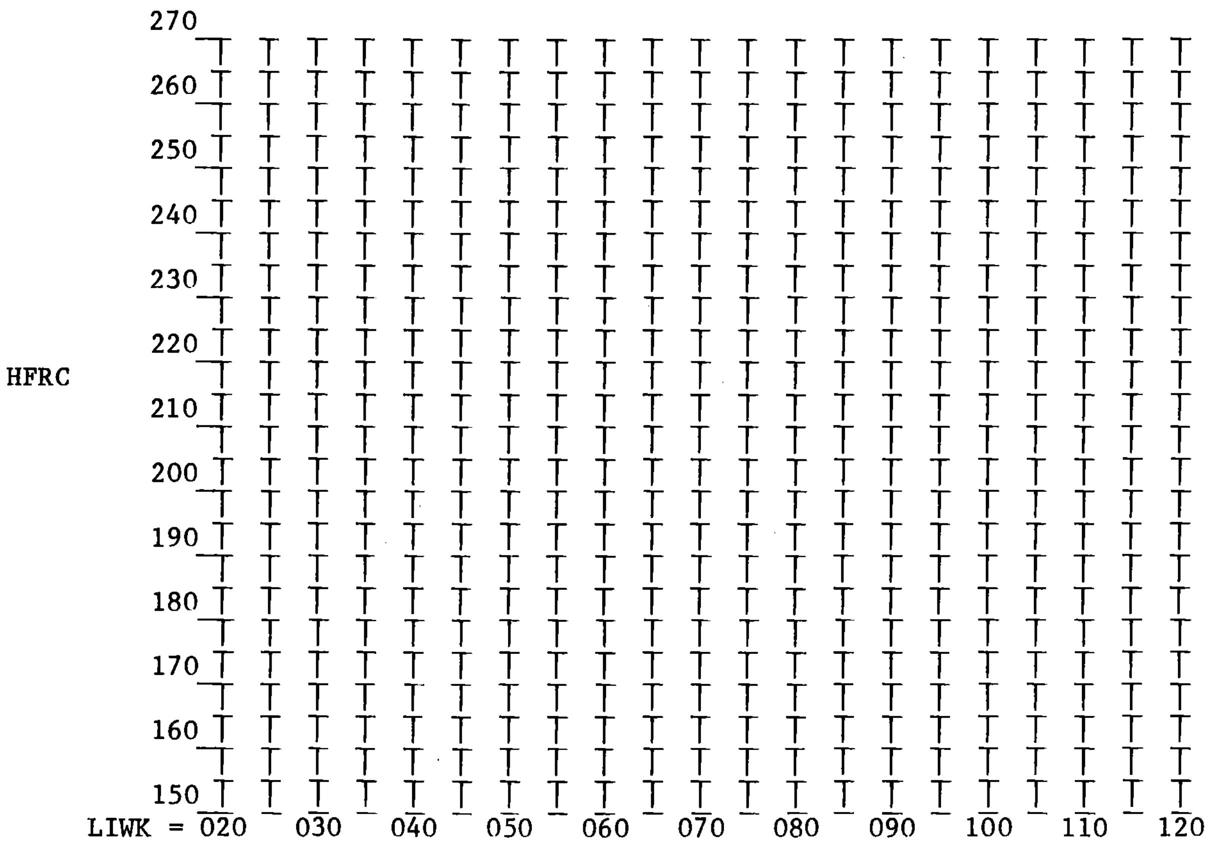
CHAPTER 1, WORKSHEET 2.2b

Vertical profiles; heights of forage reached by white-tailed deer (odvi)

The heights of forage reached by white-tailed deer of different weights have been calculated from the linear measurements discussed earlier in UNIT 2.1. The equation given in Moen (1973; p. 399) is:

$$HFRC = 145 + 0.792\ LIWK$$

where HFRC = height of forage reached in cm and LIWK = live weight in kg. A deer weighing 60 kg can reach 193 cm, or just over 6.25 feet. Determine HFRC for LIWK = 20 and 120, plot the points and then draw a straight line between them to represent HFRC for any weight between 20 and 120 kg.




LITERATURE CITED

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

## UNIT 2.3: SURFACE AREAS

Surface areas have been considered by biologists for some time, and some have gone so far as to derive "surface area laws," suggesting that heat loss and therefore metabolism are proportional to surface area for a species. Surface area is altered considerably by changes in posture, however. Bedded animals expose less surface area to the atmosphere than standing ones as some body parts are in contact with other body parts when the animal curls up, and a portion of the trunk is in contact with the substrate. The magnitude of such changes for individuals is great; a surface area:metabolism "law" cannot be taken seriously. Knowledge of surface areas is necessary for the prediction of heat loss from individuals, however, so considerations of different methods of measurement are important.

Surface areas have not been determined for most species of wild ruminants so estimations must often be made from data on other species. The relationships between surface areas and weights of domestic cattle, for example, may be used to derive first approximations for bison and moose, and equations for white-tailed deer may be used to derive first approximations for mule deer and possibly other smaller wild ruminants. When the accuracy of such estimations becomes a limiting factor in analyses of relationships, then measurements on the species being evaluated should be made.

Surface areas may be estimated in several ways. Skins may be removed, laid out flat and measured directly, or indirectly by tracing their outlines on sheets of polyethelene of known weight per unit area and then weighing the polyethelene facsimile. This technique poses a problem with stretching of the skin when it is laid out. Surface areas may be measured with instruments that totalize area as they are rolled across the animal's surface. The instruments may be accurate, but wild animals do not stand still do so the areas measured are not easily defined. Three-dimensional photography has a lot of potential, but the technique is difficult and expensive to use.

A fairly quick way to estimate the surface area of wild ruminants is by considering them as a collection of cylinders, cones, and curved plates, and measuring the dimensions of these. A cylinder, for example, is a fair representation of the trunk. The head is shaped somewhat like the frustum of a cone, and the ears are curved plates. The upper parts of the legs are frustums of cones, and the lower parts may be considered cylinders. These measurements can be made quickly on dead animals lying in a lateral position. Inexpensive plastic-coated metric tapes are readily available in department and variety stores.

The lengths, widths, and circumferences marked on the silhoutte in UNIT 2.1 are used to calculate surface areas of body parts with equations for cylinders, frustums of cones, and curved surfaces by using the formulas given at the end of this UNIT. The areas of body parts may then be considered as dependent variables and weight as the independent variable and equations for surface areas of body parts in relation to weight determined by curve-fitting. The total surface area is the sum the of the surface areas of the parts. Total surface areas may be considered as the dependent variable and weights as the independent variable when determining a single equation by curve-fitting.

The formulas from Moen (1973:436) for calculating surface areas in square meters from measurements in cm indicated in UNIT 2.1 are:

| Body Parts | Formulas for Surface Areas |
|---|---|
| Face, muzzle area | $AFMM = [(C_1 + C_2)L_1]/2$ |
| Head | $AHEM = [(C_2 + C_3)L_2]/2$ |
| Neck | $ANEM = [(C_3 + C_4)L_3]/2$ |
| Ear | $AEAM = [3 (W_1 L_4)]/4$ |
| Trunk | $ATRM = [(C_5 + C_6)L_5]/2$ |
| Upper front leg | $AUFM = (C_7 + C_8)L_6$ |
| Lower front leg | $ALFM = (C_8 + C_9)L_7$ |
| Upper hind leg | $AUHM = (C_{10} + C_{11})L_8$ |
| Lower hind leg | $ALHM = (C_{11} + C_{12})L_9$ |

## LITERATURE CITED

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Company, San Francisco. 458 pp.

REFERENCES, UNIT 2.3

SURFACE AREAS

BOOKS

| type | publ | city | page | anim | kewo | auth | year |
| --- | --- | --- | --- | --- | --- | --- | --- |
| aubo | whfr | sfca | 453 | odvi | wildlife ecology | moen,an | 1973 |

SERIALS

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
| --- | --- | --- | --- | --- | --- | --- | --- |
| JANSA | 24--3 | 921 | 921 | odvi/surf area, meas, tissue wt | | whelan,jb; harts/ | 1965 |
| NAWTA | 33--- | 224 | 236 | odvi energy balance in winter | | moen,an | 1968 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
| --- | --- | --- | --- | --- | --- | --- | --- |
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| | | | | rata | | | |

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| | | | | anam | | | |

CODEN vo-nu bepa enpa anim kewo ______________________ auth ______________ year

bibi

CODEN vo-nu bepa enpa anim kewo ______________________ auth ______________ year

ovca

CODEN vo-nu bepa enpa anim kewo ______________________ auth ______________ year

ovda

CODEN vo-nu bepa enpa anim kewo ______________________ auth ______________ year

obmo

CODEN vo-nu bepa enpa anim kewo ______________________ auth ______________ year

oram

CHAPTER 1, WORKSHEET 2.3a

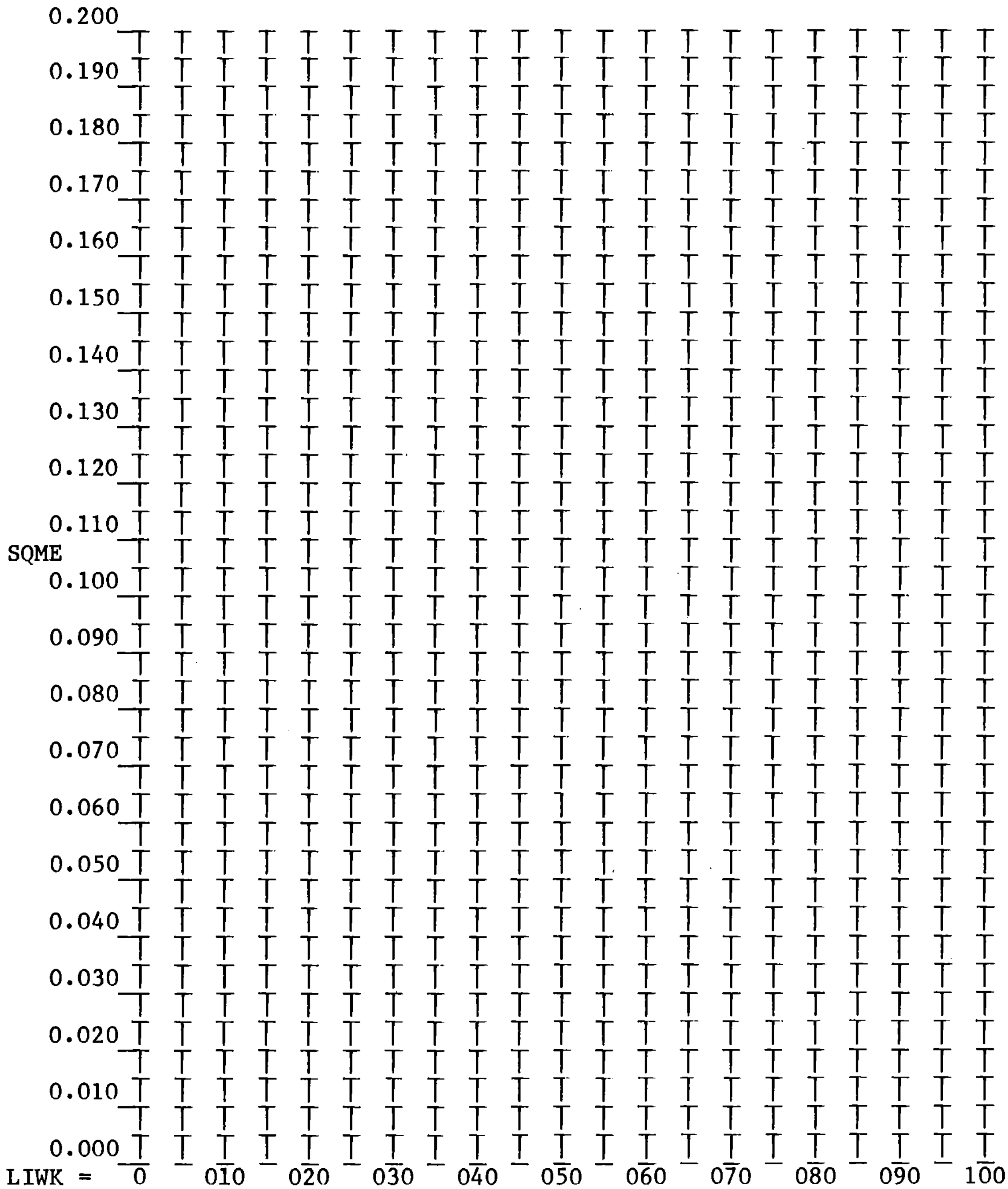
Surface areas of body parts of white-tailed deer (odvi)

Twenty-two linear measurements of several hundred white-tailed deer have been made at the Wildlife Ecology Laboratory and the equations given in UNIT 2.3 used to calculate surface areas of nine body parts. The calculated surface areas of each of these body parts have then been related to live weight in kg (LIWK) by curve-fitting (Moen 1973:437). The equations for estimating surface areas of body parts of white-tailed deer are listed below; areas are calculated in square meters (SQME).

| Body Part | Equation |
|---|---|
| face, muzzle area | $AFMM = 0.0023 (LIWK^{0.68})$ |
| head, forehead + crown | $AHEM = 0.0083 (LIWK^{0.57})$ |
| neck | $ANEM = 0.0078 (LIWK^{0.73})$ |
| ears | $AEAM = 0.0092 (LIWK^{0.40})$ |
| trunk* | $ATRM = 0.0500 (LIWK^{0.75})$ |
| upper front legs | $AUFM = 0.0130 (LIWK^{0.47})$ |
| lower front legs | $ALFM = 0.0160 (LIWK^{0.41})$ |
| upper hind legs | $AUHM = 0.0220 (LIWK^{0.51})$ |
| lower hind legs | $ALHM = 0.0240 (LIWK^{0.44})$ |

*Plot the area of the trunk in WORKSHEET 2.3b.

Plot and label the areas of each of the body parts on the next page.




## LITERATURE CITED

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

CHAPTER 1, WORKSHEET 2.3b

Total surface area of white-tailed deer (odvi)

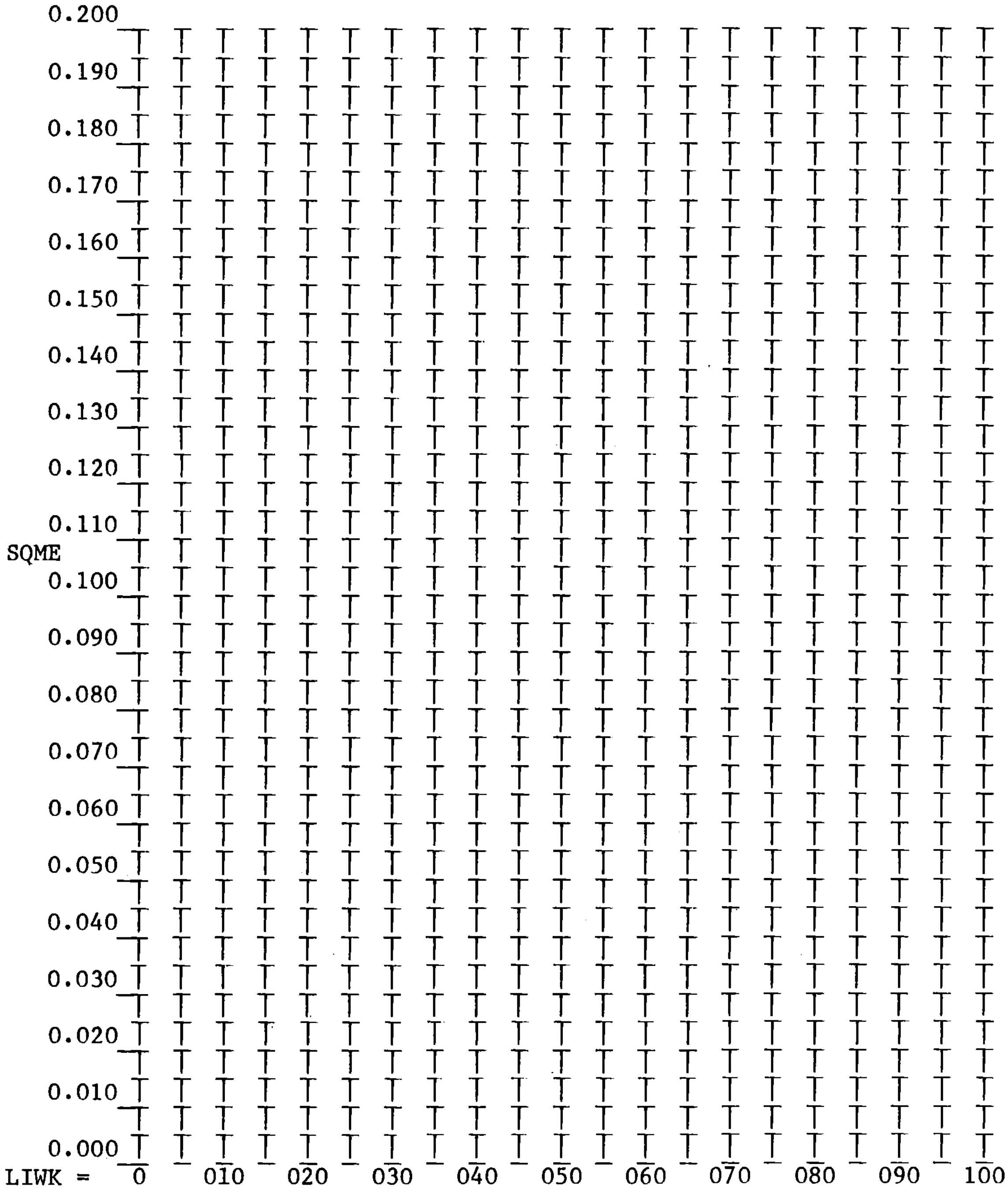
Surface areas of the nine body parts discussed in WORKSHEET 2.3a have been summed and an equation derived for calculating total surface area in meters (TSAM) in relation to live weight in kg (LIWK).

No significant differences were found between total surface area: weight relationships for male and female deer, so one equation (Moen 1973:437) is used for both sexes.

$$TSAM = 0.142 (LIWK^{0.635})$$

Verify your use of the equation (with LIWK = 50, TSAM = 1.70 SQME, complete the table, and plot TSAM at intervals of 10 for LIWK on the next page. Also plot the area of the trunk using the equation given in WORKSHEET 2.3a

| LIWK | TSAM |
|---|---|
| 10 | ____ |
| 20 | ____ |
| 30 | ____ |
| 40 | ____ |
| 50 | 1.70 |
| 60 | ____ |
| 70 | ____ |
| 80 | ____ |
| 90 | ____ |
| 100 | ____ |




## LITERATURE CITED

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

## CHAPTER 1, WORKSHEET 2.3c

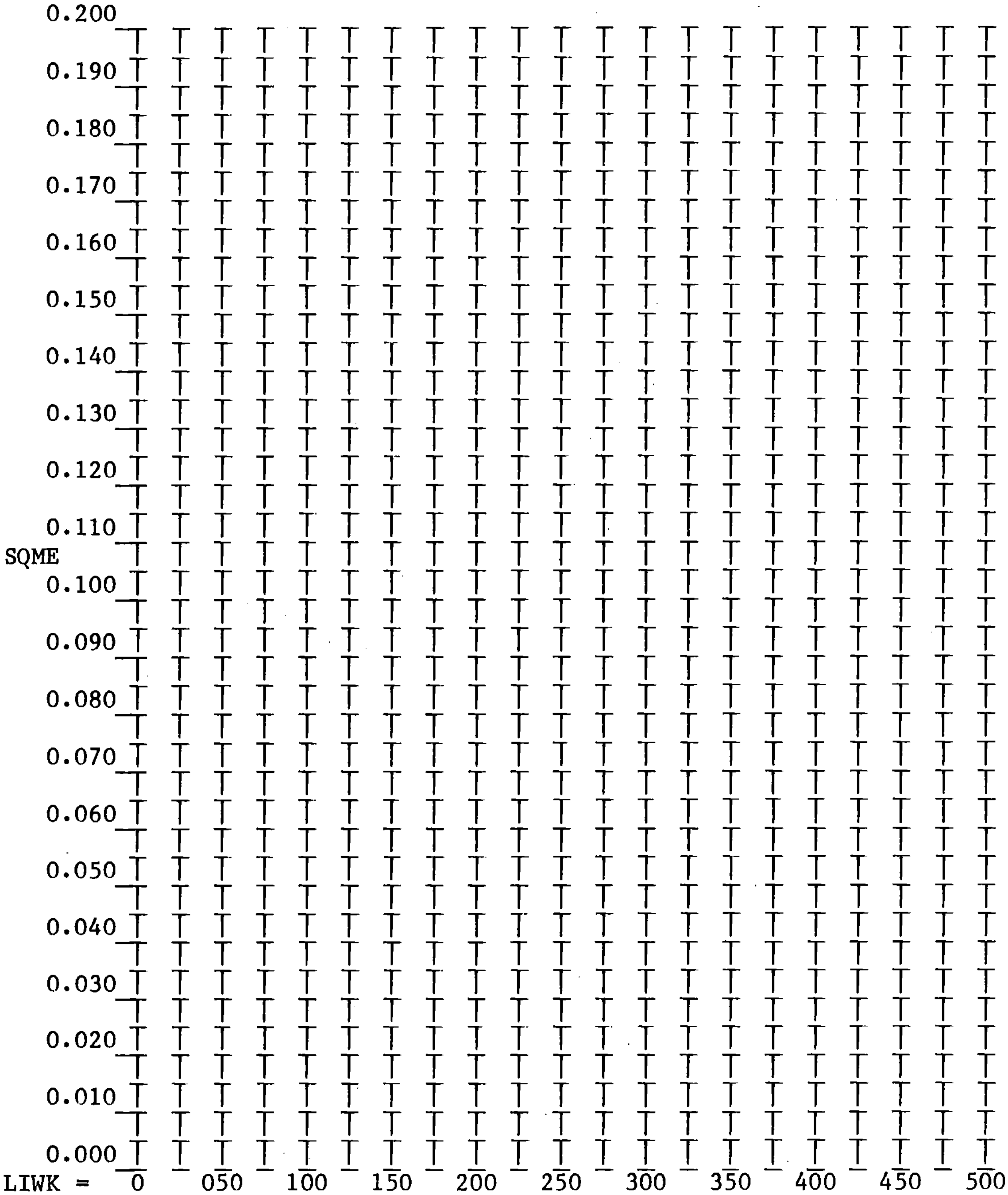
### Total surface area of large ruminants

Surface area data are not available for large wild ruminants. The equation for white-tailed deer can be extropolated, or an equation in Brody (1964) derived from holstein and jersey cattle may be used as a first approximation for bison, muskox, moose, and other wild ruminants larger than the white-tailed deer.

The equation, modified from Brody (1964:359) is:

$$TSAM = 0.15\ LIWK^{0.56}$$

Plot the line resulting from the use of this equation, and then calculate TSAM (total surface area in meters) using the deer equation in WORKSHEET 2.3b, extropolating to these weights. The larger surface area calculated with the deer equation may be a reflection of the more angular body of such a small wild ruminant as a white-tailed deer compared to a large one such as a bison. The cattle equation is likely the better representation.




LITERATURE CITED

Brody, S. 1964. Bioenergetics and growth. Hafner Publishing Company, Inc., New York 1023 pp.

## UNIT 2.4: BED AREAS

Animals spend parts of each day bedded on different kinds of substrates which may vary from dry leaves to wet snow. Animals assume bedded postures to conserve or dissipate energy;, changes in postures result in changes in surface areas exposed to both the atmosphere and the bed surface. The illustrations below show how different bed areas can be when an animal assumes different postures.

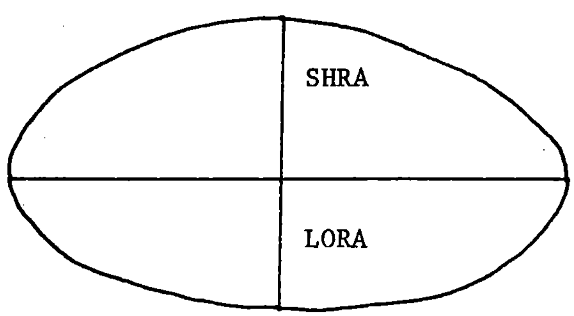
Maximum bed area

Minimum bed area

The bed area, which is part of the total surface area of an animal, is participating in conductive heat transfer to the substrate. The amount of heat dissipated in this way can be quantified when the area of the bed and the thermal characteristics of the animal: substrate interface are known. In the winter, beds are often on snow; analyses of heat loss to the snow are discussed in PART 5.

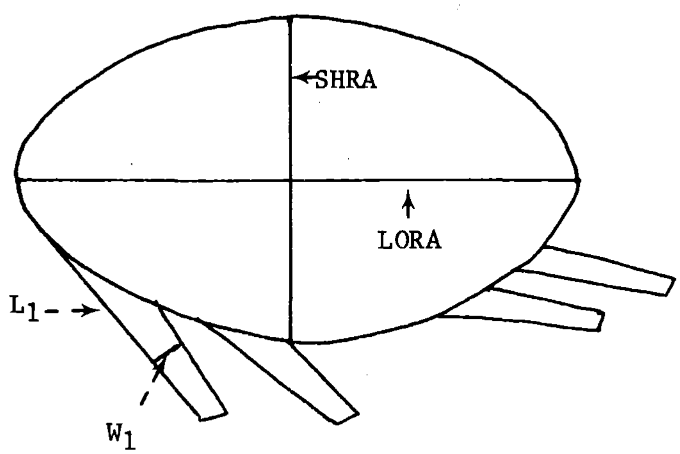
Areas of beds may be determined by direct measurement. The beds are usually somewhat elliptical, and first approximations can be made by measuring the longest radius (LORA) and shortest radius (SHRA), and calculating the bed area (BEAR) with the formula:

$$BEAR = [(LORA + SHRA)/2]^2$$



Beds with irregular shapes, such as those of animals in sprawling postures, are more difficult to measure. Extensions of the legs may be measured for their lengths and widths and the areas added to the bed area occupied by the trunk. Then, the formula for calculating BEAR is:

$$BEAR = [(LORA + SHRA)/2]^2 + L_1W_1 + \ldots L_4W_4$$




overhead view

Snow depths also add complexity to determinations of bed areas. Variations in the curvature and other bed irregularities make it difficult to measure bed dimensions precisely, but the dimensions of curved surfaces illustrated below can be measured with flexible tapes.

cross-section of a bed in the snow

Bed areas can be expressed as fractions of total surface areas, or in relation to weight. The surface area calculated may then be used in evaluating heat transfer by conduction as part of the total thermal exchange between animal species and environment. WORKSHEETS provide the format for estimating bed areas in different ways.

REFERENCES, UNIT 2.4

BED AREAS

SERIALS

CODEN vo-nu bepa enpa anim kewo auth year

odvi

CODEN vo-nu bepa enpa anim kewo auth year

odhe

CODEN vo-nu bepa enpa anim kewo auth year

ceel

CODEN vo-nu bepa enpa anim kewo auth year

alal

CODEN vo-nu bepa enpa anim kewo auth year

rata

CODEN vo-nu bepa enpa anim kewo auth year

anam

CODEN vo-nu bepa enpa anim kewo auth year

bibi

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| JOMAA | 20--4 | 440 | 455 | ovca | the bighorn sheep of texas | davis,wb; taylor, | 1939 |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | ovda | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | obmo | | | |

| CODEN | vo-nu | bepa | enpa | anim | kewo | auth | year |
|---|---|---|---|---|---|---|---|
| | | | | oram | | | |

## Bed areas of white-tailed deer (odvi)

Published data on bed areas are not available for any species of wild ruminants, yet all of them exhibit thermoregulatory behavior by altering bedded posture. First approximations must be made for bed areas when evaluating relative proportions of heat losses from animals in different bedded postures.

The white-tailed deer ratios of bed area to total surface area may be suitable for other Cervids, and may be less suitable for other wild ruminants. Bison, for example, have quite a different geometry than white-tailed deer, and the ratio of bed area to total surface area may be different. In the absence of data, however, one is forced to use what is available.

Bed areas of white-tailed deer have been estimated at the Wildlife Ecology Laboratory to be about 6.0% of the total surface area when the animal is in an open bedded posture and 4.5% when in a closed bedded posture. Using the calculations of TSAM in WORKSHEET 2.3b, determine the areas of beds of deer in open and closed bedded postures and plot below. (BASM = bed area in square meters.)