CHAPTER 1. PHYSICAL CHARACTERISTICS

Wild ruminants have many physical characteristics that are important adaptations for survival and production in their natural environments. Weights vary as fat reserves are accumulated and used in relation to seasonal variations in the availability of food resources. Pelage characteristics change as thermal conditions change from season to season. Individuals alter their exposed surface areas and postures as parts of social and thermoregulatory behavioral regimes. The volume of the gastrointestinal tract and the rate of passage of forage through the tract are related to the amount of nutrients required by the animal. These are just a few examples of physical characteristics that affect the relationships between organism and environment.

Physical characteristics are best expressed with internationally defined units of measurements. MASS, WEIGHT, and GROWTH (TOPIC 1) are expressed in kg from the fetus to the mature adult, and are used later in calculations of metabolism, reproductive rates, and other characteristics. GEOMETRY (TOPIC 2) may be described by using several linear measurements, expressed in cm, to calculate such things as vertical profiles and surface areas in different postures. SYSTEMS CHARACTERISTICS (TOPIC 3) are important when considering such things as upper limits to forage volumes that can be ingested, volume of blood in the cardiovascular system, potential mineral reserves in the bones, and many more. These are important when evaluating nutrient balances of animals.

The TOPICS and WORKSHEETS that follow provide information on physical characteristics and also on curve-fitting and statistical techniques. It is desirable to go through each of them in the sequence presented so the proper skills are available when new problems and WORKSHEETS are presented.

TOPIC 1. MASS, WEIGHT, AND GROWTH

The body of an animal is a mass subject to gravitational forces, and the measured force has traditionally been expressed as weight. The live weight of an animal is composed of the animal's metabolically active tissues (muscle, for example), tissues that have ceased metabolic activity (hair, for example), and ingested material that has not yet been digested and absorbed. The live weight of a pregnant female includes not only the weight of the female herself, but also the weight of fetuses and associated reproductive tissues. Weights increase from birth to physical maturity, with a more rapid increase early in life and a less rapid increase as maturity is approached.

Weights of wild ruminants vary seasonally, with highest weights usually observed in the fall after an abundance of forage during the growing season, and fruits and seeds, or mast, have been available. Lowest weights are observed when the balance beween resources required and resources available is most negative. This often occurs in late winter and early spring when dormant forage resources are depleted and new growth is not yet available.

Pregnant females metabolically support their own body tissue, and the increasing mass of fetal tissue plus associated membranes and other tissues in the uterus. Pregnant females may go into negative balances in order to provide nutrients for fetal growth, mobilizing their own body reserves to supplement ingested nutrients. Lowest weights of reproducing females may occur after parturition When the fetus has been expelled and the high requirements for the costly process of milk production must be met. The lactating female may mobilize her own body tissue in order to produce milk for suckling offspring.

It is desirable to express the weight of an individual as a continuous mathematical function over time. Sine functions can be used to represent weight changes through the annual cycle, providing the biological continuity desired when weights are used in the calculation of other biological functions, such as metabolism. Weight is used in many other calculations in this book also; the mathematical expressions of weight should be fully understood before proceeding to later units.

Most weight data for wild ruminants come from one of two sources: one, hunter-killed animals that are weighed at checking stations, or two, captive animals that are weighed for experimental purposes. Live weights may be estimated from field-dressed weights of hunter-killed animals with conversions equations, although there are several sources of error.

Weights of captive animals may be determined more accurately than those of hunter-killed animals, but there are questions about how well the weights of captive animals coincide with those of wild ones since they are on different diets and are living under different conditions. While there are problems associated with the measurement of weights of free-ranging and captive ruminants, weights are very important when evaluating the ecological relationships of a population. Weight data from both hunter-killed and experimental animals may be used judiciously to recognize patterns, however, and first approximations of weight structures of populations determined.

The first time-period used in deriving weight equations for a species is from conception to birth (UNIT 1.1). The second is from birth to weaning (UNIT 1.2), and then, post-weaning weights are used to derive equations for the expression of seasonal variations in weights over successive annual cycles as the animal grows older (UNIT 1.3). One important consideration when expressing weight as a mathematical function over time is that equations used for different time periods in the animal's life must merge. Fetal weights, for examqle, must end at birth weight, neonate growth must begin at the birth weight and continue to a weaning weight, and seasonal variations in growth after weaning must begin at the weaning weight used. If this consideration is not made, then there will be discontinuities between the growth curves from conception through seasonal variations of the adults, and such discontinuities are not biologically reasonable.

The UNITS that follow include descriptions of curve-fitting procedures for deriving equations from conception through physical maturity, with no discontinuities between different stages of growth.

UNIT 1.1: FETAL WEIGHTS AND GROWTH

The general pattern of growth of the ruminant fetus shows a slow of increase in the first 1/4 to 1/3 of the gestation period, a faster rate of increase in the middle of the gestation period, and a rapid rate of increase in the last 1/3 to 1/4 of the gestation period. The basic problem to be solved here is that of representing fetal weights of different species with mathematical expressions. Three kinds of formulas may be used to represent increasing rates over time. They are:

exponential: $FEWK = a\ e^{b(DIGE)}$
logarithmic: $FEWK = a + b\ \ln (DIGE)$
power: $FEWK = a\ (DIGE)$

where FEWK = fetal weight in kg and DIGE = days into gestation. FEWK are entered as the dependent variable, and DIGE as the independent variable. The best fit of the three curves is then used to express FEWK as a function of DIGE.

The lengths of the gestation periods of the wild ruminants are different; fetuses of different species have different amounts of time to develop from fertilized eggs to full-term fetuses. The aproximate lengths of the gestation periods (LEGP) from the table in TOPIC 3, UNIT 3.4, are:

	LEGP
white-tailed deer; odvi	200
mule deer; odhe	200
elk; ceel	260
moose; alal	245
caribou; rata	220
pronghorn; anam	240
bison; bibi	290
bighorn sheep; ovca	150
Dall sheep; ovda	150
muskox; obmo	270
mountain goat; oram	180

Lengths of the gestation periods are used in comparing growth between species. Mountain goat fetuses, for example, develop from conception to parturition in 0.75 of the time (150/200 = 0.75) required by white-tailed deer. Since both of these species, and all wild ruminants, give birth to well-developed young, fetal growth must be quite proportional throughout the gestation periods; development is relative throughout the length of the gestation period.

The WORKSHEETS illustrate how data on fetal growth can be expressed with equations, how first approximations of equations for fetal growth can be made when only birth weights are available, and how equations can be derived for estimating the fetal growth of all species of wild ruminants.

REFERENCES, UNIT 1.1

FETAL WEIGHTS AND GROWTH

SERIALS

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
AMNAA	43--3	650	666	odvi*	fetal develop, white-taile	armstrong,ra	1950
JOMAA	40--1	108	113	odvi	breeding records, captive	haugen,ao	1959
JOMAA	47--2	266	280	odvi	endoc glan, seas, sex, age	hoffman,ra; robin	1966
JWMAA	14--3	290	295	odvi	breeding records of white-	haugen,ao; davenp	1950
JWMAA	16--3	400	400	odvi	late breeding record for w	erickson,ab	1952
JWMAA	22--3	319	321	odvi/	determin age of young fawn	haugen,ao; speake	1958
JWMAA	34--2	383	388	odvi*	morphol develop, aging, fe	short,c	1970
JWMAA	39--4	684	691	odvi*	uterine compositio, growth	robbins,ct; moen,	1975
NAWTA	28---	431	443	odvi*	nutrit, growth, fetal, faw	verme,lj	1963

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	48--1	123	132	odhe*	development, fetal period	ommundsen,p; cowa	1970
CJZOA	48--2	275	282	odhe/	feed intake, heat producti	nordan,hc; cowan/	1970
JOMAA	36--1	145	145	odhe	unusual twin fawns in mule	illige,dj; erling	1955
JOMAA	52--3	628	630	odhe	contrib organ tot bod mass	hakonson,te; whi/	1971
JWMAA	23--3	295	304	odhe*	embryo, fetal developmentm	hudson,p; browman	1959
JWMAA	28--4	773	784	odhe	evaluat, eye lens tec, agi	longhurst,wm	1964
JWMAA	34--2	383	388	odhe	morphol developp, aging,fe	short,c	1970

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	47--6	1418	1419	ceel	sexual dimorphism, fetuses	retfalvi,l	1969
JWMAA	23--1	27	34	ceel*	breed seas, known-age embr	morrison,ja; tra/	1959
JZOOA	164-2	250	254	ceel	weight, newb calves, scotl	mitchell,b	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
				alal			

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
LBASA	21--6	817	824	rata	reindeer in biomed researc	dieterich,ra; lui	1971

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	46--3	524	525	ovca	fetal measure, milk charac	forrester,dj; sen	1965
JOMAA	58--1	106	106	ovca	brth wt, gest, capt rcky m	blunt,m: dawson,/	1977

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			

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
AMNTA	114-1	101	116	ungu/	matern repro effort, fetal	robbins,ct; robbi	1979
JPHYA	114--	306	317	mamm	relat fetal wt, concep age	huggett,astg; wid	1951

CHAPTER 1, WORKSHEET 1.1a

Fetal growth of white-tailed deer (odvi)

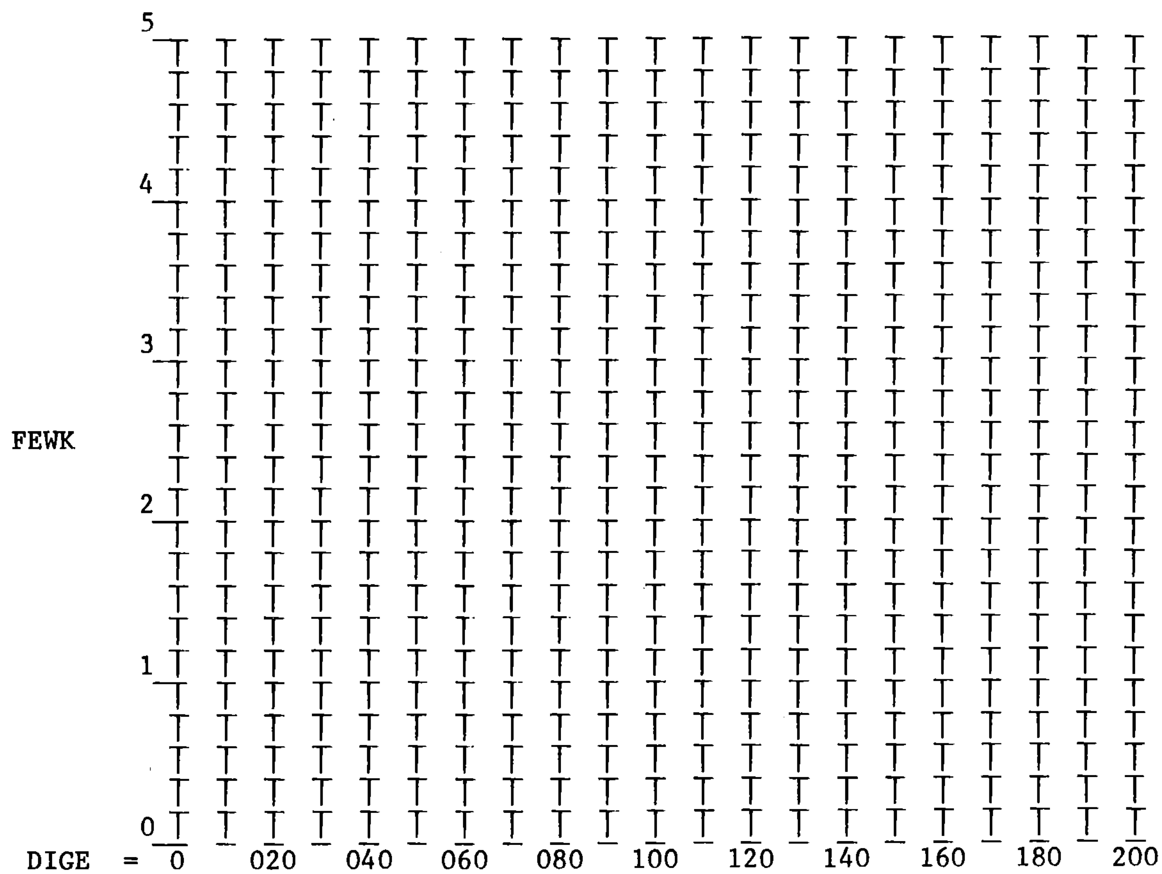
Mean weights of twin fetuses of white-tailed deer in Robbins and Moen (1975) are:

DIGE = 50;	FEWK = 0.019
100	0.289
145	1.240
190	3.580

These data fit an exponential curve with an R^2 of 0.96, a logarithmic curve with an R^2 of 0.69, and a power curve with an R^2 of 1.00, a perfect fit. The equation for a power curve is:

$$FEWK = 4.094 \times 10^{-9} (DIGE)^{3.924}$$

Verify the equation with DIGE = 200 and FEWK = 4.38, and then calculate enough data points to plot the curve from DIGE = 1 to 200.



LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Uterine composition and growth in pregnant white-tailed deer. J. Wildl. Manage. 39(4):684-691.

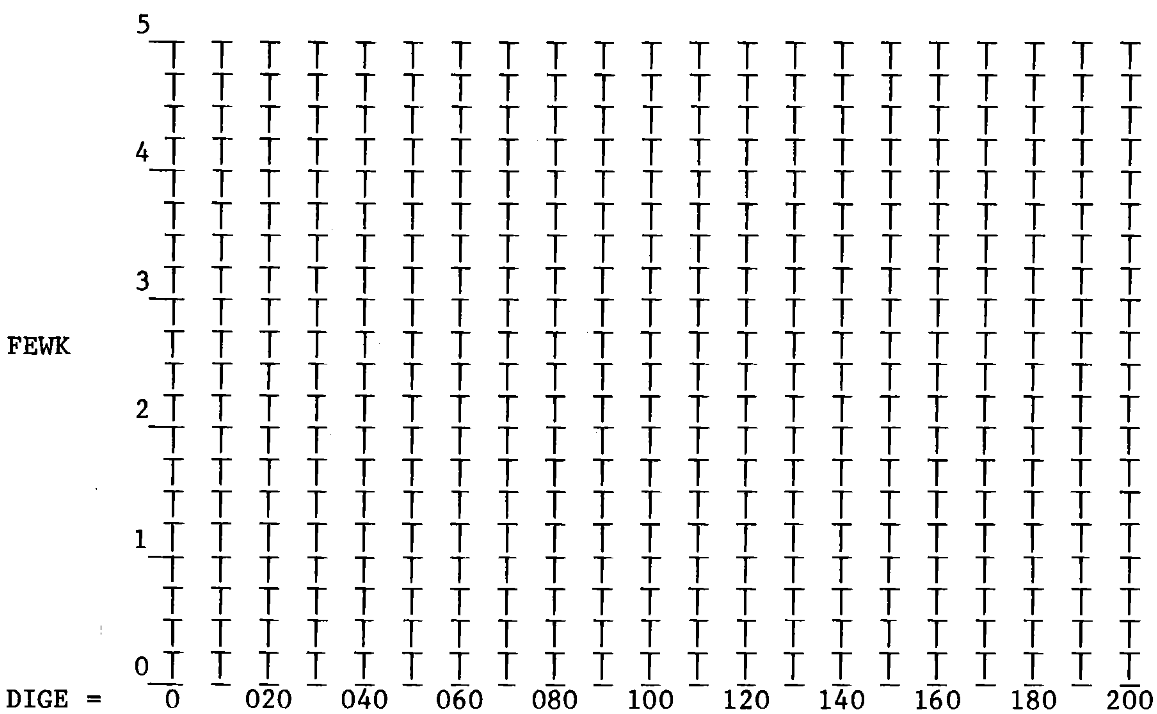
Fetal weights and growth (odvi)

This worksheet illustrates how to calculate fetal weights of white-tailed deer for any weight at birth.

Fetal growth of white-tailed deer may be represented with a power curve. The equation derived from data of Robbins and Moen (1975) resulted in a weight at AGDA = 1 of 4.094×10^{-9}, the value of the coefficient a in the equation for whitetail fawns in the previous WORKSHEET, and at birth (DIGE = 200) of 4.38 kg. Some fawns are lighter and some heavier at birth, however. An array of equations may be easily derived by fitting just two pairs of data--FEWK @ DIGE = 1, and FEWK @ DIGE = 200--to a power curve. Use FEWK = 4.094×10^{-9} (just a fraction of a gram) at DIGE = 1. This is reasonable biologically, and necessary mathematically when using a power curve as the y value in the x, y pair must be different from zero and positive. This data point is then connected to birth weight in kg (BIWK) by curve-fitting procedures. The equations for different fetal weights at birth (FWAB) are:

If BIWK = 2.0, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.776}$; @ DIGE = 100: 0.146
If BIWK = 2.5, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.818}$; @ DIGE = 100: 0.177
If BIWK = 3.0, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.853}$; @ DIGE = 100: 0.208
If BIWK = 3.5, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.882}$; @ DIGE = 100: 0.237
If BIWK = 4.0, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.907}$; @ DIGE = 100: 0.267
If BIWK = 4.5, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.929}$; @ DIGE = 100: 0.295
If BIWK = 5.0, $FEWK = 4.094 \times 10^{-9}\ DIGE^{3.949}$; @ DIGE = 100: 0.324

Plot FEWK for several DIGE for each FWAB on the graph below:



Fetal weights and growth of all wild ruminant species

The previous WORKSHEET (1.1b) illustrated how fetal weights of white-tailed deer could be calculated for any weight at birth. This WORKSHEET illustrates how fetal weights of any wild ruminant can be calculated for any birth weight. The only assumption is that the fetal weight growth pattern of these different species is similar to that of the white-tailed deer. This is a reasonable assumption; all ruminants exhibit slow fetal growth early in the gestation period and rapid growth late in the gestation period.

The parameters needed to derive an equation for calculating fetal weights of any species at any time during the gestation period are lengths of the gestation period (LEGP), days into gestation (DIGE), and birth weights in kg (BIWK). The values used in curve-fitting b (from WORKSHEET 1.1b) in relation to BIWK ARE:

BIWK	b
2.0	3.776
2.5	3.818
3.0	3.853
3.5	3.882
4.0	3.907
4.5	3.929
5.0	3.949

A logarithm curve fits these data perfectly ($R^2 = 1.00$); a = 3.6452 and b = 0.1888. The equation is:

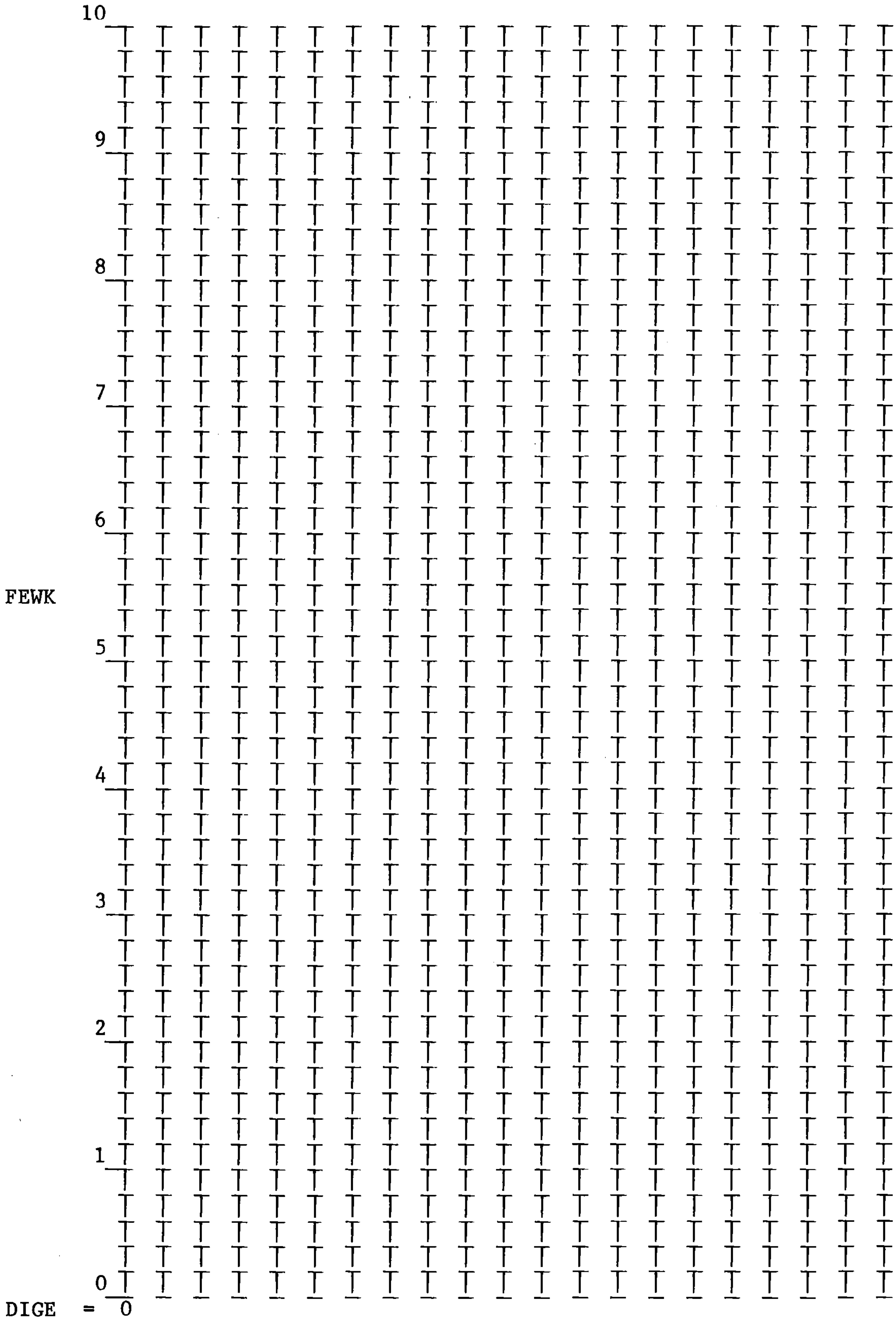
$$b = 3.6452 + \ln 0.1888 \text{ BIWK}$$

Since this is a perfect fit, extrapolation to larger birth weights results in b values that are exactly proportional to those from 2.0 to 5.0 for white-tailed deer. Thus b can be predicted for the birth weight of any wild ruminant as long as its fetal growth is proportional to the fetal growth of white-tailed deer, and the above equation substituted for b in the equation for a power curve given in WORKSHEET 1.1b. The combined overall equation is:

$$\text{FEWK} = 4.094 \times 10^{-9}[(\text{DIGE}/\text{LEGP})200]^{(3.6452 + 0.1888 \ln \text{BIWK})}$$

The phrase within the brackets, [(DIGE/LEGP)200], makes the lengths of the gestation periods porportional. For example, if DIGE = 234 and LEGP = 260, the gestation period is 90% complete, which is equivalent to 180 days of gestation (0.90 x 200 = 180) for a deer.

Since BIWK must be stipulated, the calculated FEWK will always be within the appropriate range for any species, and the fetal growth pattern will show the increasing rates characteristic of the last 1/3 to 1/4 of the gestation period which was expressed very well for white-tailed deer with a power curve. Choose a species, label the x-axis (DIGE = 0 - ________ and graph the results on the next page.


10
9
8
7
6
FEWK
5
4
3
2
1
0
DIGE = 0

UNIT 1.2: SUCKLING WEIGHTS AND GROWTH

The weight curve for the suckling animal begins with birth weight (BIWK) and continues through the suckling period to the weaning weight. The growth of suckling ruminants may be expressed with linear, exponential, logarithmic, or power functions. Growth from birth through weaning has been essentially linear for whitetail fawns at the Wildlife Ecology Laboratory; deviations from a constant rate of gain have been small and linear regression equations have been good overall representation of the growth curve. Linear regression is expressed with the formula:

$$CLWK = a + b\ AGDA$$

where CLWK = calculated live weight in kg, a is the intercept, b the slope of the line, and AGDA = age in days.

There are no data describing the growth of the suckling young of some of the wild ruminants. Linear regression equations may be used as first approximations, and can be easily determined by considering birth weight to be the intercept at AGDA = 0, and the slope calculated by subtracting birth weight from weaning weight and dividing that by AGDA at weaning. The quotient is the slope of the line, b. This is explained further and illustrated in the WORKSHEETS.

Whatever mathematical function is used, it is important that suckling weights begin at the birth weights calculated using the equations for fetal growth in the previous UNIT. Further, weaning weights must merge with weights calculated using equations for older animals in the next UNIT. This constraint must be respected or there will be discontinuities in the overall growth curves from birth through physical maturity.

REFERENCES, UNIT 1.2

SUCKLING WEIGHTS AND GROWTH

SERIAL PUBLICATIONS

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	40--1	108	113	odvi	breeding records, captive	haugen,ao	1959
JWMAA	14--3	290	295	odvi	breeding records of white-	haugen,ao; davenp	1950
JWMAA	16--3	400	400	odvi	late breeding record for w	erickson, ab	1952
JWMAA	20--3	221	232	odvi	nutri req, growt, antl dev	french,ce; mcewe/	1956
JWMAA	24--4	439	441	odvi	rear, breeding fawns, capt	murphy,da	1960
JWMAA	25--1	66	70	odvi	deer milk, subst for fawns	silver,hs	1961
JWMAA	34--4	887	903	odvi	reprod, grow, residu, diel	murphy,da; korscg	1970
JWMAA	39--2	355	360	odvi*milk consumpt, weight gain		robbins,ct; moen	1975
JWMAA	41--3	506	510	odvi	growth, var ener, cons pro	holter,jb; hayes	1977
NAWTA	22---	119	132	odvi	nutrient requirements, w-t	mcewen,lc; frenc/	1957
NAWTA	28---	431	443	odvi*nutrit, growth, fetal fawn		verme,lj	1963

odvi continued on the next page

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
NFGJA	11--1	13	27	odvi	produc, growth, adiron, ny	severinghaus,cw /	1964
VJSCA	27--2	49	49	odvi	age, wt, heart girth relat	russell,md; voge/	1976

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	40--4	593	603	odhe	periodicity of growth, odo	wood,aj; cowan,i/	1962
CJZOA	48--6	1401	1410	odhe*	comparative growth, body w	bandy,pj; cowan,/	1970
GROWA	20--3	179	186	odhe	factor anal, growth, calif	mankins,jv; bake,	1956
JOMAA	52--3	628	630	odhe	contrib organ tot body mas	hakonson,te; whi/	1971
JWMAA	19--3	331	336	odhe*	growth rate of blacktailed	cowan,im; wood,aj	1955
JWMAA	20--2	212	214	odhe	post-natal grow, milk cons	kitts,wd; cowan,/	1956
JWMAA	28--4	773	784	odhe	evaluat, eye lens tec, agi	longhurst,wm	1964
JWMAA	37--3	312	326	odhe/	effect nutr chan on captiv	robinette,wl; ba/	1973

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
ATRLA	14-10	141	151	ceel	growth, devel, red deer ca	dzieciolowski,r	1969
JWMAA	9---4	295	319	ceel	roosev elk, olymp penn, wa	schwartz,je; mitc	1945
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	34--2	467	470	ceel	rearing red dee calv, capt	youngson,rw	1970

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	51--2	403	405	alal*	characteric, captive moose	verme,lj	1970
JWMAA	23--2	231	232	alal*	feeding, grow, captiv calf	dodds,dg	1959
JWMAA	26--4	360	365	alal	studies, gravelly mt. mont	peek,jm	1962
VILTA	4---1	1	42	alal	captive hand-reared calves	markgren,g	1966

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	39--7	845	856	rata/	clima, metab, therm, infan	hart,js; heroux/	1961
CJZOA	40--5	863	869	rata*	growth studies, reind fawn	krebs,cj; cowan,i	1962
CJZOA	46--5	1023	1029	rata*	growth, developm, postnata	mcewan,eh	1968
CJZOA	48--2	391	392	rata	energy metab, barren groun	mcewan,eh	1970
CJZOA	49--4	443	447	rata*	measurem milk intake, calv	mcewan,eh; whiteh	1971
CWRSB	38--4	1	71	rata	growth, reprod, ener reser	dauphine,tc,jr	1976
LBASA	21--6	817	824	rata	reindeer in biomed researc	dieterich,ra; lui	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	35--1	76	85	anam	measurem, weights, carcass	mitchell,gj	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CNJNA	38--1	87	90	bibi	doca, hybrid,feedlot study	peters,hf	1958

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	44--1	116	118	ovca	growth, behav, captiv lamb	forrester,dj; hof	1963
JOMAA	46--3	524	525	ovca	fetal measure, milk charac	forrester,dj; sen	1965
JWMAA	29--2	387	391	ovca	growth, develop, des bigho	hansen,cg	1965
JWMAA	34--2	451	455	ovca	weights,growth,west alber	blood,da; flook,/	1970

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CAFNA	90--2	157	162	ovda	weights, growth, yukon ter	bunnell,fl; olsen	1976

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

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
AMNTA	114-1	101	116	ungu	neonate growth patt, repro	robbins,ct; robb	1979

CHAPTER 1, WORKSHEET 1.2a

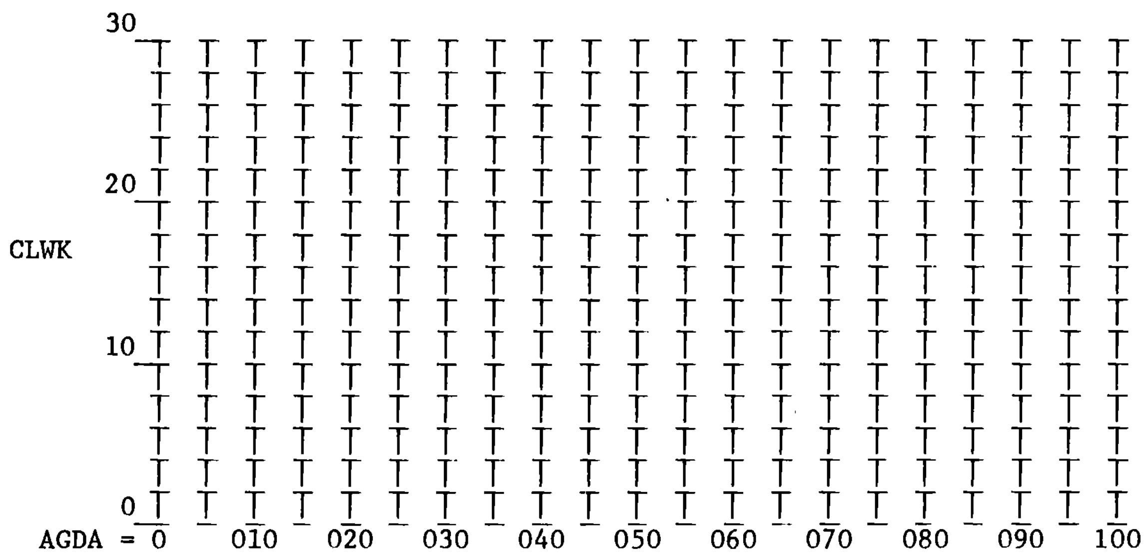
Suckling weights and growth of white-tailed deer (odvi)

Weight gains of three maternal-nursed fawns and two groups of bottle-fed fawns at the Wildlife Ecology Laboratory (Robbins and Moen 1975) were essentially linear over the suckling period. The calculated live weight in kg (CLWK) of the maternal-nursed fawns may be determined with the equation:

$$CLWK = 2.96 + 0.244\ AGDA$$

Birth weight was 2.96 (the intercept a at AGDA = 0), and the daily gain was 0.244 kg (the slope, b, of the regression line) which is 244 grams per day. Seven bottle-fed males gained an average of 250 gms per day, and two females, 247 gms per day, and another group of bottle-fed fawns, 245 gms per day.

Plot the weights using the equation above for a 100-day suckling period. Then substitute 0.250 for the 0.244 given in the equation and plot the weights again. Since the line is straight, you only need to calculate the weight at one AGDA (100 is the best one to choose in this case) and simply draw a straight line between the intercept, 2.96, and CLWK @ AGDA = 100.



LITERATURE CITED

Robbins, C. T. and A. N. Moen. 1975. Milk consumption and weight gain of white-tailed deer. J. Wildl. Manage. 39(2):355-360.

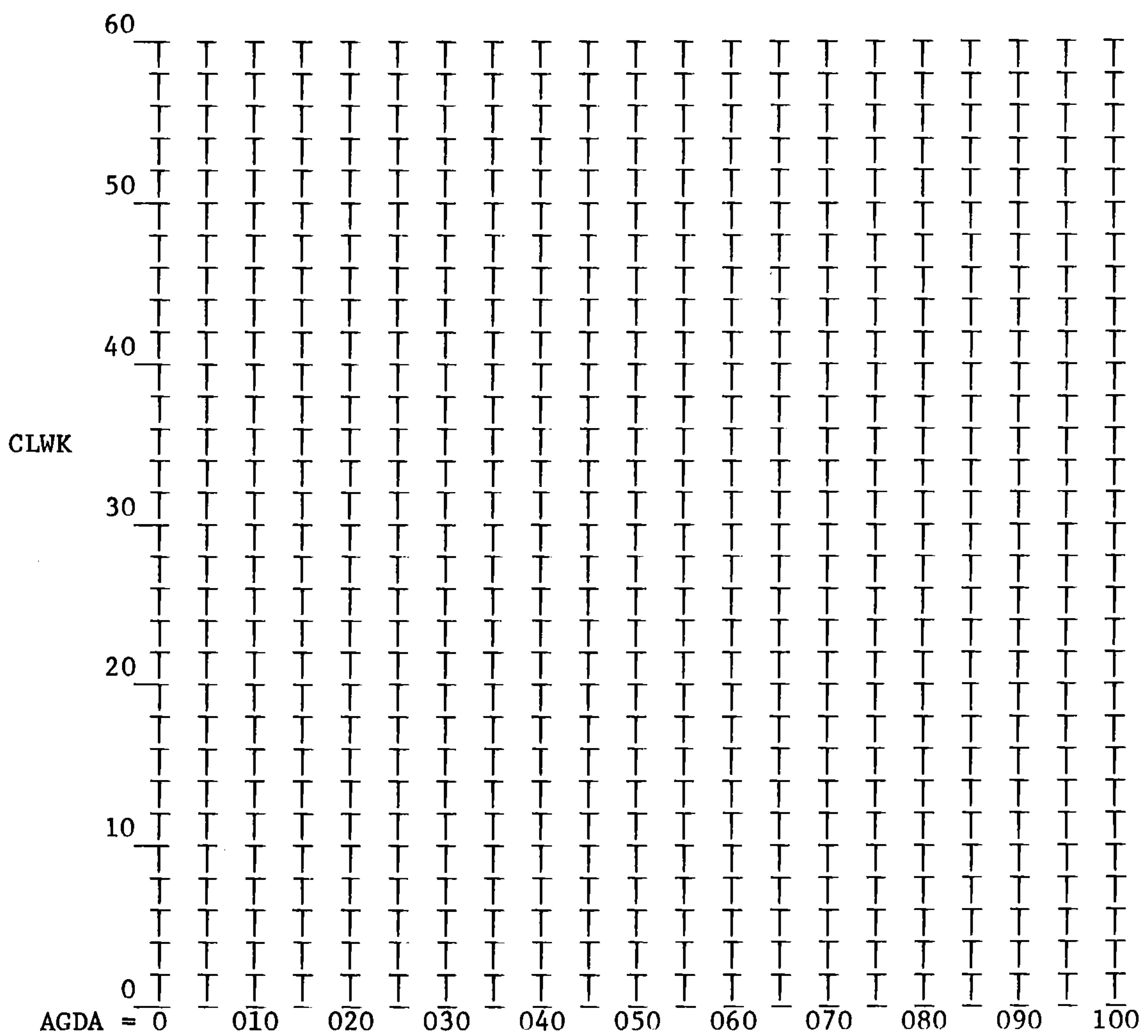
CHAPTER 1, WORKSHEET 1.2b

Linear approximations of suckling weights and growth

A range of fetal weights at birth (FWAB) from 2.5 to 5.0 were given in WORKSHEET 1.1 in the previous UNIT. Rates of gain were described as linear in WORKSHEET 1.2a in this UNIT with daily gains ranging from 244 to 250 gms per day. Suppose a fawn weighed 3 kg at birth and reached 28 kg in 100 days (AGDA = 100). The linear regression expression for that weight curve includes the intercept, a, of 3.0, and the slope, b, which is determined by (28.0 - 3.0)/100 = 0.250. The equation is:

$$\text{CLWK} = 3.0 + 0.250\ \text{AGDA}$$

Plot this weight curve, and derive additional weight curves for birth weights ranging from 2.5 to 5.0 kg and suckling weights up to 60 kg. The main idea of this exercise is to illustrate how a linear approximation of the growth curve can be made from birth weights and weaning weights. Note that birth weights must equal fetal weights at birth discussed in UNIT 1.1 if discontinuities between equations are to be avoided.



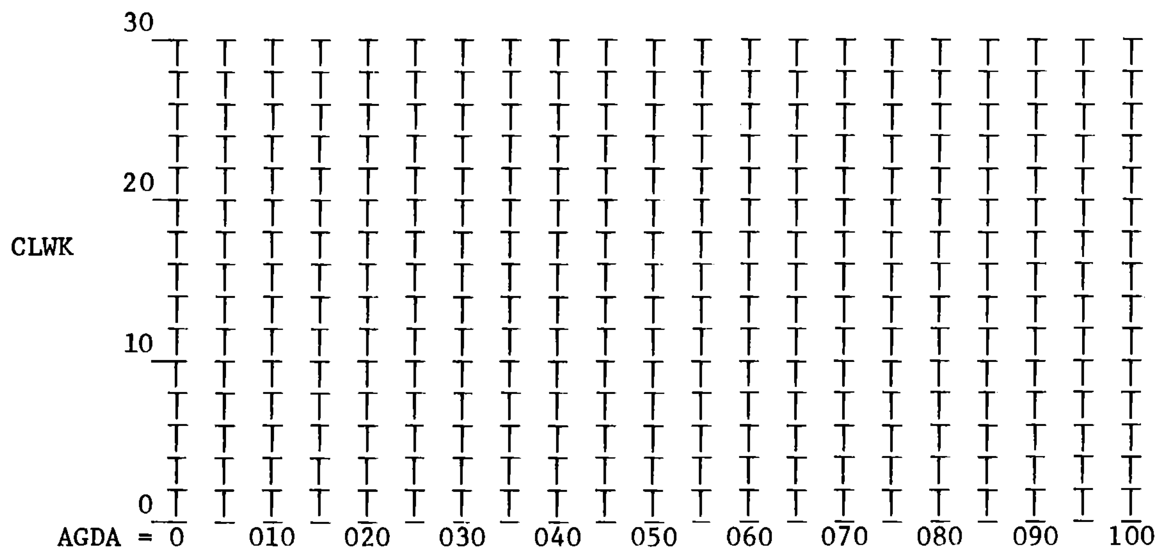
CHAPTER 1, WORKSHEET 1.2c

Suckling weights and growth of different subspecies of mule deer (odhe)

The weight curves of several individuals of different subspecies of <u>Odocoileus hemionus</u> were expressed by Wood et al. (1962) with exponential equations. The published equations were for weight in pounds. Converting to kg and substituting AGDA for the symbol "t" given in the original equations, the equations for four individuals, all males, are:

$CLWK = 3.91\ e^{0.01831\ AGDA}$; at AGDA = 100, CLWK = 24.40
$CLWK = 3.55\ e^{0.01324\ AGDA}$; at AGDA = 100, CLWK = 13.34
$CLWK = 4.32\ e^{0.00996\ AGDA}$; at AGDA = 100, CLWK = 11.70
$CLWK = 3.91\ e^{0.01134\ AGDA}$; at AGDA = 100, CLWK = 12.15

Verify the use of these equations with the CLWK given for AGDA = 100 in the table above, and plot the data points at several values of AGDA from 1 to 100 in the graph below.



LITERATURE CITED

Wood, A. J., I. McT. Cowan, and H. C. Nordan. 1962. Periodicity of growth in ungulates as shown by deer of the genus <u>Odocoileus</u>. Can J. Zool. 40(4):593-603.

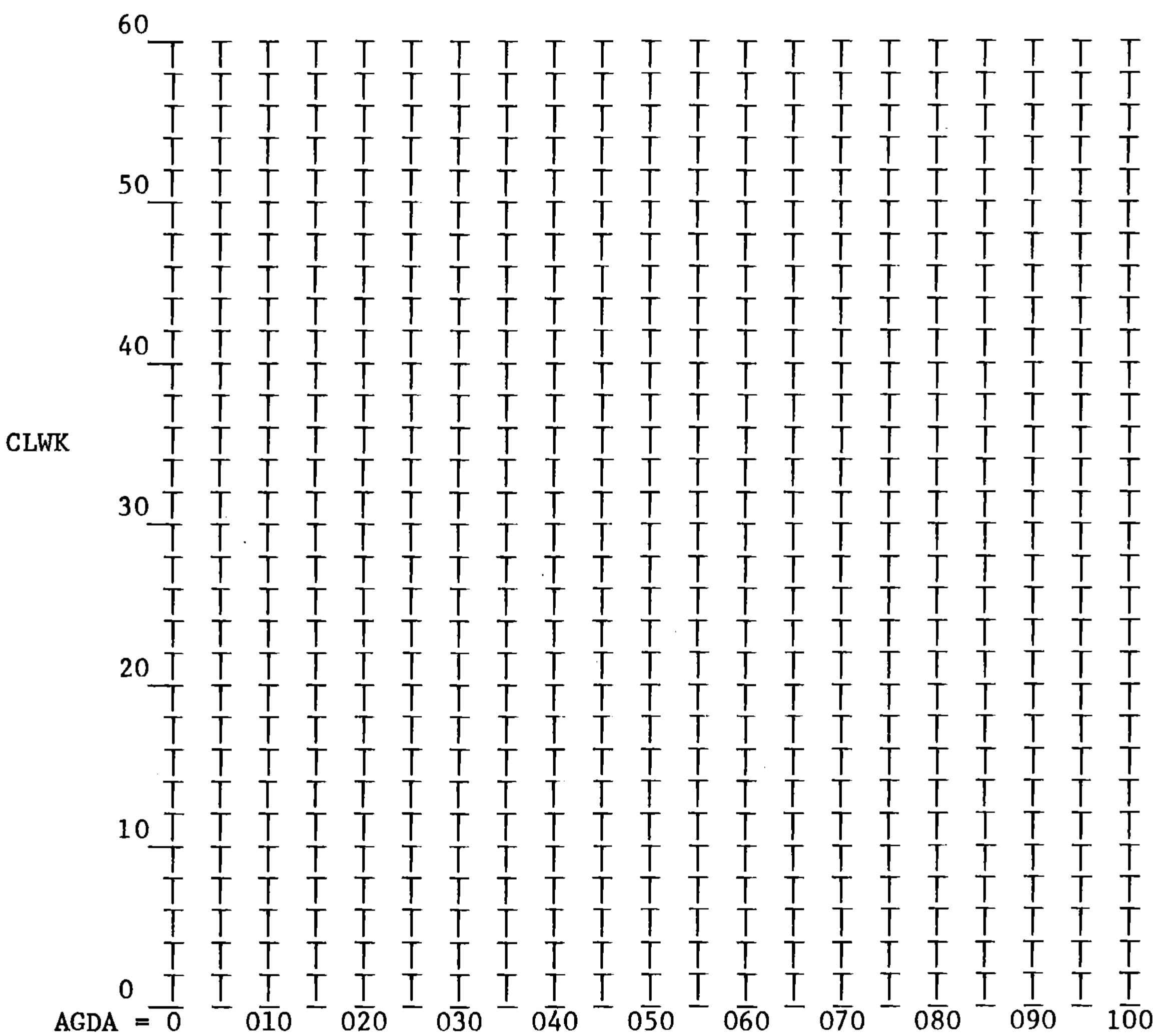
Exponential approximations of suckling weights and growth

Exponential approximations of weight curves for species of any birth weight and weaning weight can be easily derived with a curve-fitting program by entering two pairs of data inputs: birth weight at AGDA = 0 and weaning weight at whatever AGDA weaning occurs.

Suppose birth weights were 4.0 kg, and weaning weights ranged from 15 to 30 kg. The equations determined with this procedure are:

CLWK = 15 at AGDA = 100: $CLWK = 4.0\ e^{0.01322\ AGDA}$
CLWK = 20 at AGDA = 100: $CLWK = 4.0\ e^{0.01609\ AGDA}$
CLWK = 25 at AGDA = 100: $CLWK = 4.0\ e^{0.01833\ AGDA}$
CLWK = 30 at AGDA = 100: $CLWK = 4.0\ e^{0.02015\ AGDA}$

Verify the use of the equations by calculating CLWK when AGDA = 100, and then calculate several data points at selected increments from AGDA 1 to 100 and plot the weight curves. Derive additional equations for species up to 60 kg @ AGDA = 100 also.



UNIT 1.3: ADULT WEIGHTS AND GROWTH

Wild ruminants continue to grow after weaning, reaching physical maturity when they are several years old. The annual rate of growth slows as physical maturity is approached, of course. Seasonal variations are imposed on the annual rate of growth, and are considerably larger than the annual growth increases, in animals two years and older. Two expressions of adult weights and growth--maximum and minimum weights--are described in this UNIT, followed by discussions of seasonal variations in weights and growth in UNIT 1.4.

Maximum weights during each annual cycle, reached in the fall of the year, may be expressed with an equation where maximum weight in kg (MAWK) is the dependent variable Y and the age in days (AGDA) when these maximum weights occur (the independent variable X) each year. The JDAY when MAWK is observed should also be noted for use in determining phase corrections in UNIT 1.4. A tabular format for organizing these inputs for curve-fitting is shown below.

N	AGDA	MAWK	JDAY		LINE	EXPO	LOGN	POWE
1	____	____	____					
2	____	____	____					
.	.	.	.	R^2=	____	____	____	____
.	.	.	.	a =	____	____	____	____
N	____	____	____	b =	____	____	____	____

Field-dressed weights of hunter-killed animals are often the only source of data for estimating maximum live weights. Conversions of field-dressed weights to live weights are described in UNIT 1.5. If live weights need to be estimated from field-dressed weight data, go to UNIT 1.5 for the conversion equations and then come back to this UNIT to derive the live weight equations.

Live weights estimated from field dressed weights of hunter-killed animals may not be maximum, however, since the animals could already be in the weight-decline period when they are removed from the range. Conversions may be made after evaluating the concepts and techniques discussed in UNIT 1.4. For now, use the best estimate of maximum fall weights that you have and begin the curve-fitting procedures.

After tabulating the AGDA when maximum weight (MAWK) is reached and estimating JDAY of maximum weight, determine the R^2, a, and b values for the linear, exponential, logarithmic, and power curves. The equation with the best fit is then selected for the overall equation used in determining seasonal fluctuations in weights discussed in the next UNIT.

An equation expressing the relationship between minimum weights in kg (MIWK; the dependent variable Y), and AGDA (the independent variable X) is determined in the same way as for MAWK. The JDAY when minimum weights occur should also recorded for use in UNIT 1.4. As minimum weights occur after the maximum weights, the animals are older, of course, and this must be considered when tabulating AGDA. The tabular format is illustrated below.

N	AGDA	MAWK	JDAY		LINE	EXPO	LOGN	POWE
1	____	____	____					
2	____	____	____					
.	.	.	.	R^2=	____	____	____	____
.	.	.	.	a =	____	____	____	____
N	____	____	____	b =	____	____	____	____

After tabulating the AGDA when minimum weight (MIWK) is reached and estimating JDAY of minimum weight, determine the R^2, a, and b values for the linear, exponential, logarithmic, and power curves. The equation with the best fit is then selected for the overall equation used in determining seasonal fluctuations in weights discussed in the next UNIT.

The biggest problem in determining the minimum weight equation is the lack of data. Weights of animals that have died in the winter are seldom measured. Animals live-trapped in the winter are seldom weighed, and such weights are not necessarily the minimums possible for recovery from winter stress anyway. Nevertheless, minimum weights can be represented with good approximations by using good judgement and common sense in interpreting available data and deriving the equation.

REFERENCES, UNIT 1.3

ADULT WEIGHTS AND GROWTH

SERIALS

CODEN	vo-nu	bepa	enpa	anim kewo	auth	year
CPSCA	7---4	217	218	odvi*organ, body weight relatio	robinson,pf	1966
JOMAA	17--1	67	68	odvi size, weight adironda deer	schoonmaker,wj	1936
JOMAA	31--1	5	17	odvi*weight relation, george re	hamerstrom,fn; ca	1950
JWMAA	5---2	182	190	odvi study, edward plateau, tex	saunders,e	1941
JWMAA	17--2	166	176	odvi irruption, necedah refuge	martin,fr; krefti	1953
JWMAA	18--4	482	495	odvi management study, mud lake	hunt,rw; mangus,l	1954
JWMAA	19--3	346	352	odvi controlled deer hunts,	kruefting,iw; eri	1955
JWMAA	20--3	221	232	odvi nutri req, growth antl dev	french,ce; mcewan	1956
JWMAA	20--3	286	292	odvi regional differ, size,pro	gill,j	1956
JWMAA	33--3	482	490	odvi energy req, winter mainten	ullrey,de; youat/	1969
JWMAA	33--4	1027	1028	odvi longevi rec, females, mich	ozoga,jj	1969
JWMAA	34--4	887	903	odvi repro, grow, resid, dieldr	murphy,da; korsch	1970
JWMAA	39--1	48	58	odvi/morph char, crab orch herd	roseberry,jl; kli	1975
NAWTA	2----	446	457	odvi weigh, antl meas, pop dens	johnson,fw	1937
NAWTA	3----	261	279	odvi wt, meas, alleghen nat for	park,bc	1938
NAWTA	22---	119	122	odvi*nutri requirements of deer	mcewen,rc; french	1957
NAWTA	34---	137	146	odvi nutri, climate, south deer	short,hl; newsom,	1969
NFGJA	2---2	154	160	odvi weig as index to range con	severinghaus, cw	1955
NFGJA	2---2	247	247	odvi fawn weights, regul, antle	severinghaus, cw	1955
NFGJA	11--1	13	27	odvi growth, adirondacks, new y	severinghus,cw; t	1964
NYCOA	14---	30	31	odvi big, little deer, food key	severinghaus, cw/	1959
PAABA	600--	1	50	odvi*nutri req, growt, antl dev	french,ce; mcewa/	1955
PAABA	628--	1	21	odvi*nutri req, growt, antl dev	magruder,nd; fre/	1957
PCGFA	13---	62	69	odvi mast abund, weigh, reprod	harlow,rf; tyson,	1959
PIAIA	61---	615	630	odvi results, iowa's first seas	sanderson,gc; spe	1954
VIWIA	14--3	18	19	odvi report, 1952 big le refuge	moshby,hs	1952
VIWIA	14-10	18	19+	odvi highligh, vir 1952 dee stu	richards,ev	1953
VIWIA	16--9	5	7+	odvi report on glades the deer	davey,sp	1955
WSCBA	4--10	49	51	odvi wisconsins large dee, 1938	hopkins,r	1939

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	40--4	593	603	odhe*	periodicity of growth, odo	wood,aj; cowan,i/	1962
CJZOA	48--6	1401	1410	odhe	comparat growth in 4 races	bandy,pj; cowan,i	1970
JANSA	36--6	1201	1201	odhe	wt, plasma minrl indx, fem	lesperance,al; h/	1973
JOMAA	45--1	48	53	odhe	comp 3 morph attrib, n mex	anderson,ae; fra/	1964
JOMAA	52--3	628	630	odhe	contrib organ tot body mas	hakonson,te; wh/	1971
JWMAA	15--2	129	157	odhe	in nebraska national fores	mohler,ll; wampo/	1951
JWMAA	17--3	256	267	odhe	operation, check stat, col	rogers,ge	1953
JWMAA	37--3	312	326	odhe/	effect nutr chan on captiv	robinette,wl; b/	1973
NAWTA	22---	179	188	odhe	ovca, feed req, grow, main	cowan,i mct; wood	1957
PMASA	19---	72	79	odhe	ann cycl of condit, montan	taber,rd; white,k	1959

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
ATRLA	11--5	129	194	ceel	morph varia, skul, bod wei	mystkowska,et	1966
ATRLA	14-10	141	151	ceel	growth, dev, calves, capti	dzieciolowski,r	1969
ATRLA	15---	253	268	ceel	relat age and size, poland	dzieciolowski,r	1970
BUFOA	9--97	75	82	ceel	size, recent, prehistoric	walvius,mr	1961
BVJOA	133--	215	218	ceel	dada observ, weighing, dee	dansie,o	1977
JWMAA	15--1	57	62	ceel	weights, measurem, rock mt	quimby,dc; johnso	1951
JWMAA	24--1	15	21	ceel	on afognak island, alaska	troyer,wa	1960
JWMAA	30--1	135	140	ceel*	measurements, weight relat	blood,da; lovaas	1966
NAWTA	29---	237	248	ceel	winter weights, yellowston	greer,kr; howe,re	1964
POASA	47---	406	413	ceel	size, weight, wichita moun	halloran,af	1968
UAABB		80	82	ceel	wt dynam, free ranging elk	gates,cc; hudson,	1979
ZEJAA	1---1	92	98	ceel	[weights, red deer,germny]	ueckermann,e	1955
ZEJAA	2---1	13	20	ceel	[pop densit, wt, antl dev]	caesar,h	1956
ZEJAA	3---4	145	153	ceel	[reprod rates, body weigh]	kroning,f; vorrey	1957
ZOGAA	33---	85	105	ceel	[bod gro, siz eur red dee]	stubbe,c	1966

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CAFNA	81---	263	269	alal	weight, measurements, albe	blood,da; mcgill/	1967
JOMAA	27--1	90	91	alal	weigh of a minnesota moose	breckinridge,wj	1946
JOMAA	50--2	302	310	alal*odvi,	structur adapt, snow	kelsall,jp	1969
JOMAA	51--2	403	405	alal*charact	of captive, michig	verme,lg	1970
JOMAA	51--4	808	808	alal	weights and measurements o	doutt,jk	1970
JZAMD	6---4	10	12	alal	winch/tripod device, weigh	arneson,pd; franz	1975
VILTA	2---7	409	417	alal	puber, dentit, weigh, swed	markgren,g	1964

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
AJVRA	3---8	308	311	rata	fattening, sex, increase	hadwen,s	1942
BJNUA	29--2	245	259	rata	seas variation, gluc metab	luick,jr; perso/	1973
CJZOA	44--3	401	411	rata	growth, developmen, bar gr	mcewan,eh; wood,a	1966
CJZOA	46--5	1023	1029	rata*growth,	developm, post-nat	mcewan,eh	1968
CJZOA	48--5	905	913	rata	seas chan, energ, nitr int	mcewan,eh; white/	1970
CWRSB	38---	1	71	rata	kaminuriak barr gr, growth	dauphine,tc	1976
JWMAA	32--2	350	367	rata	introduct, increase, crash	klein,dr	1968
JWMAA	36--2	612	619	rata	growth, domest, wild, norw	reimers,e	1972
NJZOA	24--4	407	417	rata*morph,	fat stor, org weigh	krog,j; wika,m; /	1976
TNWSD	28---	91	108	rata	phys variab, condit, bgcar	dauphine,tc,jr	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	16--3	387	389	anam	measurements, hart mt ante	mason,e	1952
JWMAA	34--2	470	472	anam	derivation, whole weights	o'gara,bw	1970
JWMAA	35--1	76	85	anam	measurem, weights, carcass	mitchell,gj	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	45--4	630	632	bibi	data on bison bison athaba	bayrock,la; hille	1964
POASA	41---	212	218	bibi	weight, meas, wichita moun	halloran,af	1961

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	24--1	1	11	ovca	life hist, rocky mt, color	spencer,cc	1943
JOMAA	44--1	116	118	ovca	growth, behav, captiv lamb	forester,dj; hoff	1963
JOMAA	52--1	242	243	ovca	influence lambing on weigh	woolf,a	1971
JWMAA	22--4	444	445	ovca	some weights and measureme	aldous,mc; craig/	1958
JWMAA	34--2	451	455	ovca	weigh growth, west alberta	blood,da; flook,/	1970

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CAFNA	90--2	157	162	ovda/wt, grow, kluane pk, yukon		bunnell,fl; olsen	1976
JOMAA	22--4	448	449	ovda	the weights of dall's shee	ulmer,fa	1941

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	12--3	292	297	obmo	experim in re-estab, alask	bell,wb	1931
JOMAA	35--3	456	456	obmo	muskox longevity	buckley,jl; spen/	1954

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
				oram			

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

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
BICOB	2---1	55	62	dada	observa, biology, england	chapman,di; chapm	1969
JZOOA	157-1	125	132	dada	teeth, wt, antlr, male age	chaplin,re; white	1969

CHAPTER 1, WORKSHEET 1.3a

Weights and growth of adult white-tailed deer (odvi)

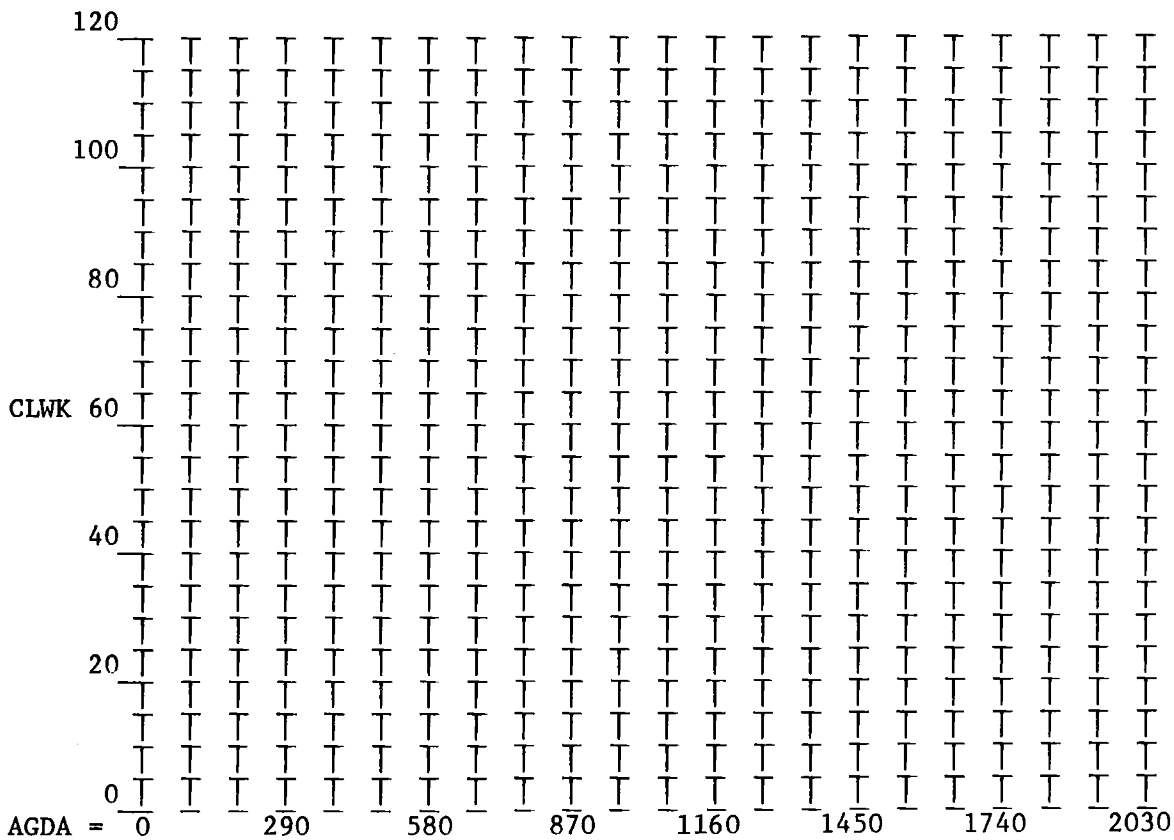
Maximum and minimum weight curves have been determined for white-tailed deer from three areas of New York State. For males, the power curve provided the best fit, and the equations for maximum weight in kg (MAWK) and minimum weight in kg (MIWK) are:

Central Adirondacks: $MAWK = 3.13\ AGDA^{0.45958}$
$MIWK = 0.99\ AGDA^{0.55035}$

Central and Southern Tier: $MAWK = 6.24\ AGDA^{0.38906}$
$MIWK = 2.23\ AGDA^{0.47800}$

Central Catskills: $MAWK = 3.36\ AGDA^{0.45233}$
$MIWK = 0.79\ AGDA^{0.58830}$

Plot the curves for males, comparing the weights between these three areas, below.



LITERATURE CITED

Moen, A. N. and C. W. Severinghaus. 1981 [In press.] Annual cycle weight equations and survival of white-tailed deer. N.Y. Fish and Game Journal.

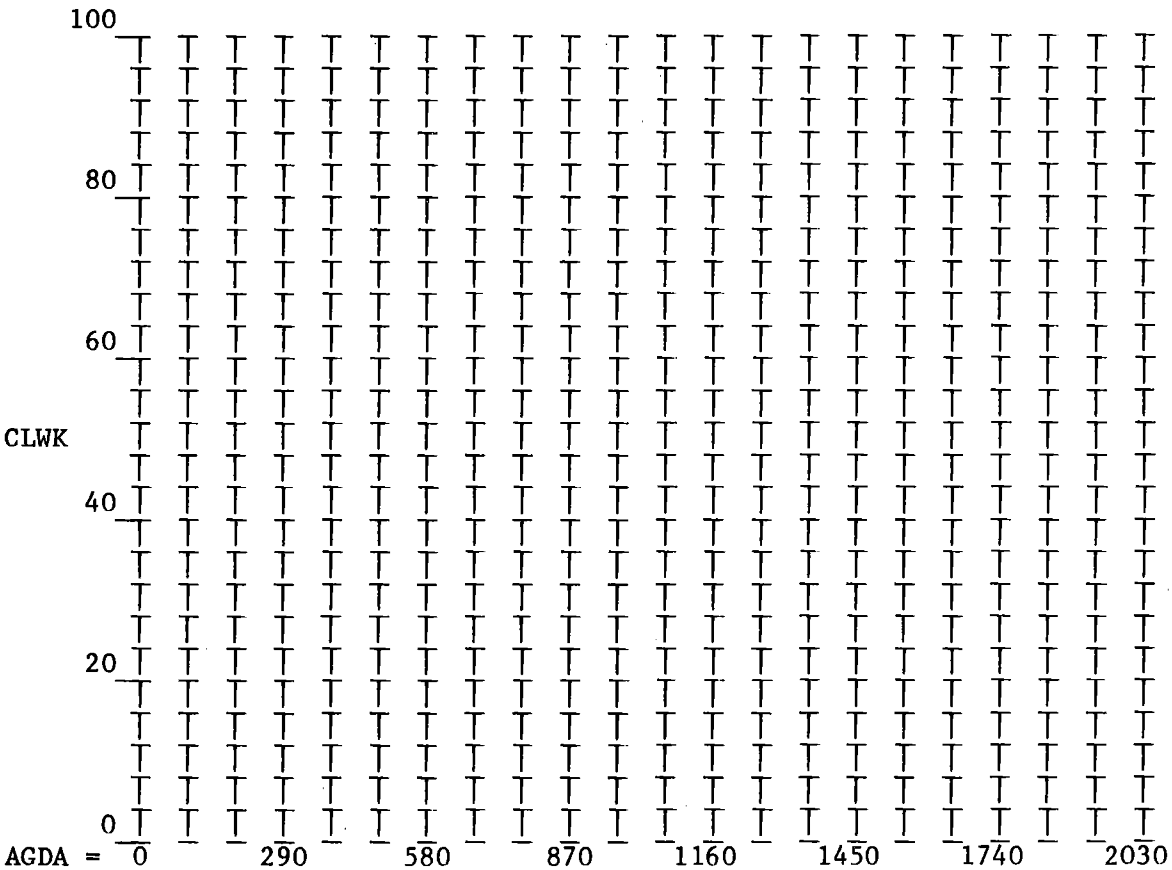
For females, logarithmic curves provided the best fit, and the equations for MAWK and MIWK are:

Central Adirondacks: $MAWK = 10.97253 \ln AGDA - 23.40$
$MIWK = 9.23499 \ln AGDA - 28.85$

Central and Southern Tier: $MAWK = 12.80383 \ln AGDA - 24.23$
$MIWK = 11.75924 \ln AGDA - 33.88$

Central Catskills: $MAWK = 13.35857 \ln AGDA - 38.05$
$MIWK = 12.25631 \ln AGDA - 47.66$

Plot the curves for females, comparing the weights between these three areas below.

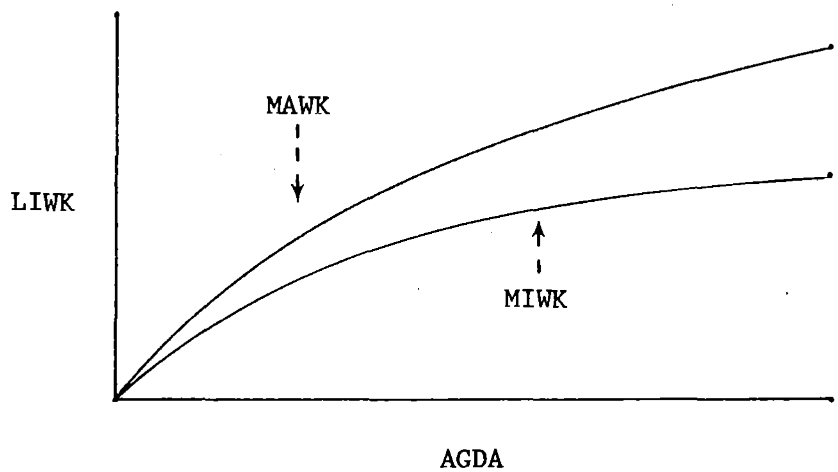


LITERATURE CITED

Moen, A. N. and C. W. Severinghaus. 1981 [In press.] Annual cycle weight equations and survival of white-tailed deer. N.Y. Fish and Game Journal.

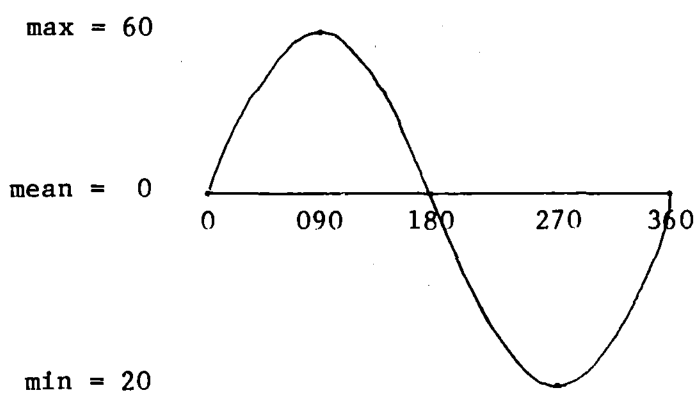
UNIT 1.4: SEASONAL VARIATIONS IN WEIGHTS

Seasonal variations in weights arm characteristic of wild ruminants on ranges with seasonal variations in the quality and quantity of forage. Maximum weights are usually reached near the end of the growing season, and minimum weights in late winter, early spring, or summer, depending on weather, snow conditions, and reproductive demands. An equation for determining calculated live weight in kg (CLWK) permits one to express weight fluctuations between these maxima and minima as indicated below.



Seasonal variations are calculated by combining the maximum weight curve, minimum weight curve, and sine functions into a single continuous equation. The sine functions smooth the change from increasing to decreasing and decreasing to increasing weights as maximums and minimums are reached.

An understanding of the basic form of a sine wave is necessary before calculating sinusoidal variations in animal weights from season to season. The sine wave shown below is labeled in degrees on the horizontal axis, beginning with 0 and ending with 360, which is one complete sine wave.



Using your hand calculator with trig functions, determine the sine of 0, 90, 180, 270, and 360. They are:

$\sin 0 =$ ___

$\sin 90 =$ ___

$\sin 180 =$ ___

$\sin 270 =$ ___

$\sin 360 =$ ___

Note that the amplitude of the sine wave varies 20 units above and below the mean value of 40, which can be expressed as:

$$40 \pm 20, \text{ range} = 20 \text{ to } 60$$

The value of Y at any point along this sine wave can be determined with a simple formula:

$$Y = 40 + \sin X\ [(\text{maximum} - \text{minimum})/2].$$

Substituting numerical values for X, the equations are:

If $X = 0$: $Y = 40 + \sin 0\ [(60 - 20)/2] = 40 + 0(20) = 40$

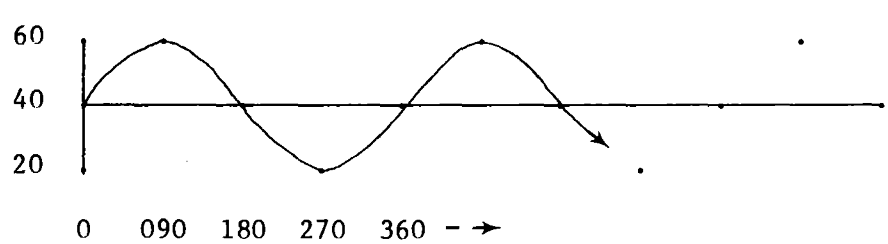
If $X = 90$: $Y = 40 + \sin 90\ [(60 - 20)/2] = 40 + +1(20) = 60$

If $X = 180$: $Y = 40 + \sin 180\ [(60 - 20)/2] = 40 + 0(20) = 40$

If $X = 270$: $Y = 40 + \sin 270\ [(60 - 20)/2] = 40 + -1(20) = 20$

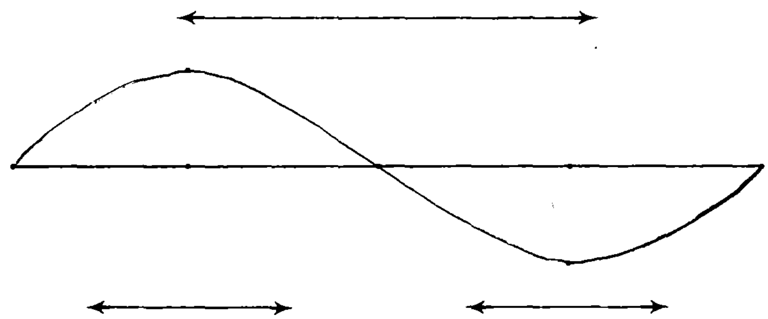
If $X = 360$: $Y = 40 + \sin 360\ [(60 - 20)/2] = 40 + 0(20) = 40$

This basic relationship is used to calculate weights of animals exhibiting one maximum and one minimum weight through one annual cycle. The X axis is the days in the year, where each day is 360/365 = 0.9863, and the Y axis is weight. The range in weights is determined by subtracting the calculated minimum weight for a given date from the calculated maximum weight on that date, using equations derived for maximum and minimum weights. This is comparable to the (60 - 20) component of the equation above. The deviation from the mean is determined by dividing this range by 2. The deviation from the mean is multiplied by the sine function (sign considered), and added to the mean value (40 in the equations above). The relationships are illustrated for three annual cycles below.



The time of occurrence of the maximum and minimum weights throughout the year is an important consideration when deriving the overall equation. Maximum weights may not fall on 90 (when sine = +1.0) and minimum weights may not fall on 270 (when sine = -1.0), and they may not be exactly six months apart. Phase corrections are used to represent the time of occurrence of maximum and minimum weights. These involve shifting of the entire sine wave (primary phase correction) and of the maximum and minimum deviations (secondary phase corrections) as illustrated below.

Primary Phase Correction



Secondary
Phase
Corrections

The steps used to make the necessary phase corrections for adjusting the sine components of the weight equation so weights reach maximums and minimums at the appropriate times of the year are shown below.

Step 1. Determine the number of days from maximum to minimum weight: ______

Step 2. Subtract 182.5 from the answer in Step 1: ______

Step 3. Divide the difference in Step 2 by 2 to get the secondary phase correction, SEPC: SEPC = ______

Step 4. Add (sign considered) the quotient in Step 3 to JDAY for maximum weight to get adjusted JDAY for maximum weight:

adj. JDAY = ______

Step 5. Determine the primary phase correction by:

sin[(adj. JDAY for MAWK)(0.9863) + PRPC] = 1.0

Since sin 90 = 1.0,

[(adj. JDAY)(0.9863) + PRPC = 90

90 - (__________)(0.9863) = PRPC PRPC = ______

Primary and secondary phase corrections determined in this way result in sine values that are within 2% when the JDAYs of maximum and minimum weights are greater than 126.5 and less than 238.5 days apart (See Step 1).

The overall formula for calculating live weights through successive annual cycles consists of three parts. They are: one, the average weight, which is the sum of the maximum and minimum divided by 2; two, the sine expressions with both primary and secondary phase corrections; and three, the deviation from the average weight, determined by dividing the difference between maximum and minimum weights by 2. The formula is shown, with parts labeled (the middle line is the sine expression), below.

$$\mathrm{CLWK} = \overbrace{[\mathrm{MAWK} + \mathrm{MIWK}]/2}^{\text{Average weight}} + \sin\left\{(\mathrm{JDAY})(0.9863) + \left[\left(\sin\left\{[(\mathrm{JDAY})(0.9863) + \mathrm{PRPC}] + (\mathrm{SEPC})\right\}\mathrm{SEPC}\right) + \mathrm{PRPC}\right]\right\} \underbrace{[\mathrm{MAWK} - \mathrm{MIWK}]/2}_{\text{Deviation from average weight}}$$

Note that there are no biological constants in the formula. Maximum weight equations, minimum weight equations, and phase corrections are all determined from observed data; the formula may be used for any population for whom data are available.

There is one further consideration to be made when calculating the weights of reproducing females. The weight of the pregnant female may be divided into two compartments: maternal tissue, and fetal plus associated reproductive tissues. An immediate weight loss occurs at parturition as fetuses, fluids, and other tissues are expelled; their weight is subtracted from the total live weight at that time. After parturition, maternal weights may remain low during the first part of the lactation period due to the high cost of milk production. As milk production decreases in the last two-thirds of the lactation period, weight gains begin to occur, and the animals reach maximum weights in the fall again. This consideration will be discussed again in later analyses.

The three main components of the overall weight equation are illustrated in the WORKSHEETS that follow, with several examples to provide practice in deriving equations for seasonal variations in weights over successive annual cycles.

REFERENCES, UNIT 1.4

SEASONAL VARIATIONS IN WEIGHTS

SERIALS

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CPSCA	7---4	217	218	odvi	organ/body wt rel, marylnd	robinson,pf	1966
JOMAA	41--1	23	29	odvi	response bucks, artif ligh	french,ce; mcewe/	1960
JOMAA	47--2	267	280	odvi*	seas chang, sex, age, glan	hoffman,ra; robin	1966
JWMAA	18--4	482	495	odvi	deer management study: mud	hunt,rw; mangus,l	1954
JWMAA	20--3	221	232	odvi	nutri req, growth antl dev	french,ce; mcewan	1956
JWMAA	33--3	482	490	odvi	energy req, winter mainten	ullrey,de; youat/	1969
NAWTA	22---	119	122	odvi*	nutri requirements of deer	mcewen,rc; french	1957
NAWTA	34---	137	146	odvi	nutri, climate, south deer	short,hl; newsom,	1969
PAABA	PR209	1	11	odvi	feed, season, antler devel	long,ta; cowan,r/	1959
PAABA	600-1		50	odvi	nutr req, growth, antl dev	french,ce; mcewa/	1955
PAABA	628-1		21	odvi	nutr req, growth, antl dev	magruder,nd; fre/	1957
PIAIA	61---	615	630	odvi	resul, 1st recent iowa sea	sanderson,gc; spe	1954
PCGFA	21---	24	32	odvi	seas wt gain, food consump	fowler,jf; newso/	1967

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CAFGA	31--1	3	11	odhe	conditio, sequoia nat park	dixon,js; herman,	1945
CJZOA	40--4	593	603	odhe*	periodicity of growth, odo	wood,aj; cowan,i/	1962
PMASA	19---	72	79	odhe	ann cycl of condit, montan	taber,rd; white,k	1959
SZSLA	21---	89	96	odhe	nutrit req, growth, captiv	nordan, hc, cowa/	1968

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
NAWTA	29---	237	248	ceel	winter weights, yellowston	greer,kr; howe,r	1964
POASA	47---	406	413	ceel	size, wt, wichita mt, okla	halloran,af	1968
ZEJAA	1---1	92	98	ceel	[weights, red de,germany]	ueckermann,e	1955

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	56--2	298	306	alal*	weights, measureme, alaska	franzmann,aw; le/	1978

alal continued on the next page

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	51--2	403	405	alal*	charact of captive, michig	verme,lg	1970
JZAMD	6---4	10	12	alal	winch/tripod, weighi moose	arneson,pd; franz	1975
VILTA	2----	409	416	alal	pubert, dentit, wt, sweden	markgren,g	1964

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
AJVRA	3---8	308	311	rata	fattening, sex, increase	hadwen,s	1942
BJNUA	29--2	245	259	rata	seas variatio, gluc metabo	luick,jrs; perso/	1973
CJZOA	46--5	1023	1029	rata*	growth, developm, post-nat	mcewan,eh	1968
CJZOA	50--1	107	116	rata*	seas chang, body h20, flui	cameron,rd; luick	1972
CWRSB	38---	1	71	rata*	growth, reprod, ener reser	dauphine,tc jr	1976
JWMAA	36--2	612	619	rata	growth, domest, wild, norw	reimers,e	1972
PASCC	22---	12	12	rata	wint grow patt,female calv	luick,jr;white;re	1971
TNWSD	28---	91	108	rata	phys variab, condit, bar g	dauphine,tc,jr	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	34--2	470	472	anam	derivation, whole weights	o'gara,bw	1970
JWMAA	35--1	76	85	anam	measurem, weights, carcass	mitchell,gj	1971

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	34--2	451	455	ovca	weigh growth, bigh, albert	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
				oram			

CHAPTER 1, WORKSHEET 1.4a

Primary and secondary phase corrections

Primary and secondary phase corrections are determined with the five steps listed below.

Step 1. Determine the number of days from maximum to minimum weight: ______

Step 2. Subtract 182.5 from the answer in Step 1: ______

Step 3. Divide the difference in Step 2 by 2 to get the secondary phase correction, SEPC: SEPC = ______

Step 4. Add (sign considered) the quotient in Step 3 to JDAY for maximum weight to get adjusted JDAY for maximum weight:

adj. JDAY = ______

Step 5. Determine the primary phase correction by:

sin[(adj. JDAY for MAWK)(0.9863) + PRPC] = 1.0

Since sin 90 = 1.0,

[(adj. JDAY)(0.9863) + PRPC = 90

90 - (__________)(0.9863) = PRPC PRPC = ______

Using the JDAYs of MAWK and MIWK given below, determine the primary and secondary phase correctins, verifying the use of the five steps.

Sex	Region	JDAY MAWK	JDAY MIWK*	PRPC	SEPC
M	Central Adirondacks	301	106	-200.71	-6.25
F		301	121	-208.71	+1.25
M	Central and Southern Tier	301	106	-200.71	-6.25
F		331	106	-215.51	-21.25
M	Central Catskills	301	106	-200.71	-6.25
F		316	106	-208.11	-13.75

*Early spring minimum; further reductions occur at parturition.

These phase corrections, from Moen and Severinghaus (1981), are combined with the MAWK and MIWK equations from WORKSHEET 1.3a to derive the overall weight equation discussed in the next WORKSHEET, 1.4b.

LITERATURE CITED

Moen, A. N. and C. W. Severinghaus. 1981. Annual cycle weight equations and survival of white-tailed deer. N. Y. Fish and Game Journal. [In press].

Annual cycle weight equations for white-tailed deer (odvi)

The equations for MAWK and MIWK from WORKSHEET 1.3a and the PRPC and SEPC from WORKSHEET 1.4a may now be combined in the overall formula for calculating weights during the annual cycle below.

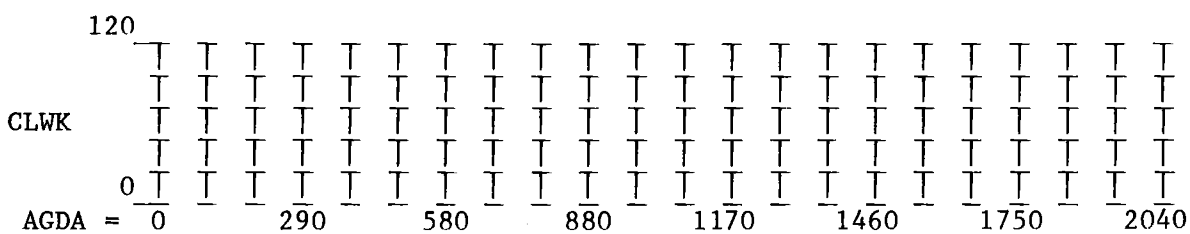
$$\mathrm{CLWK} = \overbrace{[\mathrm{MAWK} + \mathrm{MIWK}]/2}^{\text{Average weight}} + \sin\left\{(\mathrm{JDAY})(0.9863) + \left[\left(\sin\{[(\mathrm{JDAY})(0.9863) + \mathrm{PRPC}] + (\mathrm{SEPC})\}\mathrm{SEPC}\right) + \mathrm{PRPC}\right]\right\} \underbrace{[\mathrm{MAWK} - \mathrm{MIWK}]/2}_{\text{Deviation from average weight}}$$

Calculate the weights and plot the curves for successive annual cycles. Begin with birth on JDAY 151, so an animal reaches AGDA = 105 on JDAY 256, and increment with 15-day intervals as in the JDAY: AGDA pattern below.

JDAY	AGDA	JDAY	AGDA	JDAY	AGDA	JDAY	AGDA
256	105	301	150	346	195	31	245
271	120	316	165	361	210	.	.
286	135	331	180	16	230*	.	.
						Continue to maturity	

*Note that five extra days are added to AGDA at the end of the year, resulting in the next JDAY being 16. Fifteen-day intervals could be used throughout, resulting in different JDAYs through each annual cycle. The above format is simpler, requiring one adjustment at the end of the year.

The use of 15-day increments results in very smooth weight curves over several annual cycles. Write out the overall equations for male and female deer by substituting the equations for MAWK, MIWK, PRPC, AND SEPC and begin the calculations. Results will be obtained quickly if programmed computing is used. Plot the data on a full-size sheet of graph paper for five successive annual cycles. The labels are shown below.



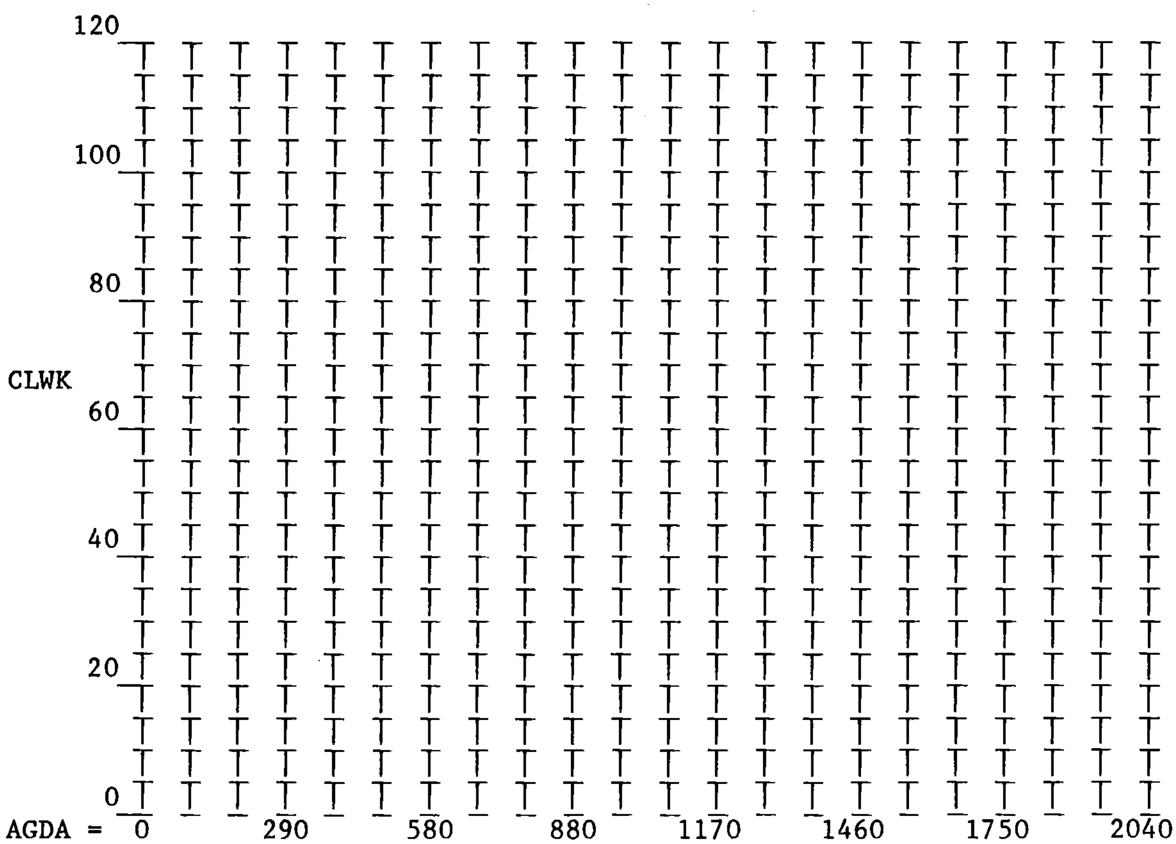
LITERATURE CITED

Moen, A. N. and C. W. Severinghaus. 1981. Annual cycle weight equations and survival of white-tailed deer. N. Y. Fish and Game Journal. [In press].

Seasonal variations in weights of black-tailed deer (odhe)

The weights of several black-tailed deer from birth through four years of age are plotted in Wood et al. (1962), and the equations given for maximum and minimum weights. The patterns of seasonal variations can be easily calculated with the annual cycle weight formula given in WORKSHEET 1.4b. Since equations for both MAWK and MIWK are given by Wood et al., phase corrections are all that remain to be determined. Estimate the JDAYs of MAWK and MIWK from their plotted figures and determine the phase corrections with the steps in WORKSHEET 1.4a. Then, write the equations below, make the calculations, and plot on a full sheet of graph paper using labels given.

$$\text{CLWK} = \overbrace{[\text{MAWK} + \text{MIWK}]/2}^{\text{Average weight}} + \sin\left\{(\text{JDAY})(0.9863) + \left[\left(\sin\{[(\text{JDAY})(0.9863) + \text{PRPC}] + (\text{SEPC})\}\text{SEPC}\right) + \text{PRPC}\right]\right\} \underbrace{[\text{MAWK} - \text{MIWK}]/2}_{\text{Deviation from average weight}}$$



LITERATURE CITED

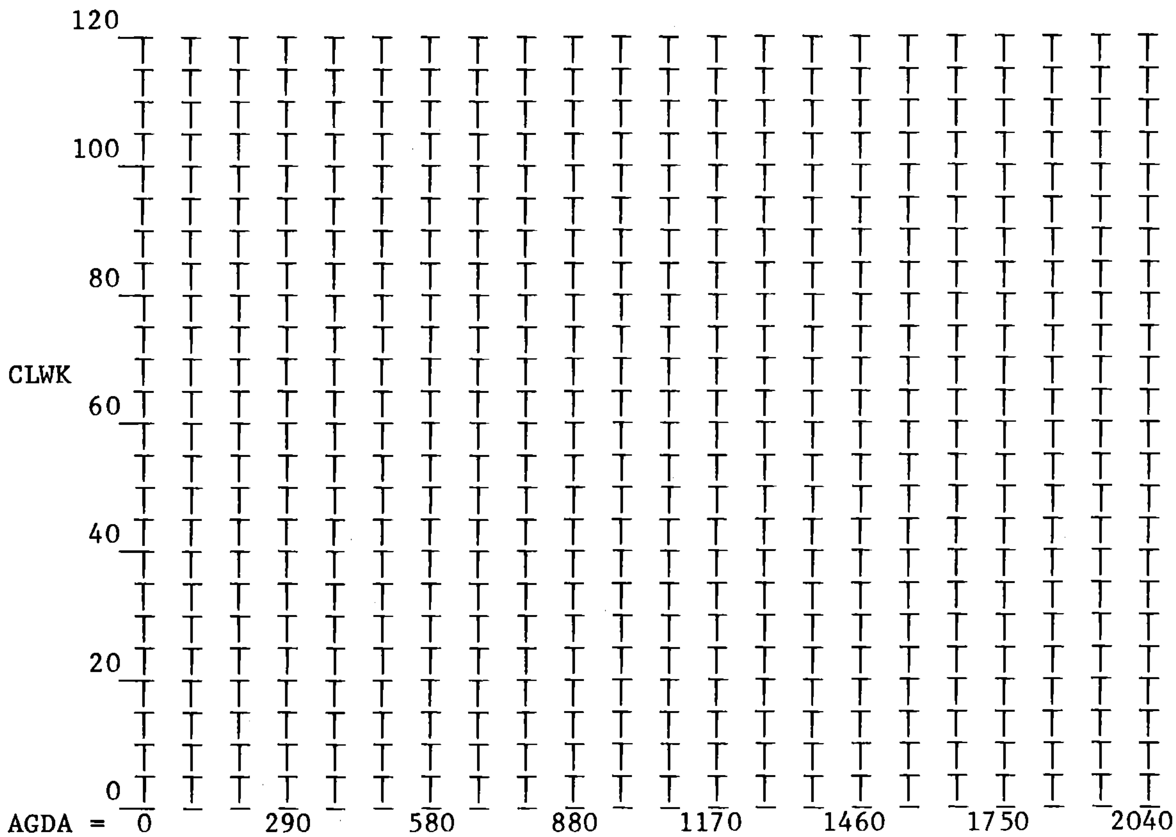
Wood, A. J., I. McT. Cowan, and H. C. Nordan. 1962. Periodicity of growth in ungulates as shown by deer of the genus Odocoileus. Can. J. Zool. 40(4): 593-603.

CHAPTER 1, WORKSHEET 1.4d

Seasonal variations in weights of deer (odvi)
and of caribou (rata) from plotted data

Plots of deer weights in Hoffman and Robinson (1966) and caribou weights in Dauphine (1976) clearly illustrates seasonal variations in weights. Data points may be estimated by laying transparent gridded overlays on the figures and estimating the x and y values. Estimates of MAWK and MIWK may then be tabulated in relation to AGDAs and JDAYs and curve-fitting of MAWK and MIWK completed. The equations are:

Derive the equations and plot estimates of CLWK below.



LITERATURE CITED

Dauphine, T. C., Jr. 1976. Biology of Kaminuriak population of barren-ground caribou. Part 4: Growth, reproduction and energy reserves. Can. Wildl. Serv. Rep., Ser. No. 38.

Hoffman, R. A. and P. F. Robinson. 1966. Changes in some endocrine glands of white-tailed deer as affected by season, sex and age. J. Mammal. 47(2):267-280.

UNIT 1.5: LIVE WEIGHT, INGESTA-FREE, AND DRESSED WEIGHT RELATIONSHIPS

It is difficult to measure live weights of free-ranging ruminants, and most of the weights available in the literature are for some fractions of live weights. Field dressed weights are often measured at check-stations where hunters bring field-dressed animals. Some data are available in the literature on weights of ingesta and organs of the gastrointestinal tract, and of the heart, lungs, and liver. These data may be used to estimate the weights of ingesta and organs removed in field-dressing and help establish the validity of equations for converting field-dressed weights to live-weights when the weights of ingesta and all organs are removed in field-dressing are summed, the total should be equal to the differences between field-dressed and live weight as determined by equations expressing live weight--field dressed weight relationships.

Some of the references listed contain equations that have been determined for different species in different areas. No single weight conversion equation is applicable everywhere, however, as the weights of body components, especially fat, vary between range, during the year, and from year to year. The best equation for the species in your area or a first approximation based on expected similarities with animals in other areas may be used to convert dressed weights to estimated live weights.

Live weight--field-dressed weight relationships. Field-dressed weights are applied to the carcass with the entrails removed but with the heart, liver, and lungs left in. Estimated live weights in kg (ELWK) from field-dressed weights in kg (FDWK) are useful when weight data on wild ruminants are needed for analyses of ecological relationships.

Gastrointestinal tract weight characteristics. Stomach and intestinal weights in relation to live weights are used when partitioning weight differences between field-dressed weights and live weights. While the organs of the gastrointestinal tract contribute to the total gastrointestinal weight, the weight of the ingesta is a major component of this difference.

Ingesta-free weight. The weight of the ingesta within the gastrointestinal tract should be known when calculating energy metabolism since the ingesta are not part of the animal's metabolic tissue. Direct measurements of heat production are usually completed when the animals are in a post-absorptive condition; the gastrointestinal tracts are essentially empty. This is necessary because the exothermic metabolic processes of many millions of rumen microflora, both bacteria and protozoa, contribute thermal energy to the host that is measured by direct calorimetry. If the host is not in a negative thermal energy balance, this heat must be dissipated to prevent a rise in total body heat content and body temperature. If the host is in a negative thermal energy balance, heat energy released by rumen microflora breaking down the mass of ingesta is a desirable contribution to the total thermal energy balance of the host.

Live weight--hog-dressed weight relationships. Hog-dressed weights are applied to the carcass with the entrails, heart, liver, and lungs removed. Weights of the heart, liver and lungs may be subtracted from field-dressed weights to determine hog-dressed weights.

Live weight--field-dressed--edible meat relationships. Edible meat includes the muscle tissue available for consumption. The amount of edible meat on the carcasses of wild ruminants is an obviously important parameter for calculating their economic values. Data are very limited, however; studies are needed on just about every species.

The total live weight of an animal equal to the sum of the weights of all the individual organs and ingesta. The accountability of the separate equations may be evaluated by comparing the sum to the total weight. These live weight:dressed weight equations and the equations for the organs of different body systems given in TOPIC 3 in this CHAPTER may be compiled for such comparisons.

Comparisons of independently-calculated values of parameters of ecological importance is an excercise in "ecological accounting." Such comparisons are important because so many parameters of ecological importance must be measured indirectly or estimated for different animals and species in different areas, and the results compiled. Errors in measurements and differences between animals from different areas may result in unreasonable conclusions. The sum of all calculated organ and ingesta weights might exceed measured live weight, for example, which is biologically unreasonable.

Statistical tests for differences between population characteristics are essential when evaluating the magnitude of differences. Uses of statistical tests are described later in this text. For now, remember the concept of "ecological accounting," keeping in mind that equations from different areas should not be combined without caution.

REFERENCES, UNIT 1.5

LIVE WEIGHT, INGESTA-FREE, AND DRESSED WEIGHT RELATIONSHIPS

SERIALS

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JOMAA	18--4	435	442	odvi	mammals of anticostiislan	newsom,wm	1937
JOMAA	31--1	5	17	odvi*	weight relation, george re	hamerstrom,fn,jr/	1950
JWMAA	11--4	349	350	odvi*	dressed weights, edible me	hamilton,wj,jr	1947
JWMAA	18--4	482	495	odvi	deer manage, mud lake wild	hunt,rw; mangus,l	1954
JWMAA	20--3	286	302	odvi	regional diff, size, produ	gill,j	1956
JWMAA	37--4	553	555	odvi	weight tape, deer in virgi	smart,cw; giles,/	1973
JWMAA	39--1	48	58	odvi*	morphol charact, crab orch	roseberry,jl; kle	1975
NYCOA	14---	30	31	odvi	big, little d, food is key	severinghaus,cw;/	1959

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	40--4	593	603	odhe	periodicity of growth, odo	wood,aj; cowan,i/	1962
JOMAA	45--1	48	53	odhe	three morpholog attrib, nm	anderson,ae; fra/	1964
WAEBA	589--	1	6	odhe	the mule deer carcass	field,ra; smith,/	1973

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
ATRLA	15---	253	268	ceel	relat age and size, poland	dzieciolowski,r	1970
JOMAA	27--4	308	327	ceel	mammals of northern idaho	rust,hj	1946
JWMAA	15--1	57	62	ceel*	weights, measurem, rock mt	quimby,dc; johnso	1951
JWMAA	24--1	15	21	ceel*	roosev elk afognak isl, al	troyer,wa	1960
JWMAA	30--1	135	140	ceel	meas, weight relat, manito	blood,da; lovaas,	1966
NAWTA	29---	237	248	ceel	weights, north yellowst el	greer,kr; howe,re	1964
WAEBA	594--	1	8	ceel	the elk carcass	field,ra; smith,/	1973

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CAFNA	81--4	263	269	alal*	weights, measurem, alberta	blood,da; mcgilli/	1967
JOMAA	27--1	90	91	alal	weights of a minnesota moo	breckinridge,wj	1946
JOMAA	50--2	302	310	alal*	odvi, struct adap for snow	kelsall,jp	1969

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
				rata			

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	34--2	470	472	anam	derivation of whole weight	o'gara,bw	1970
WAEBA	575--	1	6	anam	pronghorn antelope carcass	field,ra; smith,f/	1972

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
CJZOA	43--1	173	178	bibi	age criter, dres carc weig	novakowski,ns	1965
JOMAA	38--1	139	139	bibi	*live, dressed weights	halloran,af	1957
POASA	41---	212	218	bibi	weights, measure, oklahoma	halloran,af	1961

CODEN	vo-nu	bepa	enpa	anim	kewo	auth	year
JWMAA	22--4	444	445	ovca	*weights, measurem, dese bh	aldous,mc; craigh/	1958

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			

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

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

Linear regression equations for live weight:field dressed weight relationships have been determined for "normal" and "acorn" years in Michigan. Published equations in pounds have been converted to new equations for estimated live weight in kg (ELWK). They are (Hamerstrom and Camburn 1950):

1. Normal year: ELWK = 3.89 + 1.265 (FDWK)
2. Acorn year: ELWK = 1.19 + 1.251 (FDWK)

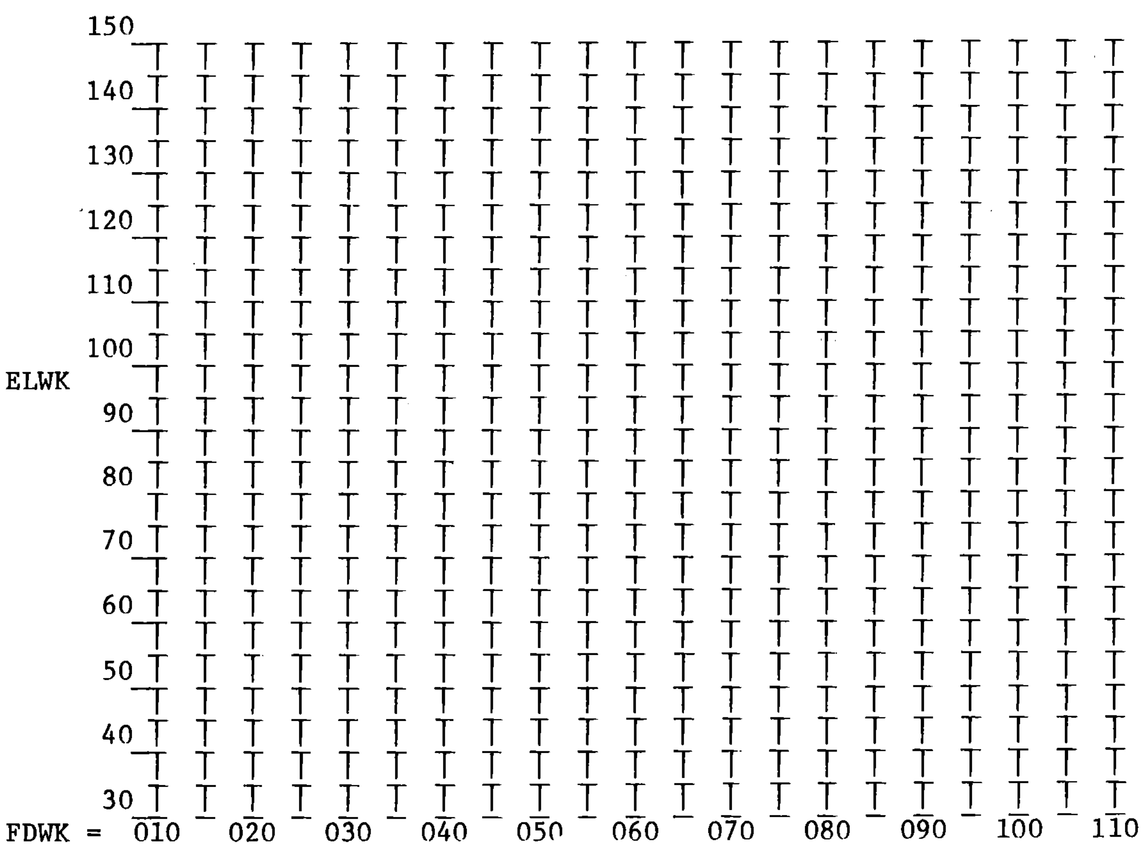
Severinghaus and Cheatum (1956) present an equation for New York deer on "good" range. The equation is:

3. ELWK = 1.89 + 1.249 (FDWK)

An equation by Hesselton and Sauer (unpublished) for the Seneca Army Depot and Dutchess County, New York, is:

4. ELWK = 1.61 + 1.238 (FDWK)

Since all of these equations are linear, it is necessary to calculate only two Y values to determine the line for each equation. Plot and label each of the lines on the graph below.



LITERATURE CITED

Hamerstrom, R and F. L. Camburn. 1950. Weight relationships in the George Reserve Deer Herd. J. Mammal. 31(1):5-17.

Severinghaus, C. W. and E. L. Cheatum. 1956. Pages 57-186 In Taylor, W. P., Ed., The Deer of North America. The Stackpole Company, Harrisburg, PA.

CHAPTER 1, WORKSHEET 1.5b

Stomach tissue weights of white-tailed deer (odvi)

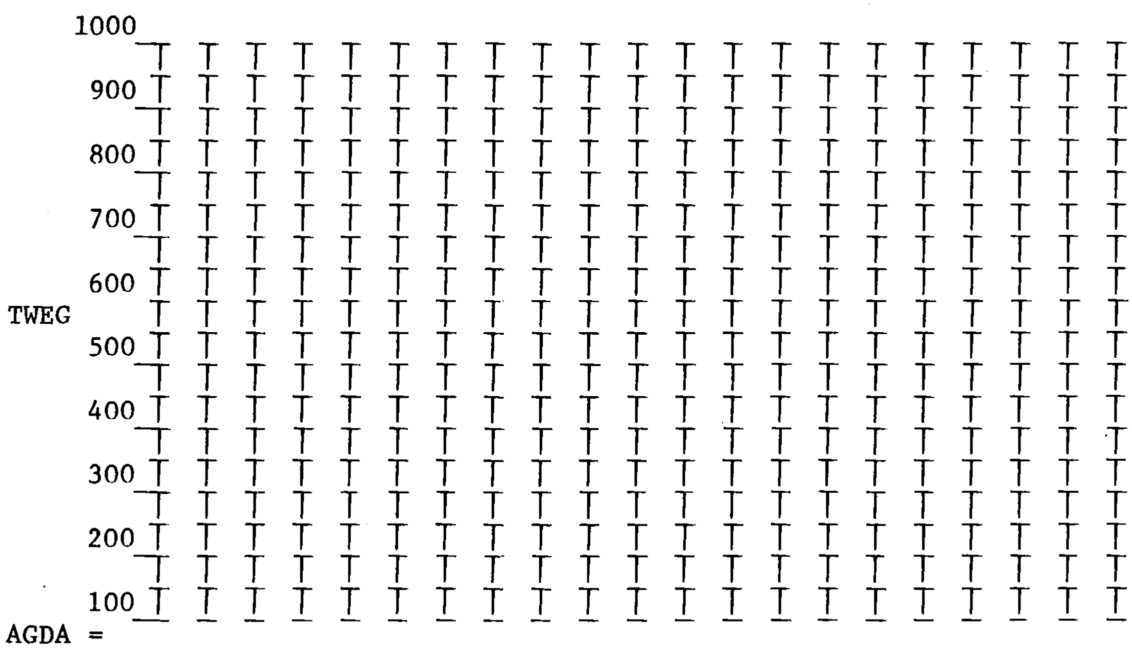
Weights of stomach tissue by parts given by Short (1964) are:

Tissue Weights in grams (TWEG)

AGMO	AGDA	Rumen	Reticulum	Omasum	Abomasum	SUMS
0	1	7	2	2	25	36
0.5	15	26	7	5	47	85
1.0	30	47	7	3	32	89
2.0	60	183	27	17	70	297
3.0	90	189	21	11	45	266
4.0	120	321	29	19	48	417

AGYE	AGDA	Rumen	Reticulum	Omasum	Abomasum	SUMS
1.5	548	845	64	58	101	1068
5.5	2008	935	75	102	145	1257

Label the x axis, plot the points and curve-fit the data to find the best-fitting equations.



LITERATURE CITED

Short, H. L. 1964. Postnatal stomach development of white-tailed deer. J. Wildl. Manage. 28(3):448.

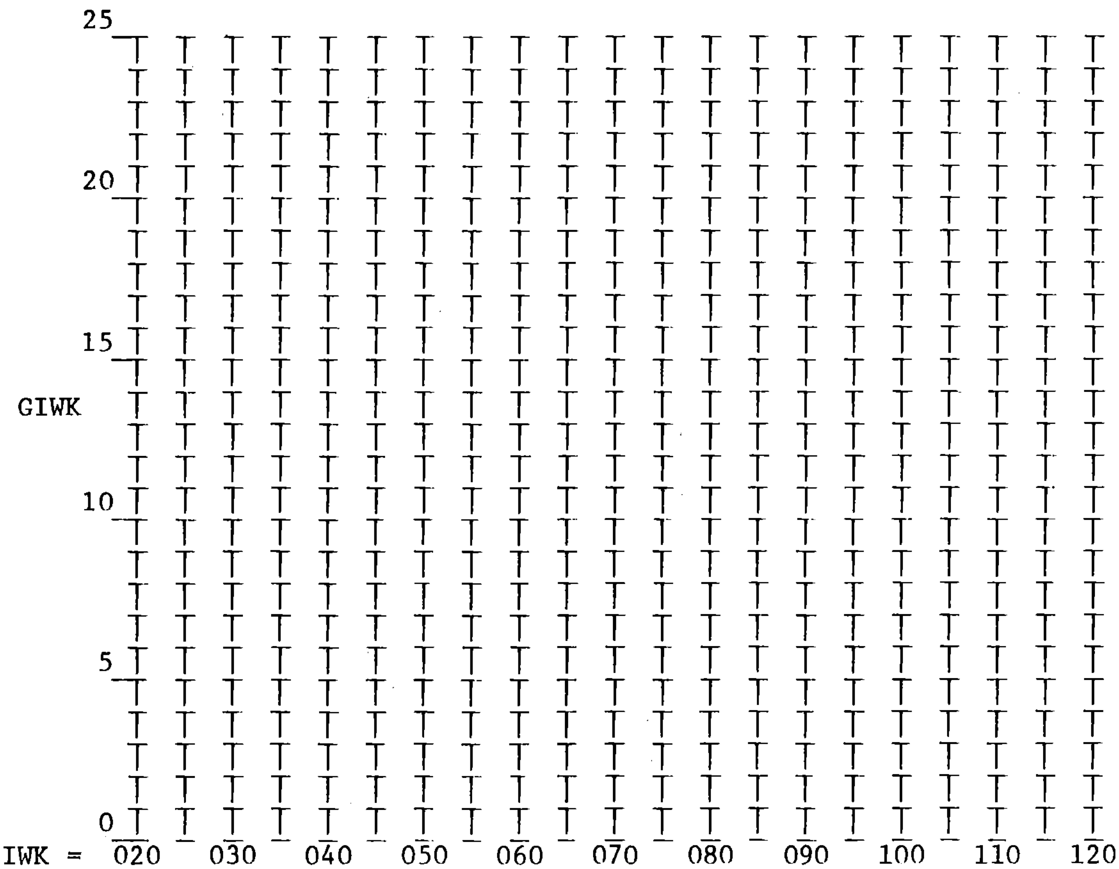
CHAPTER 1, WORKSHEET 1.5c

Gastrointestinal tract weights of white-tailed deer (odvi)

The weights of the gastrointestinal tract, including the 4-part stomach, small and large intestines, and rectum of white-tailed deer were obtained by Hamerstom and Camburn (1950). The equation expressing these gastrointestinal weights in kg (GIWK) in relation to live weight in kg (LIWK) is:

$$GIWK = 0.327 + 0.197\ LIWK$$

Calculate 2 points and draw the line below.



LITERATURE CITED

Hamerstrom, F. N. and F. L. Camburn. 1950. Weight relationships in the George Reserve deer. J. Mammal. 31(1):5-17.

CHAPTER 1, WORKSHEET 1.5d

Ingesta-free weights of white-tailed deer (odvi)

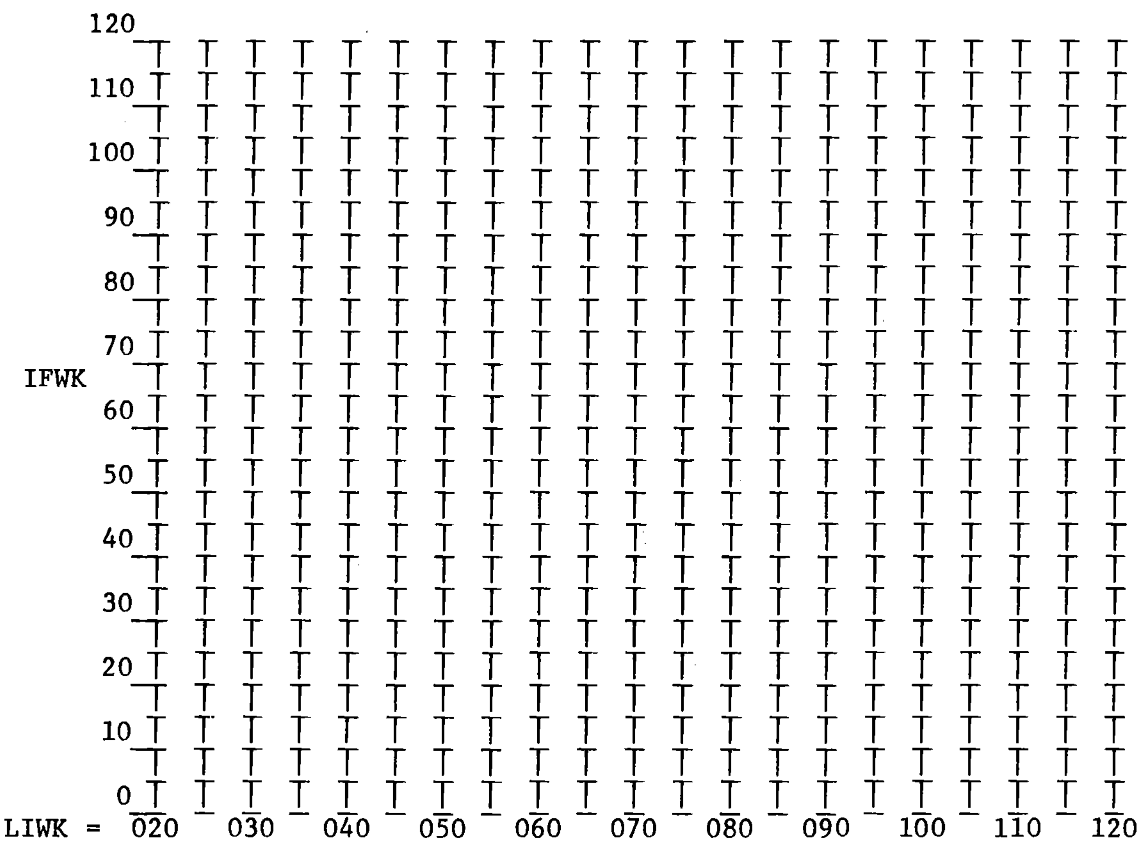
Ingesta-free weights in kg (IFWK) have been determined in relation to live weights in kg (LIWK) by Robbins et al. (1974). The exponential equation, rearranged from the published equation, is:

$$IFWK = e^{(0.9928 \ln LIWK - 0.0771)}$$

There is less than 1% error, however, when using the approximation,

$$IFWK = 0.9\ LIWK$$

Complete the calculations and plot the values for both equations. How much error is involved when using this equation as an approximation for a larger species, such as moose?



LITERATURE CITED

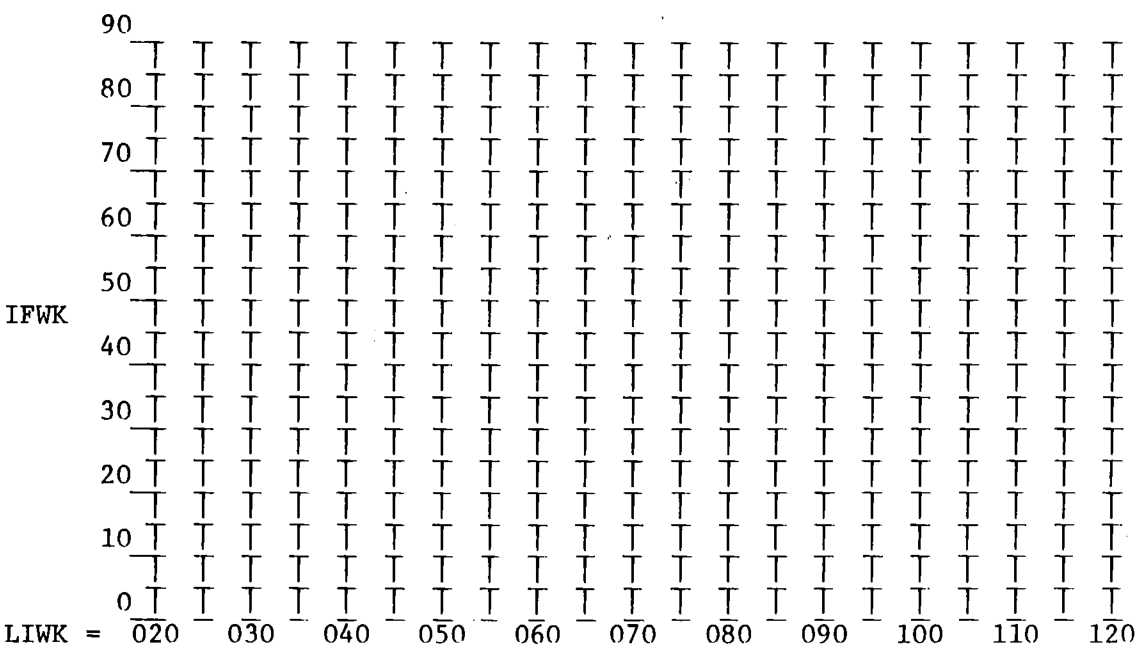
Robbins, C. T., A. N. Moen, and J. T. Reid. 1975. Body composition of white-tailed deer. J. Anim. Sci. 38(4):371-387.

CHAPTER 1, WORKSHEET 1.5e

Live weight: field-dressed and gastrointestinal tract weight relationships of white-tailed deer (odvi)

This worksheet illustrates the determination of the contributions of the weight of ingesta and gastrointestinal tract organs to the weight removed in field-dressing a deer.

The live weight of a deer less the field dressed weight = the weight of the ingesta and the organs removed in field-dressing. Equations have been presented for weights of ingesta and organs of the gastrointestinal tract. Subtract gastrointestinal organ ingesta weights as calculated in WORKSHEETS 1.5b and 1.5c from live weights and compare to the live weight: field dressed weight relationships described in WORKSHEET 1.5a. What are the sources of differences?



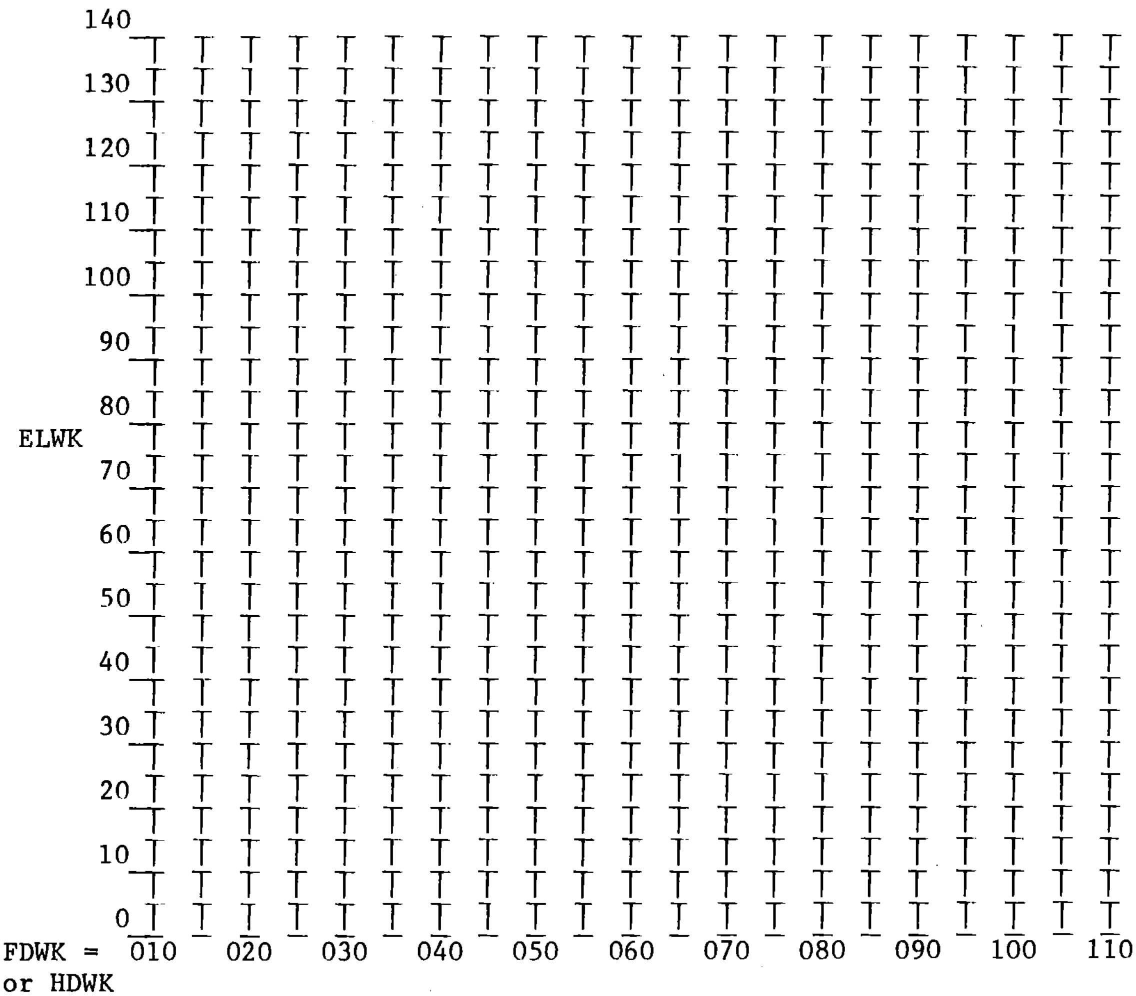
CHAPTER 1, WORKSHEET 1.5f

Live weight: field dressed: hog dressed weight relationships of white-tailed deer (odvi)

Field dressed weights have been used to estimate live weights with regression equations. Field-dressed weights generally include the weight of the carcass with the entrails removed, but with the heart, liver, and lungs left in. Hog-dressed weight refers to carcass weights with the entrails, heart, liver, and lungs removed.

Field dressed weights (FDWK) and hog dressed weights in kg (HDWK) may be used to derive estimated live weight in kg (ELWK) with the equations below, derived from data in the table in Cowan et al. (1968).

$$ELWK = 4.05 + 1.14\ FDWK$$
$$ELWK = 5.32 + 1.17\ HDWK$$



LITERATURE CITED

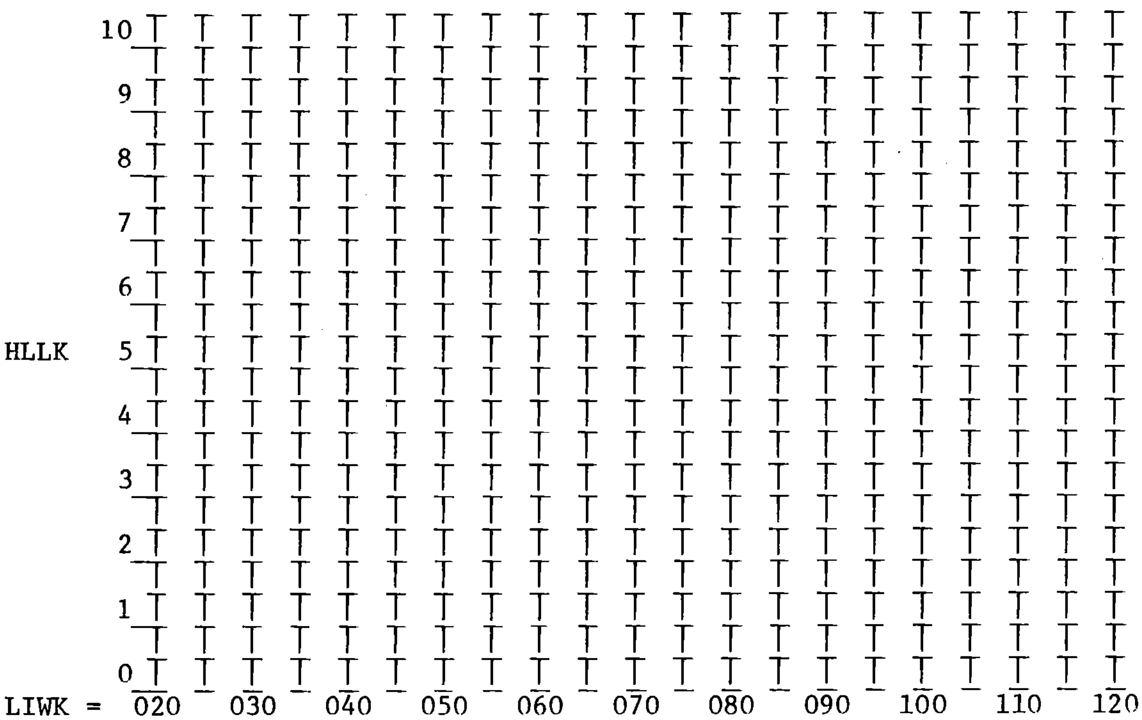
Cowan, R. L., E. W. Hartsook, J. B. Whelan, J. L. Watkins, J. S. Lindzey, R. W. Wetzel, and S. A. Liscinsky. 1968. Weigh your deer with a string. Pennsylvania Game News 39 (11): 17-18.

Heart, lung and liver weights in relation to live weight of white-tailed deer (odvi)

Heart, lungs, and liver weights in relation to live weight of white-tailed deer have been determined by Hamerstrom and Camburn (1950) for deer from the George Reserve, Michigan. The equation in kilograms (HLLK) is:

$$HLLK = 0.114 + 0.0525\ LIWK;\ r^2 = 0.8$$

Plot the relationship below.



LITERATURE CITED

Hamerstrom, R. and F. L. Camburn. 1950. Weight relationships in the George Reserve Deer Herd. J. Mammal. 31(1):5-17.