TOPIC 3. ESTIMATES OF ENERGY COSTS FOR PRODUCTION

Production results in the formation of new individuals (reproduction) and the deposition of new tissue by the individual (growth). Both of these productive functions are essential for the growth of the population. The growth rates of individuals often become indicators of the reproductive potentials of populations. Populations with smaller than average individuals will likely have lower than average reproductive rates because when requirements for a high rate of growth are not met, resources are not available for a high rate of reproduction. In white-tailed deer, for example, first conception becomes probable at a weight of about 40 kg. If a fawn does not attain this weight by its first winter, it is unlikely to reproduce until it is a yearling.

Inadequate nutrition during the gestation period may result in abortion, resorption of fetal tissue, or reduced fetal growth during the final stages of gestation. When fetal growth is reduced, the young weigh less at birth and have decreased chances of survival.

Inadequate maternal nutrition may impair lactation, possibly reducing the growth rate of the nursing young. Lactation is the single greatest sustained energy and protein requirement of mammals, and the major factor contributing to the high metabolic rate in the summer. The timing of this high cost is ecologically sound, however, as offspring are produced in late spring, just in time for the nursing dam to have access to a range with new growth as a source of nutrients for the costly process of lactogenesis.

While forage resources are more abundant and often quite digestible in the summer, this does not suggest that nutrients are unlimited on a green and growing range. Wild ruminants forage rather selectively, and will not consume any plant just because it is present. In fact, they often exhibit a high degree of selection not only for a particular plant species, but also for plant parts such as flowers. Ingestion of selected plant parts contributes to a higher quality diet (Whittemore and Moen 1980).

When nutrients are ingested in sufficient quantities to result in the production of new tissue, the nutrient balance is positive. The new tissue may be milk, which is made available to the dependent offspring whose growth may be at the expense of the body tissue of the lactating female. Weight curves have been calculated (CHAPTER 1) showing that annual minimum weights of lactating females occur at about the time of peak lactation.

LITERATURE CITED

Whittemore, S. and A. N. Moen. 1980. Composition and digestibilities of various forages of the white-tailed deer. Can. J. Anim. Sci. 60:189-192.

UNIT 3.1: THE ENERGY COST OF BODY GROWTH

Growth of wild ruminants that have not yet reached their full adult size occurs in the spring, summer and fall. Unbred yearlings may grow from spring through fall. Nursing young grow in the summer, and reproducing females will grow in late summer and fall as lactation demands are reduced. Antler and horn growth occurs in mature males from spring to early fall. The amount of growth is partially related to body weight and growth, so it is also related to range conditions, and partially related to the genetic potentials of the individual.

The cost of body growth is equal to the amounts of nutrients deposited plus the cost of synthesizing the tissue. These costs are directly dependent on tissue composition. Suppose that an animal gained 10 kg over a 100-day period. Suppose that 8 kg of this increase was water, 1.5 kg fat, and 0.5 kg protein. The energy increment in the animal's body is equal to 1.5 kg fat times 9,500 kcal per kg = 14,250 plus 0.5 kg protein times 5,500 kcal = 2750 kcal, totaling 17,000 kcal of tissue energy. This is 170 kcal per day.

One very important parameter must also be considered, and that is the efficiency of growth. If the efficiency were 50% in the example above, then the energy cost of tissue deposition would be equal to twice the energy in the tissue and the total cost would be 2 x 170 = 340 kcal. Efficiency of growth is related to physiologic age. But body composition is related to body weight and age, so the older and larger mammal, gaining less but depositing more fat, is depositing tissue with a higher caloric density. Thus while efficiency of growth goes down, changes in efficiency are reflected in changes in body composition. Examples illustrating how the cost of growth can be calculated on the basis of chemical composition and the cost of tissue synthesis are given in a WORKSHEET.

REFERENCES, UNIT 3.1

THE ENERGY COST OF BODY GROWTH

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	20--3	221	232	odvi	nutrit req, growth, antler	french,ce; mcewe/	1956
JWMAA	37--3	301	311	odvi	energ requiremnts of fawns	thompson,cb; hol/	1973
JWMAA	39--2	355	360	odvi	milk consumpt, weight gain	robbins,ct; moen,	1975
JWMAA	39--4	684	691	odvi	uterin comp, grow, pregnan	robbins,ct; moen,	1975
NAWTA	22---	119	132	odvi	nutrient requirements of	mcewen,lc; frenc/	1957
PAARA	209-1	1	11	odvi	eff feed restric, antl dev	long,ta; cowan,rl	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	22---	179	186	odhe	feed requirem, grow, maint	cowan,imct; wood/	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NATUA	215--	1134	1136	ceel	comparitive nutr, pregnanc	payne,pr; wheele/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	391	392	rata	energ metab, bar gro carib	mcewan,eh	1970
CJZOA	48--5	905	913	rata	seas chan, energ, nit inta	mcewan,eh; whiteh	1970

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

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

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

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

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

obmo

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

oram

CODEN-VO-NU-BEPA-ENPA-ANIM-KEWO					AUTH	YEAR
WLMOA	14---	1	78		pharm, physiol of restrain	hartoorn,am	1965

CHAPTER 7, WORKSHEET 3.1a

The energy cost of body growth

Experiments designed to measure the cost of body growth are not as easily completed on wild ruminants as on domestic ruminants. Estimates of the cost of growth may be made by determining change in weight over a specified time period, changes in body composition in relation to weight, and the caloric equivalents of the tissue involved. The steps are:

1. Subtract final weight from initial weight.

2. Determine body composition at final and initial weights and the amounts of each of the following:

    a. Water
    b. Fat
    c. Protein
    d. Ash

3. Multiply the change in the fat and protein components by their approximate combustion values (Brody 1945:35).

    Fat = 9.5 kcal per gm
    Protein = 5.7 kcal per gm

4. Add the energy contents of the fat and protein gain together and divide by the number of days between the initial and final weight used in Step 1.

5. Multiply the answer in Step 4 by the reciprocal of the efficiency (50% efficiency: 1/0.50 = 2; 33% efficiency: 1/0.33 = 3).

Specific equations for the energy cost of growth may be compiled from the weight equations and chemical composition equations in PART I.

LITERATURE CITED

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

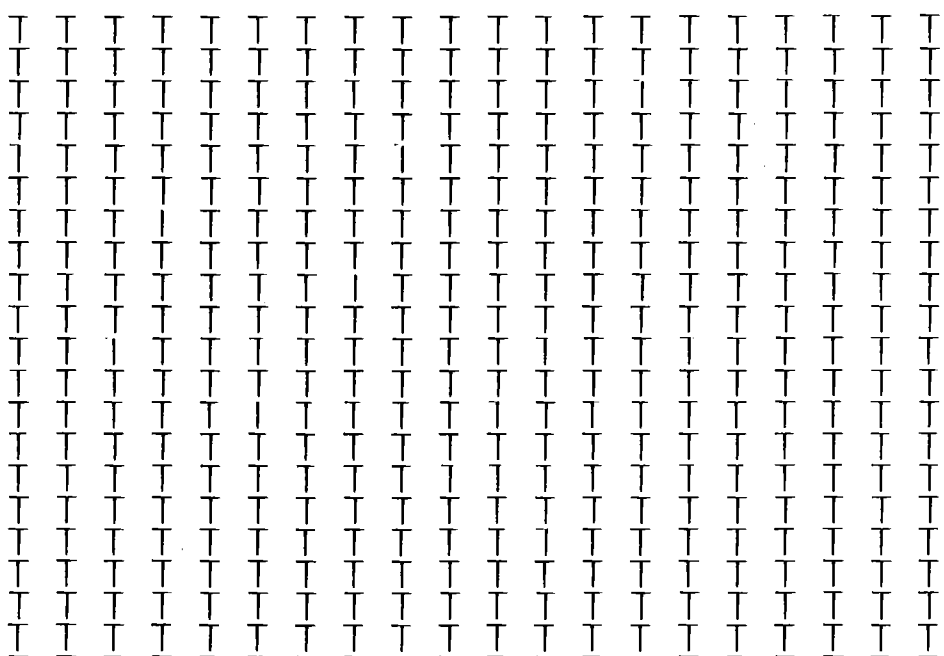
CHAPTER 7, WORKSHEET 3.1b

Total energy content of white-tailed deer
as a function of ingesta-free weight

The total energy content of white-tailed deer in relation to ingesta-free weight has been determined by Robbins et al. (1974), simplifying calculations of the cost of growth. Only slight differences were observed in males and females so a single equation may be used to estimate total caloric content in kcal (TCCK).

$$TCCK = e^{1.3720 \ln IFWK - 0.5876}$$

Using this equation and the seasonal weight equations in CHAPTER 1, the caloric content can be quickly determined after initial and final weights have been determined. Set up some weight differences based on the calculations in CHAPTER 1, UNIT 1.4, determine the daily change in energy content, and estimate the energy cost of these changes. Label and plot the results below. Differences in efficiencies may be represented as a family of curves.



LITERATURE CITED

Robbins, C. T., A. N. Moen and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.2: THE ENERGY COST OF HAIR GROWTH

The cost of hair growth may be determined in a manner similar to that for body growth. Time-periods of hair growth, amounts of hair, and chemical composition of the hair need to be known when making these calculations. These parameters were discussed in CHAPTER 2; calculations are illustrated in the WORKSHEETS.

REFERENCES, TOPIC 3.2

THE ENERGY COST OF HAIR GROWTH

SERIALS

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

JWMAA 38--4 871 876 odvi body composition of white- robbins,ct; moen, 1974

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

odhe

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

ceel

CODEN-VO-NU-BEPA-ENPA-ANIM-KEWO-----------------------AUTH--------------YEAR

alal

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

rata

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

anam

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

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

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	45--4	826	831	doca	hair indic calor-prot stat	haaland,gl; mats/	1977

CHAPTER 7, WORKSHEET 3.2a

The energy cost of hair growth of white-tailed deer

The energy cost of hair growth may be estimated by determining the weight of the hair coat, chemical composition, and caloric values of the hair to give the energy content of the hair coat. The daily cost may be estimated by multiplying the energy content by the reciprocal of the efficiency of hair growth and dividing by the numbers of days during which the hair growth occurred. The formula may be written as:

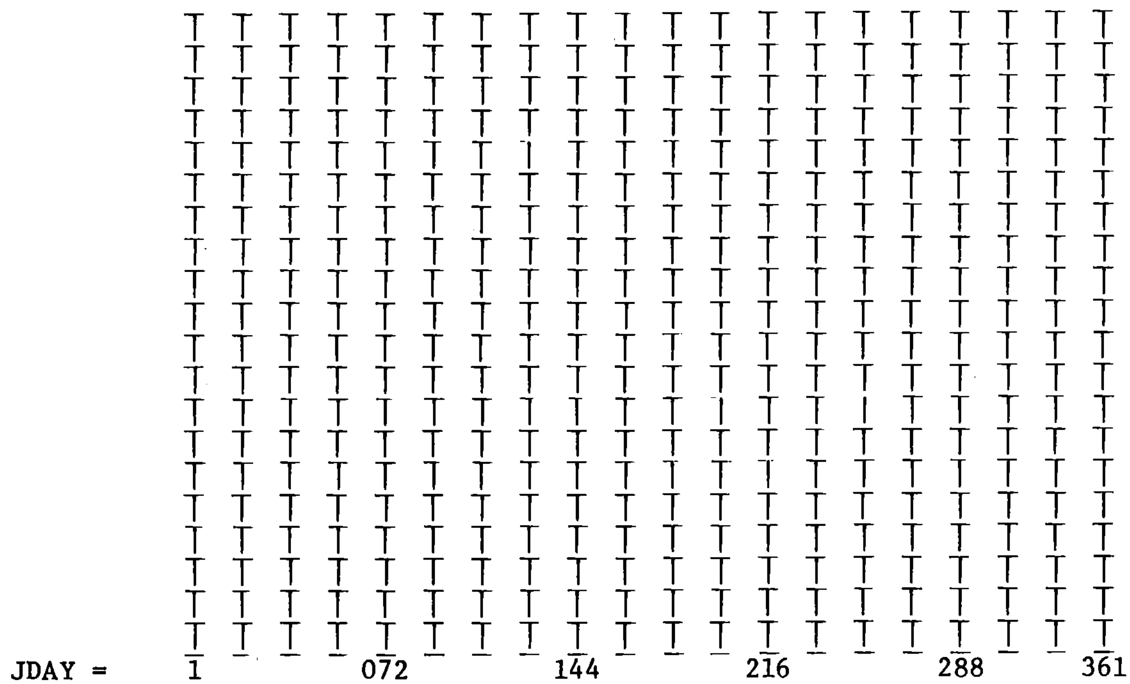
$$ECHD = \left\{[(HAWG)(FACO)(9.74) + (HAWG)(PRCO)(5.61)]\ 1/PEHG\right\} /DHGD$$

where ECHD = energy cost of hair growth per day
HAWG = hair weight in grams
FACO = fat content expressed as a decimal fraction = 0.098
PRCO = protein content expressed as a decimal fraction = 0.890
PEHG = physiological efficiency of hair growth expressed as a decimal fraction
DHGD = duration of hair growth in days

The caloric values and fat and protein contents are taken from Robbins et al. (1974). HAWG is determined from WORKSHEET 1.3b in CHAPTER 2. PEHG is a variable, and DHGD is dependent on the biochronology of the species or population group being considered.

Calculate and plot HAWG and ECHD on the next page, labeling the y-axis with the appropriate units of measurement. The effects of different physiological efficiencies of hair growth may be expressed with a family of curves.

How much does variation in PEHG contribute to variation in ecological metabolism? This question may be answered after all of the maintenance, activity, and production costs have been considered and ecological metabolism per day (ELMD) determined. Completion of the WORKSHEETS in this CHAPTER will enable the user to evaluate the cost of any process in relation to the total.



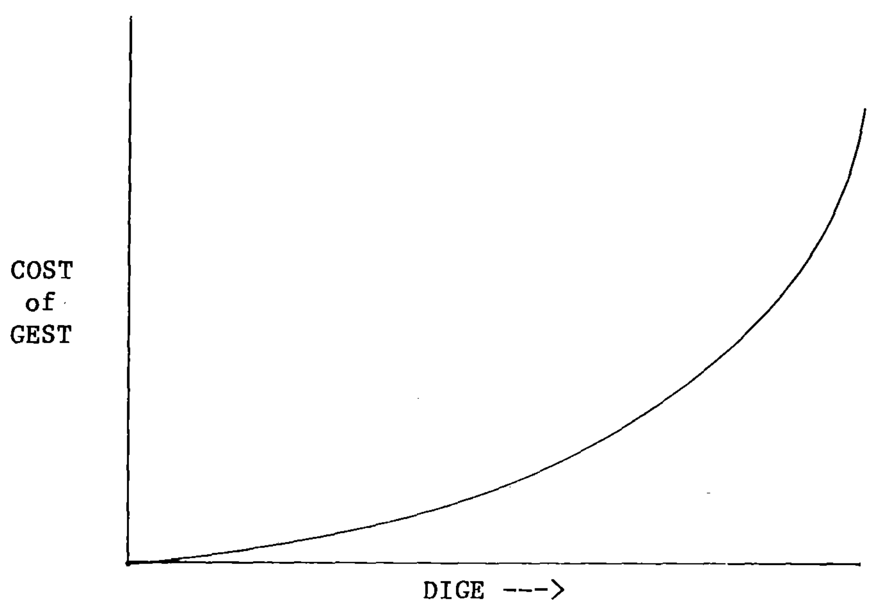
LITERATURE CITED

Robbins, C. T., A. N. Moen and J. T. Reid. 1974. Body composition of white-tailed deer. J. Anim. Sci. 38(4):871-876.

UNIT 3.3: THE ENERGY COST OF GESTATION

Accelerating requirements for gestation must be met in the last one-third of pregnancy. This acceleration generally coincides with the period of renewed plant growth, although differences in the lengths of winters result in different times of renewed plant growth from year to year. A late-arriving spring may have considerable effect on the condition of pregnant females during the last one-third of pregnancy (see Moen 1978). Conception occurs in the fall, and its timing is not related to the termination of winter several months later, of course. High conception rates may be followed by reduced birth rates if winter conditions are extended.

Increases in the requirements for gestation are related to increases in fetal growth and in the energy content of the uterus and associated reproductive tissues. The trends are illustrated below; curve-fitting of actual data may result in logarithmic, exponential, or power curves. Costs for associated uterine tissues increase in the same way, and are added to the costs of fetal growth to determine the total energy cost of gestation.



Calculations of the cost of gestation are made in the WORKSHEETS, with equations given for white-tailed deer and proportionalities described for other species.

LITERATURE CITED

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. J. Wildl. Manage. 42(4):715-738.

REFERENCES, UNIT 3.3

THE ENERGY COST OF GESTATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	43--3	650	666	odvi	fetal develop, white-taile	armstrong,ra	1950
JOMAA	47--2	266	280	odvi	endoc glan, seas, sex, age	hoffman,ra; robin	1966
JWMAA	33--3	482	490	odvi	dig energ req, wintr, does	ullrey,de; youat/	1969
JWMAA	34--2	383	388	odvi	morphol develop, aging, fe	short,c	1970
JWMAA	34--4	863	869	odvi	dig, met ener, wintr, does	ullrey,de; youat/	1970
JWMAA	39--4	684	691	odvi	uterin comp, grow, pregnan	robbins,ct; moen,	1975
JWMAA	42--4	715	738	odvi	seas chan, heart rate, act	moen,an	1978
NAWTA	28---	431	443	odvi	nutrit, growth, fetal, faw	verme,lj	1963
NAWTA	22---	119	132	odvi	nutrient requirements of w	mcewen,lc; frenc/	1957
VJSCA	23--3	116	116	odvi	aspects of early pregnancy	scanlon,pf; murp/	1972
VJSCA	24--3	112	112	odvi	ovula, pregnan, lactat dee	scanlon,pf; murp/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--1	123	132	odhe	development, fetal period	ommundsen,p; cowa	1970
JWMAA	23--3	295	304	odhe	embryo, fetal development	hudson,p; browman	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--6	1418	1419	ceel	sexual dimorphism, fetuses	retfalvi,l	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--5	905	913	rata	seas chan, energ, nit inta	mcewan,eh; whiteh	1970

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	46--3	524	525	ovca	fetal measure, milk charac	forrester,dj; sen	1965

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	114-1	101	116	ungu	matern repro effort, fetal	robbins,ct; robbi	1979

CHAPTER 7, WORKSHEET 3.3a

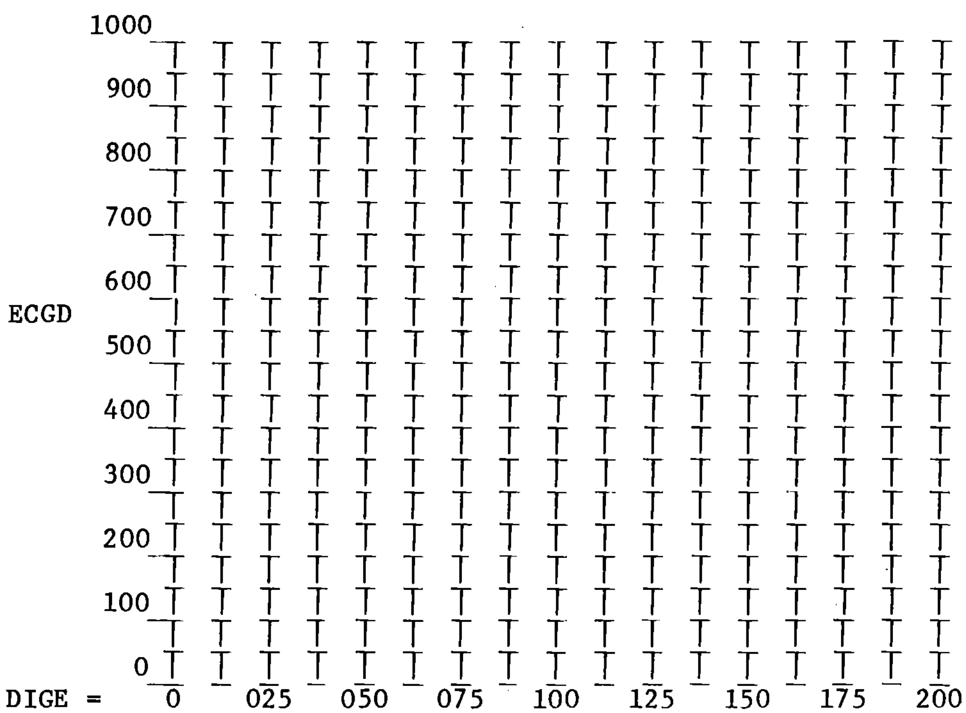
The energy cost of gestation in white-tailed deer

The energy cost of gestation is equal to the energy deposited in the gravid uterus each day times the efficiency of the physiologic processes involved. The energy content of the gravid uterus has been determined by Robbins and Moen (1975), and may be used to calculate the energy cost of gestation with the following equation.

$$ECGD = (e^{0.2803 + 0.0282\ DIGE})(1/PEGE)$$

where ECGD = energy cost of gestation per day,
DIGE = days into gestation, and
PEGE = physiological efficiency of gestation

Plot ECGD below, expressing PEGE as a family of curves again.



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.

CHAPTER 7, WORKSHEET 3.3b

The energy costs of gestation in several species of wild ruminants

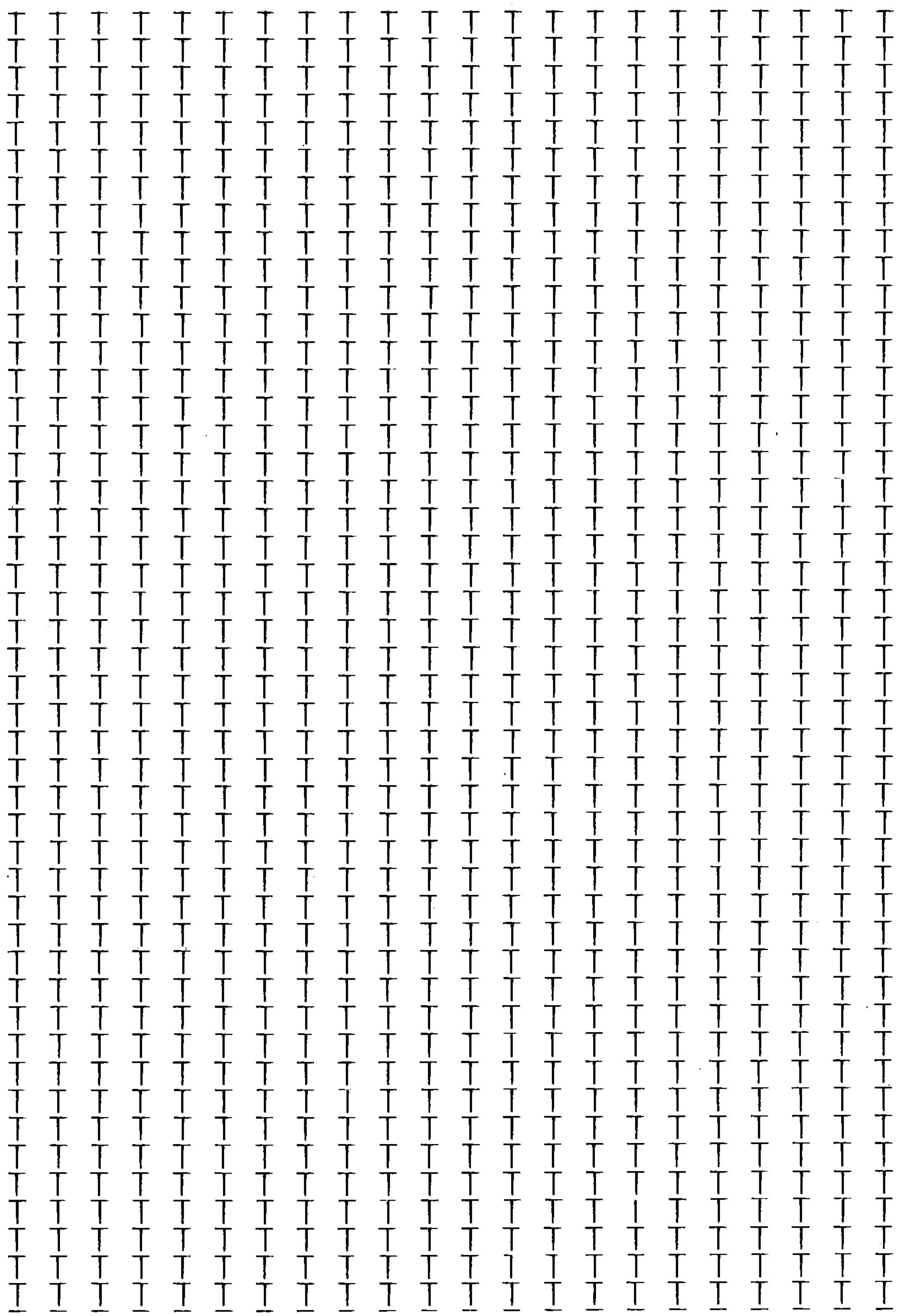
The energy costs of gestation have been estimated for several species of wild ruminants in Robbins and Moen (1975) by considering the costs for these species to be proportional to the costs for deer. Fetal weights and lengths of the gestation period vary, of course.

The equations for estimating ECGD for different species, modified modified from those in Robbins and Moen (1975), are listed below.

Species	Equation	LEGP
ceel:	$ECGD = (e^{0.0193\ DIGE\ -\ 1.7938})(1/PEGE)$	260
alal:	$ECGD = (e^{0.0204\ DIGE\ -\ 1.7358})(1/PEGE)$	245
rata:	$ECGD = (e^{0.0226\ DIGE\ -\ 1.6198})(1/PEGE)$	220
anam:	$ECGD = (e^{0.0209\ DIGE\ -\ 1.7140})(1/PEGE)$	240
bibi:	$ECGD = (e^{0.0173\ DIGE\ -\ 1.9036})(1/PEGE)$	290
ovca:	$ECGD = (e^{0.0334\ DIGE\ -\ 1.2443})(1/PEGE)$	150
oram:	$ECGD = (e^{0.0278\ DIGE\ -\ 1.4281})(1/PEGE)$	180

Complete the numbering of the x and y axes and plot the energy costs of gestation on the grid on the next page. Note again that different physiological efficiencies may be expressed a a family of curves.

ECGD



DIGE =

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.

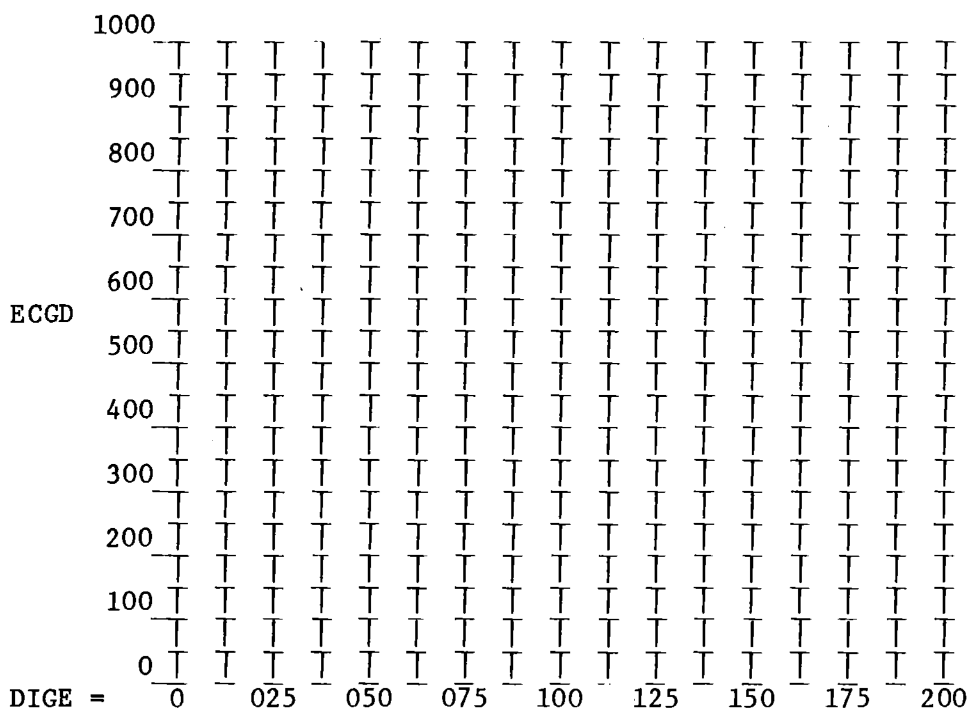
The energy costs of gestation in relation to days into gestation and fetal weight at birth

The two previous WORKSHEETS have included equations for selected species with averge fetal weights and gestation periods built into the equations. An alternative equation in Robbins and Moen (1975) may be used to provide the flexibility needed when applying the proportional costs to any species. The formula for calculating the energy contents of the uterus and contents (kcal) per fetal weight at parturition (kg) is:

$$\text{ECGD} = \left\{ \left[e^{(2.1548 + 5.01\,(\text{HIGR DIGE}/\text{LEGP})} \right] - \left[e^{(2.1548 + 5.01(\text{LOWR DIGE}/\text{LEGP})} \right\} (\text{BIWK}) / (\text{HIGR DIGE} - \text{LOWR DIGE})(1/\text{PEGE})$$

where ECGD = energy cost of gestation per day
HIGR DIGE = higher number of days into gestation
LOWR DIGE = lower number of days into gestation
LEGP = length of the gestation period
BIWK = birth weight in kg
PEGE = physiological efficiency of gestation

Make the calculations for selected species with different birth weights and evaluate the daily costs associated with gestation. The results may be plotted below.



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.

UNIT 3.4: THE ENERGY COST OF MILK PRODUCTION

Milk production has been mentioned several times already as a very costly biological process. One might come to this conclusion simply by observing the condition of lactating females; they are often in the worst condition of the year during the lactation period. The weight pattern shows minimum weights during the lactation period, and it is well known that if milk production of dairy cattle is to remain high, a high quality ration must be fed in large quantities.

If milk production is the most costly sustained biological process there is, then it is imperative that ways be found to quantify the cost. Direct measurements of milk production might be made by actually milking the animal, but this is difficult because wild ruminants are not inclined to stand while being milked. Further, milk production is partly dependent on the demand for milk, and this varies with the suckling young as they grow and their diet includes increasing amounts of forage. Since the demand of the young for milk cannot be duplicated by hand-milking the female, estimates of milk production obtained in this way will not be accurate.

Animals in captivity might be weighed before and after nursing, and either the dam's weight loss or the sucklings' weight gain measured. Scales sufficiently large to weigh the dam before and after nursing are not accurate enough to weigh the difference in her weights, however. The suckling animal often urinates and defecates while nursing--the dam usually licks the anal region to stimulate release--so accurate measurements of milk intake are difficult to make. Furthermore, it is difficult to be present to weigh the animals each time the young nurse, which could be several times a day.

The only practical way to determine milk production of wild ruminants is by mathematical means. There is a fundamental relationship that can be considered the basis for mathematical calculations, and that is that the milk production of the females of a species will be adequate to supply that portion of the nutrients derived from milk by the young of that species to meet their total metabolic costs for growth and activity. The amount of nutrients supplied by the milk varies as the rumen develops and the young become increasingly more dependent on forage for nutrients. This mathematical approach, then, requires a knowledge of three things, including the rate of rumen development so that the ratio of milk nutrients: forage nutrients is known, the chemical composition of the milk, and the ecological metabolism of the nursing young. These were discussed in earlier chapters, and they can be assembled here in WORKSHEETS to calculate the cost of milk production.

REFERENCES, UNIT 3.4

THE ENERGY COST OF MILK PRODUCTION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	cerv	composi milk, cerv species	arman,p; kay,rnb/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	24--4	439	441	odvi	rearing, breedi fawns, cap	murphy,da	1960
JWMAA	25--1	66	70	odvi	deer milk, substitute milk	silver,h	1961
JWMAA	29--1	79	84	odvi	comp milk,bld nursng doe,f	youatt,wg; verme/	1965
JWMAA	37--3	301	311	odvi	energ requiremnts of fawns	thompson,cb; hol/	1973
JWMAA	39--2	355	360	odvi	milk consumpt, weight gain	robbins,ct; moen,	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	odhe	composit, deer milk, calif	hagen,hl	1951
JOMAA	36--3	473	474	odhe	mule deer milk	browman,lg; sears	1955
JOMAA	58--3	420	423	odhe	changes nutri compos, milk	mueller,cc; sadle	1977
JWMAA	20--2	212	214	odhe	postnat grow, comp of milk	kitts,wd; cowan,/	1956
JWMAA	44--2	472	478	odhe	milk yield, black-tailed d	sadleir,rmfs	1980

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	37--1	67	84	ceel	comp, yield of milk, red d	arman,p; kay,rnb/	1974
JWMAA	40--2	330	335	ceel	nutrition, gestat, reprodu	thorne,et; dean,/	1976
ZTTFA	31--5	227	238	ceel	comp, milk, red deer, pt 1	brueggemann,j; d/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--2	213	215	alal	gros comp milk, fat, minrl	cook,hw; rausch,/	1970
JWIDA	12--2	202	207	alal	milk, hair, element relati	franzmann,aw; fl/	1976
NCANA	101-1	227	262	alal	review of energy requireme	gasaway,wc; coady	1974
PNUSA	27--2	129	138	alal	compar nut in preg, lactat	payne,pr; wheele/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	45--6	1101	1106	rata	milk, gros comp, fat, prot	hatcher,vb; mcew/	1967
CJZOA	49--4	443	447	rata	measurement milk intake, r	mcewan,eh; white/	1971
JDSCA	57-11	1325	1333	rata	milk comp chang, grazing r	luick,jr; white,/	1974
ZOBIA	32--6	746	750	rata	alal, electroph, milk prot	shubin,pn; turub/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	37--2	217	218	anam	odhe, compos milk, compars	hagen,hl	1951
JWMAA	34--4	908	912	anam	enrgy flux, water kinetics	wesley,de; knox,/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--2	305	308	bibi	the lipids in bison bison	wilbur,cg; gorski	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	41--2	131	143	ovca	rearing lambs in captivity	deming,ov	1955
CJZOA	43--5	885	888	ovca	milk, gross comp, fat cons	chen,ech; blood,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	48--4	629	633	ovda	milk, stage lact, composit	cook,hw; perarso/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	34--6	569	571	obmo	gross composition of milk	tener,js	1956
CJZOA	48--6	1345	1347	obmo	gros comp,ftty acid, minrl	baker,be; cook,h/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	47--1	5	8	oram	gross compos, fat acid con	lauer,bh; blood,/	1969
CJZOA	47--2	185	187	oram	miner const, milk, arctic	luer,bh; baker,b	1969

CHAPTER 7, WORKSHEET 3.4a

The energy cost of milk production in white-tailed deer

The energy cost of milk production may be estimated if the quantity of milk being produced is known. Estimates of the latter may be made with an equation in Moen (1973:355), modified to include new terms and parameters. The formula is:

$$MPGD = [(MBLM)(70)(MEWK)]\ [(PNDM)(1/NECM)/GENM]$$

where MPGD = milk production in gms per day
MBLM = multiple of base-line metabolism
MEWK = metabolic weight in kg
PNDM = percent nutrients derived from milk = [1.136 - 0.045 LWKG]
NECM = net energy coefficient for milk
GENM = gross energy in the milk

The formula can be used only if numerical values for each of the paramaters are available. The first one needed, MBLM, has not been discussed in the ecological context yet (see TOPIC 6). The MBLM of resting fawns was usually between 2.10 and 2.25 (see CHAPTER 7, WORKSHEET 1.1a). The MBLM for ecological metabolism of suckling fawns is discussed in CHAPTER 7, UNIT 6.1. In the absence of a derived MBLM, MBLM = 2.5 may be used as a first approximation.

MEWK is the metabolic weight, or $IFWK^{0.75}$, where IFWK is the ingesta-free-weight of the fawns. Growth and weights were discussed in CHAPTER 1.

PNDM is an expression for determining the percent nutrients derived from milk, a function of rumen development. Derivation of this equation is discussed in Moen (1973:342).

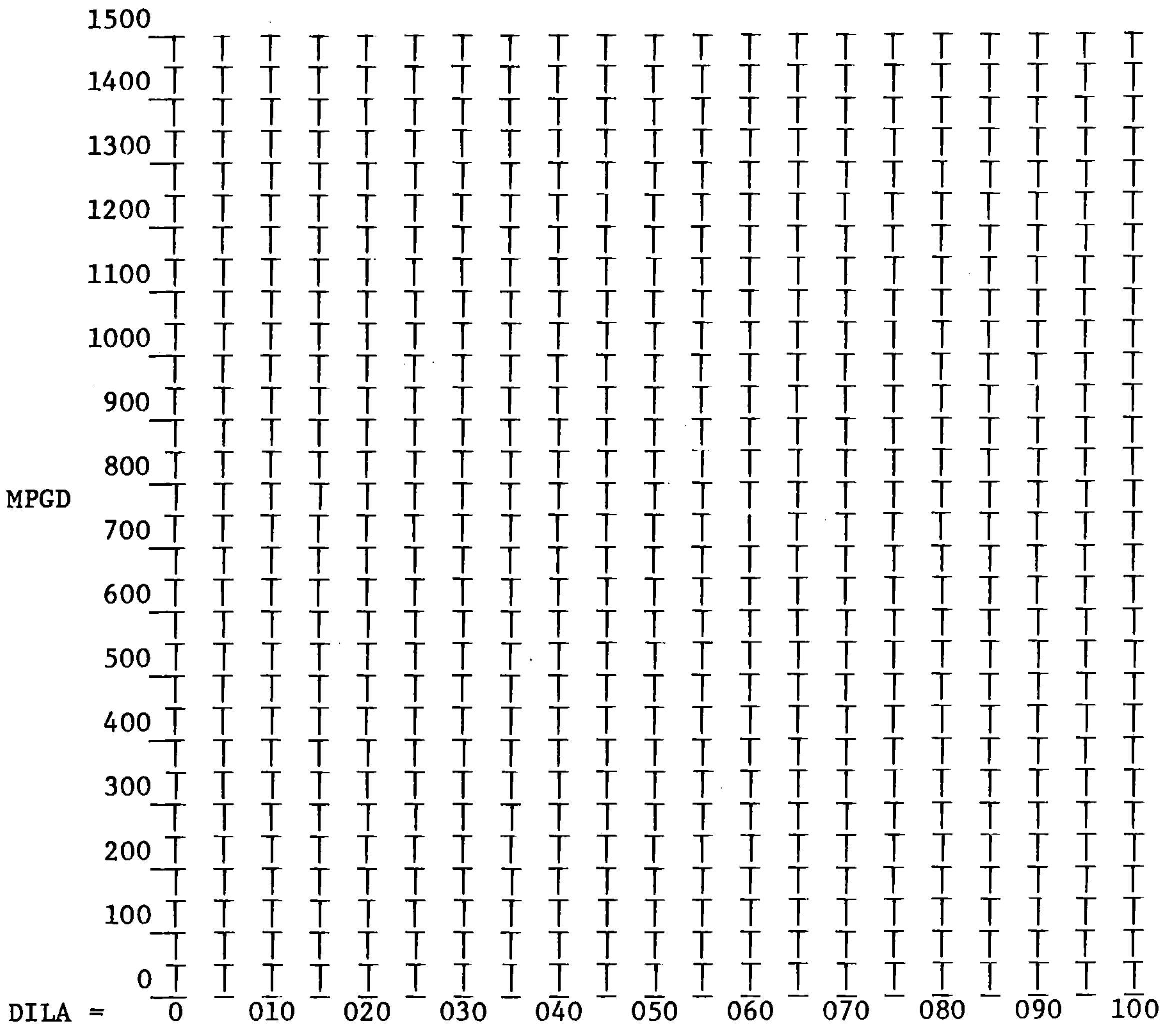
NECM is an expression of gross to net energy efficiency, including both the digestible energy and metabolizable energy coefficients.

GENM, the gross energy in the milk, may be measured directly or determined from the chemical composition of the milk, especially fat percent (FATP). FATP may be calculated with an equation derived from data in Youatt et al. (1965).

$$FATP = 1.036\ e^{(-1.0117)(DILA)};\ R^2 = 0.995$$

where FATP = fat percent and
DILA = days into lactation.

Using the equation in CHAPTER 2, WORKSHEET 2.2b, p. 46b, GENM may be estimated from FATP. MPGD may then be calculated by substituting these numbers and equations in the formula near the top of this WORKSHEET. A grid is provided on the next page for plotting the results.



LITERATURE CITED

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

Youatt, W. G., L. J. Verme, and D. E. Ullrey. 1965. Composition of milk and blood in nursing white-tailed does and blood composition of their fawns. J. Wildl. Manage. 29(1):79-84.