PART VI. POPULATIONS AND THE CONCEPT OF CARRYING CAPACITY

A large amount of attention has been given to populations and carrying capacities by wildlife managers. Management efforts are generally directed toward keeping numbers within the carrying capacity of a range. For wild ruminants, this usually means that numbers are in balance with the food supply. In the early years of management, neither numbers nor the quantity of forage were known, but the conditions of the range could be evaluated by those with experience in the field. Now, subjective evaluations are not enough. Biologists and managers are expected and sometimes required by law to have reasonable estimates of numbers. This is a difficult assignment as no simple field method for making population estimates exists.

The three CHAPTERS in this PART VI include information on the population characteristics that result in population growth curves, and on the factors causing deviations from an idealized population growth curve. Characteristics of individuals--weight, metabolism, reproductive potentials, thermal exchange, forage intake, and more--have been discussed in PARTS I through V, and the effects of changes in these characteristics are evaluated in relation to changes in populations in this PART VI. This approach results in an understanding of the roles of variations in these factors in the population dynamics of wild ruminants. Further, management decisions are often based on the effects of these variations. A severe winter, for example, alters the age, weight, metabolic, and reproductive structures of a wild ruminant population, and changes in hunting regulations are often made as a result of these changes.

The different roles of various members of a population of wild ruminants affect the carrying capacity of the range. Rather than consider carrying capacity as "a minimum number . . . , " it should be considered as a dynamic concept, a balance between resources required and resources provided. This approach, discussed in Moen (1973), recognizes the different roles of various members of a population and allows one to evaluate the effects of different population structures on changes in balances of resources required and resources supplied.

This PART includes CHAPTER 18, POPULATION STRUCTURES, CHAPTER 19, POPULATION ESTIMATES AND PREDICTIONS, and CHAPTER 20, CALCULATIONS OF CARRYING CAPACITY. These chapters include methods for determining the effects of differences in the characteristics and requirements of wild ruminants in relation to range characteristics, all of which have been discussed in the previous PARTS.

LITERATURE CITED

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

REFERENCES, PART VI

POPULATIONS AND THE CONCEPT OF CARRYING CAPACITY

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS-EDITORS--	YEAR
aubo	rokp	loen	597	cerv	deer of g. britain, irelan	whitehead,gk	1964
aubo	huho	nyny	426	od--	deer & antelope of america	caton,jd	1877
edbo	stac	hapa	668	od--	the deer of north america	taylor,wp,ed	1956
aubo	stac	hapa	128	od--	if deer are to survive	dasmann,w	1971
aubo	omcc	eail	107	odvi	the white-tailed deer	madson,j	1961
edbo	nhfg	conh	256	odvi	the white-tai deer, new ha	siegler,hr	1968
aubo	ucap	beca	567	odhe	a herd of mule deer	linsdale,jm; tomi	1953
aubo	stac	hapa	386	ceel	elk of north america	murie,oj	1959
aubo	wiwe	eail	125	ceel	the elk	madson,j	1966
aubo	ucap	beca	209	ceel	tule elk	mccullough,dr	1971
aubo	utop	toon	280	alal	north american moose	peterson,rl	1955
aubo	macm	nyny	300	rata	bar-gr car of north canada	pike,w	1892
aubo	ukap	laka		rata	bar-ground carib, keewatin	harper,f	1955
edbo	uaec	ortn	1250	rata	envir of cape thomp, alask	wilimovsky,nj,ed	1966
aubo	qupr	oton	339	rata	migratory, barren-ground c	kelsall,jp	1968
aubo	stac	hapa	238	anam	the pronghorn antelope	einarsen,as	1948
aubo	utop	toon	957	bibi	the north american buffalo	roe,fg	1951
aubo	thcr	nyny	242	bibi	the buffalo	haines,f	1970
aubo	aakn	nyny	339	bibi	time of the buffalo	mchugh,t	1972
aubo	swap	atoh	374	bibi	the buffalo book, saga ani	dary,d	1974
aubo	coup	itny	248	ov--	mt sheep, man, norther wil	geist,v	1975
edbo	bccl	pipa		ov--	the wild sheep, north amer	trefethen,jb	1975
aubo	usgp	wadc	242	ovca	the bighorn of death valle	welles,re; welles	1961
aubo	usfw	wadc	8	ovca	desert bighorn sheep	anonymous	1966
aubo	qupr	oton	166	obmo	muskoxen in canada	tener,js	1965
aubo	ropr	nyny	129	many	wildlife in alaska, ecolog	leopold,as; darli	1953
aubo	rmna		75	many	range relatnships: lit rev	capp,jc	1968
aubo	blsp	loen	308	many	guide, study of productivi	golley,fb; buechn	1968
aubo	whfr	sfca	458	many	wildlife ecology	moen,an	1973
aubo	utop	toon	438	many	the mammals of canada	banfield, awf	1974

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS-EDITORS--	YEAR
aubo	saco	phpa	837		principles of anim ecology	allee,wc; emerso/	1949
aubo	dove	nyny	465		elements of mathemati biol	lotka,aj	1956
aubo	prup	prnj	342		dynamic programming	bellman,r	1957
aubo	saco	phpa	546		fundamentals of ecology	odum,ep	1959
aubo	isup	amia			of predation and life	errington,pl	1967
edbo	oost	neth	611		phenom, preda order, natur	den boer,pj; grod	1970
aubo	wbsc	phpa	574		fundamentals of ecology	odum,ep	1971
aubo	grpc	lmia	130		time to cry wolf	mccann,lj	1972
aubo	hapr	nyny	506		estimati, animal abundance	seber,gaf	1973
edbo	acpr	loen	358		p 183-246, appli biol, v 1	cosher,th,ed	1976
aubo	dohr	stpa	361		biblio of quantita ecology	schultz,vll; ebe/	1976
aubo	utnp	kntn	186		guides, study of anim popu	tanner,jt	1978

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	22--3	155	246	od--	od distrib & variat, calif	cowan,im	1936

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	67--1	45	64	odvi	kinds of odocoileus, arizo	hoffmeister,df	1962
BLJYA	24...	194	194	odvi	near ft smith, nrth w terr	kuyt,e	1966
JOMAA	21--3	271	282	odvi	newly located herd, pacifi	scheffer,vb	1940
JOMAA	40--2	251	252	odvi	furth incidenc in colorado	harrington,fa,jr	1959
JOMAA	44--4	518	522	odvi	do they occur in n e calif	adams,l	1963
JOMAA	53--4	907	909	odvi	range extension, se washin	o'farrell,tp; hed	1972
WLMOA	15...	1	62	odvi	ecol, manage, llano b, tex	teer,jg; thomas,/	1965

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	36--4	343	365	odhe	in chaparral forest, calif	cronemiller,ep; /	1950
JWMAA	24--3	265	271	odhe	cassia herd of south idaho	mcconnell,br; dal	1960

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	97--1	230	232	ceel	prehistori range extension	curren,cb,jr	1977
TWASA	43---	5	23	ceel	the elk in early wisconsin	schorger,aw	1954
VILTA	3---3	177	376	ceel	stud, scandin; ecol invest	ahlen,i	1965
WLMOA	16---	1	49	ceel	status and ecology, califo	harper,ja; harn,/	1967
WLMOA	23...	1	66	ceel	the sun river elk herd	knight,rr	1970

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	34...	396	397	alal	n amer's most westerly moo	brooks,jw	1953
JOMAA	49--3	528	529	alal	occu near pt barrow, alask	chesemore,dl	1968
JOMAA	53--1	129	138	alal	northern limits in w canad	kelsall,jp	1972
NCANA	101-1	51	65	alal	distribu, habitat & status	dodds,dg	1974
NCANA	101-1	81	100	alal	dist, hab selec in nc n am	krefting,lw	1974
NTRLA	21...	38	41	alal	wilderness moose	peek,jm	1970
WSCBA	29...	16	17	alal	the moose returns	dahlberg,bl	1964

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	49--2	344	345	rata	archaeol evid in ny & mass	guilday,je	1968
NCANA	83	225	234	rata	hstry, dist, anal pop, mgt	moisan,g	1956
PCZOA	1	206		rata	postglac dispersal, americ	banfield,awf	1964

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDW-----------------	AUTHORS----------	YEAR
BNMFD	12---	1	103	anam	the antelope of new mexico	russell,tp	1964
CAFGA	30--4	221	241	anam	pronghorn antelop in calif	mclean,dd	1944
JOMAA	38--3	423	423	anam	prnghrn in pioneer missour	mckinley,d	1960
NMWIA	9....	6	8	anam	some answers about antelop	larsen,pa	1964

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	8....	60	61	bibi	altitude limit of bison	warren,er	1927
JOMAA	36--3	470	471	bibi	altitud record, nrth color	beidleman,rg	1955
PAPCA	112-4	299	305	bibi	bis, human occup ohio vall	jakle,ja	1968
QJFAA	17...	228	232	bibi	occurren of bison, florida	sherman,hb	1954
TJSCA	7---2	130	135	bibi	bison beyond the pecos, tx	reed,ek	1955

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	24	505	580	ov	distrib, variation, n amer	cowan,im	1940

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AZWBA	1----	1	153	ovca	desert bigh sheep, arizona	russo,jp	1956
CAUDA	30--3	92		ovca	bighorn range extended	anonymous	1968
IGWBA	1----	1	154	ovca	the bighorn sheep in idaho	smith,dr	1954
JWMAA	34--2	473	475	ovca	abundan & distri in n amer	spalding,dj; mitc	1970

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	34--1	1	15	obmo	muskox, nunivak is, alaska	spencer,dl; lensi	1970

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
IGWBA	2----	1	142	oram	life histry & mgt in idaho	brandborg,sm	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	79--2	346	363		paleoecol lg mammal, alask	guthrie,rd	1968

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	38--3	422	422	caca	roe deer in new york	manville,rh	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CPSCA	5---4	212	213	ceni	distrib in maryland & virg	flyger,v; davis,n	1964
JOMAA	41--1	140	140	ceni	on islands in marylnd & va	flyger,v	1960

OTHER PUBLICATIONS

Proceedings of the White-tailed Deer Disease Symposium
Proceedings of the White-tailed Deer in the Southern Forest Habitat Symposium
Transactions of the Annual Meeting of the Northeast Deer Study Group

Proceedings of the North American Moose Conference

Proceedings of the International Reindeer/Caribou Symposium

Proceedings of the Biennial Antelope States Workshop
Transactions of the Interstate Antelope Conference

Transactions of the North American Wild Sheep Conference
Transactions of the Desert Bighorn Council

Proceedings of the International Mountain Goat Symposium

Proceedings of the Annual Conference of Western Association of State Game & Fish Commissioners
Transactions of the Congress of the International Union of Game Biologists

LIST OF PUBLISHERS - PART VI

aakn	Alfred A. Knopf	New York	nyny
acpr	Academic Press	New York	nyny
bccl	Boone and Crockett Club	Pittsburgh, PA	pipa
blsp	Blackwell Scientific Publications	London	loen
coup	Cornell University Press	Ithaca, NY	itny
dohr	Dowden, Hutchinson, & Ross	Stroudsburg, PA	stpa
dove	Dover Publishing Company	New York	nyny
grpc	Graphic Publishing Company	Lake Mills, IO	lmia
hapr	Hafner Press	New York	nyny
huho	Hurd Houghton	New York	nyny
isup	Iowa State University Press	Ames, IA	amia
macm	MacMillan Co.	New York	nyny
nhfg	New Hampshire Fish & Game Department	Concord, NH	conh
omcc	Olin Mathieson Chem. Corp.	E. Alton, IL	eail
oost	Oosterbeek	The Netherlands	neth
prup	Princeton University Press	Princeton, NJ	prnj
qupr	Queen's Printer	Ottowa, Ontario	oton
rmna	Rocky Mountain Nature Association and Colorado State University		
rokp	Routledge & K. Paul	London	loen
ropr	Ronald Press	New York	nyny
saco	Saunders Publishing Company	Philadelphia, PA	phpa
stac	The Stackpole Company	Harrisburg, PA	hapa
swap	Swallow Press	Athens, OH	atoh
thcr	Thomas Crowell Co.	New York	nyny
uaec	U. S. Atomic Energy Commission	Oak Ridge, TN	ortn
ucap	University of California Press	Berkely, CA	beca
ukap	University of Kansas Press	Lawrence, KA	laka
usfw	U. S. Fish & Wildlife Service	Washington, D. C.	wadc
usgp	U. S. Government Printing Office	Washington, D. C.	wadc
utnp	University of Tennessee Press	Knoxville, TN	kntn
utop	University of Toronto Press	Toronto, Ontario	toon
wbsc	W. B. Saunders Co.	Philadelphia, PA	phpa
whfr	W. H. Freeman Co.	San Francisco, CA	sfca
wiwe	Winchester-Western Press	East Alton, IL	eail

GLOSSARY OF CODE NAMES, PART VI

Code names (CODEN) of Serials are defined in a GLOSSARY OF CODENS at the end of each CHAPTER. The GLOSSARY below includes the CODENS listed as Serials in this PART VI. It is a miniature version of the lists given at the ends of CHAPTERS.

AMNAA American Midland Naturalist
AZWBA Arizona Game and Fish Department Wildlife Bulletin

BLJYA Blue Jay
BNMFD New Mexico Department of Game and Fish Bulletin

CAFGA California Fish and Game
CAUDA Canadian Audubon
CPSCA Chesapeake Science

IGWBA Idaho Department of Fish and Game Wildlife Bulletin

JOMAA Journal of Mammalogy
JWMAA Journal of Wildlife Management

NCANA Naturaliste Canadien, Le
NMWIA New Mexico Wildlife
NTRLA Naturalist, The (Leeds)

PAPCA Proceedings of the American Philosophical Society
PCZOA Proceedings of the International Congress of Zoology

QFJAA Quarterly Journal of the Florida Academy of Science

TJSCA Texas Journal of Science
TWASA Transactions of the Wisconsin Academy of Sciences, Arts, and Letters

VILTA Viltrevy

WLMOA Wildife Monographs
WSCBA Wisconsin Conservation Bulletin

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER EIGHTEEN

POPULATION ESTIMATES AND STRUCTURES

by

Aaron N. Moen

Professor of Wildlife Ecology

Department of Natural Resources

College of Agriculture and Life Sciences

Cornell University

Ithaca, N.Y. 14853

and

Certified Wildlife Biologist

(The Wildlife Society)

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CONTENTS OF CHAPTER EIGHTEEN

POPULATION ESTIMATES AND STRUCTURES

CHAPTER 18. POPULATION ESTIMATES AND STRUCTURES

Populations consist of N individuals. The number, N, exists, whether it is known to the biologist or not. In fact, it is almost always unknown for free-ranging animals, and the sampling problems associated with censusing are, in most cases, great.

The number of animals may be estimated most accurately for large animals living in a range with no overhead vegetation. Large ruminants on the prairie, such as bison, and on the tundra, such as muskox, may be counted very accurately. Deer, elk, and moose are much more difficult to count because they are often under plant canopies. No matter how difficult it may be to count or estimate N, however, some number N is to be recognized as a biological reality. TOPIC 1 focuses on different ways to estimate populations.

Populations may be divided into groups and classes of individuals with common characteristics. It is customary to divide populations of wild ruminants into two categories--sex and age--when analyzing population dynamics. Sex ratios are obviously important when predicting the reproductive potential of a population as a whole. Age is used in predicting natality and mortality rates. Age may not be a good predicter of natality and mortality rates for different areas since both natality and mortality rates are affected by the physical conditions of the animals, which is affected by range conditions. Weights may be a better basis for predicting natality and mortality rates.

Biomasses of populations have been considered by ecologists interested in the relationships between various trophic levels in ecosystems. The biomass of an individual, a function of both age and range conditions, is of value in understanding relationships between the animals and their range, for it is a basis for estimating metabolism, forage intake, and reproductive rates. Perhaps age <u>and</u> weight combined are the best predicters of natality and mortality rates. Age and weight-based population structures are discussed in TOPIC 2.

There may be hesitation on the part of some persons to come up with estimates of numbers in a population. Sampling problems are present whenever populations are estimated over large land areas. Many other biological and statistical problems also exist in the collection of population data. Nevertheless, it is absolutely necessary to come up with some estimate of N, since the expression

$$[(?) + (?)(\text{reproductive rate}) = ?]$$

is not an acceptable base to work on. Rather,

$$[(N) + (N)(\text{reproductive rate}) = N+],$$

where N should represent a best estimate of the number of animals in a population, is. Further, N must also be broken down into best estimates of numbers in sex, age and weight groups when dealing with population dynamics.

This CHAPTER provides ideas and formats for estimating populations and determining population structures. Try the ideas and formats out, using data in the published literature, and your understanding of factors affecting population changes will increase.

REFERENCES, CHAPTER 18

POPULATION ESTIMATES AND STRUCTURES

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	olbo	edsc	152		numbers of man and animals	cragg,jb,ed; piri	1955
aubo	uchp	chil	281		intro to study of anim pop	andrewartha,hg	1961
edbo	wiso	wadc	419	wldl	wildlf invest tech, 2nd ed	mosby,hs,ed	1963
edbo	saco	phpa	388		readin in pop, commun ecol	hazen,we,ed	1964
aubo	amel	nyny	183		quantitv and dynam ecology	kershaw,ka	1964
aubo	jwis	nyny	200		the biology of populations	macarthur,rh; con	1966
aubo	whfr	sfca	416		wildlife management	giles,rh,jr	1978
aubo	utnp	knte	186		guide to stud, anim popula	tanner,jt	1978

TOPIC 1. POPULATION ESTIMATES

One of the most difficult tasks facing the wildlife biologist is that of making accurate estimates of populations. The problems encountered when trying to count free-ranging and elusive animals, even large ruminants, are many, and populations are very easily underestimated because of the difficulties in seeing each individual in its natural habitat.

Two kinds of estimates--direct and indirect--may be made. Direct estimates involve the counting of individuals observed in their habitat. Indirect estimates involve the observation of evidence of their presence, with interpretations of that evidence used to estimate abundance. The former is called a census, and is intended to indicate absolute numbers. The latter results in an index, and is intended to indicate relative numbers. Direct estimates are discussed in UNITS 1.1 and 1.2, and indirect estimates in UNIT 1.3.

Population dynamics may be interpreted from either direct or indirect estimates. Changes from year to year may be inferred from changes in either absolute or relative numbers. Since there are errors inherent in both kinds of estimates, errors will occur in estimations of change. These errors can be substantial, and were large enough in the analyses of the population dynamics of the Seneca Army Depot herd in New York State to make it necessary to revise the estimates annually rather than at three-year intervals (Moen and Sauer 1977).

Observed population predictions are discussed in UNIT 1.4. This unit includes references in the SERIALS list that describe population estimates determined by direct or indirect means. The large number of references will provide a data base for units in both TOPIC 1 and TOPIC 2.

LITERATURE CITED

Moen, A. N, and P. Sauer. 1977. Population predictions and harvest simulations. Pages 26-36 In: Proc. Joint Northeast-Southeast Deer Study Group Meeting, Blackstone, VA.

REFERENCES, TOPIC 1

POPULATION ESTIMATES

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	wiso	wadc	635	many	wildlf mgmnt techn, 3rd ed	giles,rh,jr,ed	1969
edbo	psup	uppa	420		statist ecol, vol II, proc	patil,gp,ed; pie/	1971
edbo	wiso	wadc	206	many	manual of wildlf conservat	teague,ad,ed	1971
aubo	hapr	nyny	506		est anim abun & rel params	seber,gaf	1973

UNIT 1.1. DIRECT ESTIMATES; AERIAL COUNTS

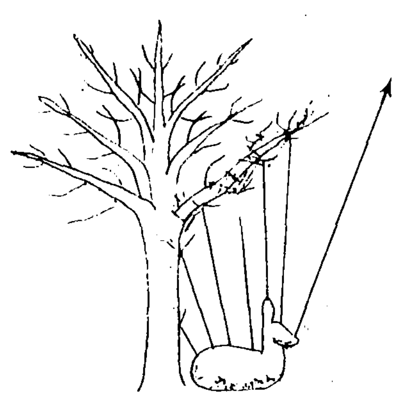
Direct estimates of populations involve the counting of individual animals from the air or from the ground. Aerial counts of wild ruminants have been conducted for over 40 years. Many flights have been made for the purpose of gathering state and local information, and the results have been used in management decisions. Many of these results are not published in the readily-available professional literature.

Aerial counts may be quite successfully made in open terrain when the animals may be distinguished from the ground surface in the background. Counts of caribou on the tundra and bison on the prairie, for example, are readily made directly from either helicopters or fixed-wing aircraft. Either entire herds may be counted, or transects flown and total numbers estimated by extrapolation.

Aerial counts of animals living in forested or shrubby habitats are much less accurate than those in open terrain. Small scattered shrubs cause difficulties by giving the ground a mottled appearance into which the animals may blend very well. An overstory conceals animals bedded under the tree canopies, often resulting in large underestimations of the actual population. Aerial counts of forested areas are best made when leaves have fallen and there is a uniform snow background.

Direct aerial counts have been supplemented by tests of remote sensing techniques. Photography may be used successfully when lighting conditions provide the necessary contrast. The pictures provide a permanent record of the areas viewed. A rather recent technique that has been evaluated is the use of thermal or infrared imagery. This technique is based on the contrast in heat emitted from an animal and from its background.

Instrumentation is available that detects differences in heat emitted from surfaces with temperatures less than 1°C apart. Thus a white-tailed deer, with a surface temperature of about 10°C in still air when air temperature is 0°C and about 5°C in a 10 mph wind at 0°C air temperature, does provide sufficient contrast for thermal detection. The infrared energy emitted, however, is absorbed and diffused by any overhead cover present. Thus an animal bedded under a canopy would not provide the contrast necessary to identify the thermal image as an animal. This is illustrated below.



There are other sources of thermal energy that provide contrast too. Rocks, water puddles, tufts of vegetation, . . . just about anything different from the desired uniform background, such as snow, provides thermal contrasts on the imagery. The problem then is in identifying the sources of thermal contrast, distinguishing animals of the target species from objects in the habitat.

There is yet another problem with the use of thermal imagery. Different species present similar thermal images. The radiant surface temperatures of white-tailed deer, mule deer, red fox, cottontail, and snowshoe hare all overlapped in part of the air temperature - wind velocity combinations tested (Moen 1974). These results, along with the problems considered in preceding paragraphs, lead me to conclude that thermal sensing introduces many new problems but few new advantages over good contrast photography. The best conditions for infrared imagery -- large animals against a snow background -- are also the best for black and white or color photography. Standard photography equipment is much less expensive than thermal detection equipment, and the photography equipment is readily available.

Aerial counts may provide considerable information in addition to just numbers of animals. Information on sex and age ratios may be obtained for some species while they are being counted from the air. Muskox, ideally suited for direct counts, may also be aged by body size and horn length while being counted (Taber 1969). Bison calves are smaller and lighter in color than adults, but yearlings may be difficult to distinguish from adults. The horns of sheep indicate both sex and age, but horns of goats are not different enough to be distinguished. Such information, gathered while counting numbers, is very useful when representing population structures.

Direct aerial counts are often supplemented by ground counts. Comparisons between the two are useful, and usually made to evaluate less-costly ground methods in relation to more costly aerial methods. Direct estimates by ground counts are discussed in UNIT 1.2.

LITERATURE CITED

Moen, A. N. 1974. Radiant temperatures of hair surfaces. J. Range Manage. 27(5):401-403.

Taber, R. D. 1969. Criteria of sex and age. Chapter 20 In: R. H. Giles, Jr. (Ed.). Wildlife Management Techniques. The Wildlife Society, Washington, D. C. 623 p.

REFERENCES, UNIT 1.1

DIRECT ESTIMATES; AERIAL COUNTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	17--1	97	98	od--	aerial deer counts	petrides,ga	1953
JWMAA	20--3	327	328	od--	conduct deer stud, helicop	aldous,cm	1956
NAWTA	10---	234	241	od--	ceel, meth det nums & rnge	hunter,gn	1945

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	88--1	41	45	odvi	dist, number, wint, quebec	miller,fl	1974
ICNSA	12--1	98	98	odvi	aerial deer survey	sanderson,gc	1953
JWMAA	36--3	875	884	odvi	cens airborn therm imagery	graves,hb; ellis/	1972
JWMAA	38--2	366	368	odvi	chang rad temp, anim, wind	moen,an; jacobsen	1974
JWMAA	41--2	197	206	odvi	aer sampl, mark recap cens	rice,wr harder,j	1977
JWMAA	43--3	777	780	odvi	precisi in helic censusing	beasom,sl	1979
NAWTA	24---	201	215	odvi	food habits, everglades de	loveless,cm; liga	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	25--6	480	481	odhe	deer detec by therm scanng	parker,hd,jr: dri	1972
JWMAA	21--1	33	37	odhe	comp air, groun count, col	gilbert,pf; grieb	1957
NEXAA	567--	1	32	odhe	ft stanton hrd, ecol, n mx	wood,je; bickle,/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	15--1	81	87	ceel	censusin by airplane, wash	buechner,hk; bus/	1951
JWMAA	24--1	15	21	ceel	on afognak island, alaska	troyer,wa	1960
JWMAA	30--2	364	369	ceel	aerial count, 2 herds, mon	lovaas,al; egan,/	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BFRNA	23...	1	9	alal	an aerial moose census, bc	edwards,ry	1952
JWMAA	18--3	403	404	alal	compar, aerial ground cens	edwards,ry	1954
JWMAA	19--3	382	387	alal	aerial reconnaissa, summer	bowman,ri	1955
JWMAA	30--4	767	776	alal	aer cens, quadrat samp uni	evans,cd; troyer/	1968
JWMAA	33--4	910	916	alal	aerial census, newfoundlan	bergerud,at; manu	1969
JWMAA	38--2	175	182	alal	accur, precis, aerial cens	leresche,re; raus	1974
PNSIA	27---	43	58	alal	od, surv, kejimujik nat pk	wood,tj	1973
WLMOA	48---	1	65	alal	habitat select, forest mgt	peek,jm; urich,d/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CWPNB	40...	1	18	rata	obmo, aerial surve, nw ter	miller,fl; russel	1974
CWPNB	44...	1	8	rata	obmo, aerial surve, nw ter	miller,fl; russel	1975
JWMAA	27--3	438	449	rata	aerial winter census carib	bergerud,at	1963
JWMAA	28--2	391	401	rata	aer cens, strat rand sampl	siniff,db; skoog,	1964
NAWTA	21---	499	509	rata	aerial cens, nelchina herd	watson,gw; scott,	1956
NPOAA	1972-	83	88	rata	air and ground surv, norwy	gossow,h; thorbjo	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	14--3	295	298	anam	aerial census, west states	springer,lm	1950
NAWTA	15---	627	644	anam	rang ecol, wichita mt, kan	buechner,hk	1950

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	14--4	445	451	bibi	aerial censu, wood buff pk	fuller,wa	1950

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	12--3	302	304	ovda	air cens, mt mckinl nat pk	sumner,l	1948

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CWPNB	33...	1	9	obmo	rata, prelim surv, nw terr	miller,fl; russe/	1973

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	33--4	441	450	anim	exp meths in popul dynamcs	smith,fe	1952
JOMAA	22--2	148	157	mamm	techns for study populatns	blair,wf	1941
JWMAA	2---2	131	134	biga	carrying capacity of range	young,va	1938
JWMAA	14--4	472	473	wldl	use helicopter in wld work	buechner,hk	1950
JWMAA	32--4	751	759	biga	infrared scanng tech, cens	croon,gw; muccul/	1968
NAWTA	7----	343	354	biga	aerial census, nort dakota	saugstad,s	1942
NAWTA	10---	234	241	biga	meths deter numbers & rnge	hunter,gn	1945
NAWTA	20---	519	532	biga	aerial survey tech, northe	banfield,awf; fl/	1955

UNIT 1.2: DIRECT ESTIMATES; GROUND COUNTS

When the overhead canopy is dense enough to preclude aerial counts, on-the-ground drives may be used to count animals on small areas of land. Such drives require large numbers of persons to drive the animals and a line of watchers to count the animals driven through an open area or across a road where they may be easily seen. Sampling problems contribute to errors, and the results are dependent on the amount of past experience and alertness of the observers.

How many observers are needed to drive and count animals? The number is very dependent on the species being counted and on the habitat. A drive over 500 acres in east central Minnesota showed that two radio-tracked white-tailed deer ran back between drivers four times (Tester and Heezen 1965). One was not seen one of those times, even though 58 people participated in the drive and the drivers, were, presumably within sight of each other at all times. The use of 58 people on a drive covering 500 acres indicates the necessity for large numbers when making such direct estimates from the ground. Costs are very high, probably prohibitive, if persons involved must be paid for their services.

Some direct counts are made as other work is being completed. Roadside counts, for example, may be conducted by biologists and laypersons that travel the same routes repeatedly. The direct counting of animals seen is not an estimate of the actual number in the area, of course. Some conditions enhance opportunities to count larger fractions of the actual numbers. Late winter concentrations of deer in the Northeast, mule deer winter concentrations, elk congregating in winter feeding areas . . . these all provide opportunities to observe and count larger percentages of the total number in the area.

Behavior patterns must also be considered when counting animals. More are observed grazing in early morning and late evening than in mid-morning and mid-afternoon. Cervids are, in general, active around sunrise and sunset, with other activity periods around noon and during the night. If counts are dependent on the animals' normal activity patterns, then daily activity patterns discussed in CHAPTER 4 need to be given serious consideration. Drives may appear to be less dependent on the daily activity pattern, but it is my belief that a deer drive conducted just after the morning feeding period has ended will result in fewer whitetails being observed than if the drive were conducted just before the late afternoon feeding period was to begin. Some of these subtle effects may be hard to detect and prove; I suggest that they be considered and plans made accordingly as circumstances permit.

Ground counts are not always designed to be complete counts. The number seen may be used to estimate the number present by multiplication. Techniques for counting some of the population and estimating the total population have been devised for other species and applied to wild ruminants. The Petersen or Lincoln Index is one, the Leslie index is another.

The Petersen or Lincoln Index is relatively simple in theory, but more comlpex in its use. It is a method involving the marking and releasing of individuals, after which the ratio of marked animals to unmarked animals seen is the basis for estimating the population. For simplicity, suppose 10 animals were marked and released. Later 5 marked and 5 unmarked were seen regularly. One might conclude that the fraction of animals seen that were marked (5/10 = 0.5) is a good estimater of the total in the population by: 10 marked/0.5 = 20 total. In proportion form:

$$\frac{\text{number marked observed}}{\text{total number observed}} : \frac{\text{total number marked}}{\text{total population}}$$

Thus:

$$\frac{5}{10} : \frac{10}{N}$$

so 5N = 100 and N = 20.

There are a number of assumptions underlying this estimate, including such things as proportional mortality in both the marked and unmarked groups, no lost marks, marked animals are no more conspicuous, etc. More detailed treatments of the assumptions and calculations may be found in Overton and Davis (1969 433).

The Leslie Method (Overton and Davis 1969:450) is similar to the Lincoln Index in the sense that repeated observations are made, but with the Leslie Method they are recaptures. The frequency of recaptures becomes the basis for estimating N. There are assumptions to be met and conditions to be heeded when using any method for estimating N. Additional methods and further discussions are found in Overton and Davis (1969).

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Overton, W. S. and D. E. Davis. 1969. Estimating the numbers of animals in wildlife populations. Chapter 21, Pages 403-456 In: Giles, R. H., Jr. (Ed.). Wildlife Management Techniques. The Wildlife Sociey, Washington, D. C. 623 p.

Tester, J. R. and K. L. Heezen. 1965. Deer responses to a drive census determined by radio tracking. BioScience 15(2):100-104.

REFERENCES, UNIT 1.2

DIRECT ESTIMATES; GROUND COUNTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	7---2	217	220	od--	tech red man-pow, driv cen	morse,ma	1943
JWMAA	28--1	27	34	od--	factors, spotlighti counts	progulske,dr; due	1964
NAWTA	24---	457	464	od--	deer drive vs track census	tyson,el	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FLSCA	38...	157	167	odvi	popula, everglades, florid	schemnitz,sd	1974
ICNSA	7---4	30	30	odvi	1948 deer survey, iowa	faber,lf	1948
JWMAA	4---1	15	18	odvi	census meth, spring, summe	erickson,ab	1940
JWMAA	5---4	412	415	odvi	cruising meth, cens, oklah	krefting,lw; flet	1941
JWMAA	7---2	217	220	odvi	reduc man-power, drive cen	morse,m	1943
JWMAA	32--4	760	764	odvi	attempt, leslie censu meth	lewis,jc; farrar,	1968
JWMAA	43--1	258	261	odvi	impr meth, cen dec con for	floyd,tj; mech,l/	1979
NAWTA	3----	280	286	odvi	tagging, pop studies, minn	olson,hj	1938
NAWTA	4----	221	230	odvi	devel, use game drives, pa	mccain,r	1939
NAWTA	9----	150	154	odvi	roadsid count, emerg, minn	schrader,ta	1944
NAWTA	21---	555	566	odvi	large-scale dead deer surv	whitlock,sc; eber	1956
NYCOA	11--2	4	4	odvi	live-trapping white-t deer	bromley,aw; sever	1956
PCGFA	19---	26	30	odvi	cens tech, enclos, georgia	downing,rl; moor/	1965
PCGFA	20---	56	63	odvi	compar, cens methods, tenn	lewis,jc; safley,	1966
PSAFA	1962-	162	165	odvi	census tech, the southeast	johnson,fm; downi	1962
WCDBA	7----	1	32	odvi	wint hab, census meth, wis	kabat,c; collias/	1953

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	41--3	225	228	odhe	compar, 4 cens meth, calif	dasmann,rf; taber	1955
JOMAA	37--3	457	458	odhe	mule deer record for iowa	sanderson,gc	1956
JOMAA	40--1	148	149	odhe	addi mule de records, iowa	kline,pd	1959
JWMAA	18--4	537	538	odhe	use deer cal, locate fawns	diem,kl	1954
JWMAA	21--1	33	37	odhe	comp air, groun count, col	gilbert,pf; grieb	1957

odhe continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	8----	369	380	odhe	cens meth, appl, managemen	rasmussen,di; dom	1943
NAWTA	11---	349	354	odhe	census herd, sampling meth	cronemiller,fp; f	1946
NEXAA	567--	1	32	odhe	ft stanton hrd, ecol, n mx	wood,je; bickle,/	1970
NOSCA	34--4	118	126	odhe	differ range use, spruce-f	white,kl	1960

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	5---2	76	80	ceel	odhe, wint-rang util, wash	buechner,hk	1952
JWMAA	24--3	279	290	ceel	migrat pattrn sun rivr elk	picton,hd	1960
NPOAA	1974-	83	88	ceel	air and ground surv, norwy	gossow,h; thorbjo	1972
WMBAA	6----	1	25	ceel	surveys, wildlif, manitoba	colls,dg	1952

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	18--3	403	404	alal	compar, aerial ground cens	edwards,ry	1954
NCANA	101-1	615	629	alal	moose inventor meth, revie	timmermann,hr	1974
OUOKA	25--3	8	15	alal	wapiti roundup	lowry,d III	1969

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	30--4	221	224	anam	pronghorned antel in calif	mclean,dd	1944

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
ATICA	24--3	157	161	obmo	distr, abund, gr bear lake	kelsall,jp; hawl/	1971
JWMAA	35--1	103	108	obmo	pop characs, nrth wst terr	freeman,mmr	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	81--1	1	22	oram	obser, kootenay nat pk, bc	holroyd,jc	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIOKA	38---	293	306		est size mobil pops, recap	bailey,ntj	1951
ECOLA	33--4	441	450		exp meth popul dyn, critiq	smith,fe	1952
JFUSA	34--5	467	471	wldl	wildl cens meth, n england	hosley,nw	1936
JOMAA	22--2	148	157	anim	techns study animal populs	blair,wf	1941
JWMAA	2---2	131	134	biga	carrying capacity of range	young,va	1938
JWMAA	4---4	313	314	anim	intersection meth of count	graham,sa	1940
JWMAA	5---4	357	370	biga	early historicl rec, monta	koch,e	1941
NAWTA	3----	407	414	biga	wildl cens, counts vs esti	mccutchen,aa	1938
NAWTA	10---	234	241	biga	meths deter numbers & rnge	hunter,gn	1945

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--4	643	651	caca	reliabi petersen meth, pop	strandgaard,h	1967

UNIT 1.3: INDIRECT ESTIMATES

Indirect estimates of populations are often the only reasonable ways to come up with working numbers for decision-making. There are several ways to make such estimates. Fecal and pellet groups may be counted and population estimates or animal-days of use derived by dividing the total count by the defecation rate per day. This was proposed by Bennett et al. (1940), and has been used by investigators in many states in the last 40 years. The technique is based on a number of assumptions. These are discussed by Eberhardt and Van Etten (1956) for white-tailed deer in evaluating two enclosed areas in Michigan. The biological assumptions are:

(1) that all groups are found and correctly identified,

(2) all pellet groups deposited since leaf-fall will be available and counted, and

(3) that a known number of pellet groups are defecated per day.

All of these assumptions are subject to error, of course. If the errors are committed at a constant rate from year to year, their effects are less serious than if the error rate fluctuates from year to year.

The formula for estimating the number of deer present per square mile from pellet counts, with 640 acres per square mile, 1/50 acre circular sample plots, and 13 pellet groups defecated per day is:

$$DPSM = [(APGP)(50)(640)]/(DYLF)(13)$$

where DPSM = deer per square mile,
APGP = average number of pellet groups per plot, and
DYLF = days since leaf fall.

Eberhardt and Van Etten (1956) made pellet-count estimates (PECO) of known populations (KNPL) of DPSM for three years in each of two areas in Michigan. The data and the ratios of the two estimates (RTIO = ratio of PECO/KNPL) are:

	Cusino			George Reserve		
	PECO	KNPL	RTIO	PECO	KNPL	RTIO
1953	40.8	28.8	1.42	30.7	32.7	0.94
1954	25.5	25.0	1.02	28.4	36.1	0.79
1955	22.2	28.1	0.79	17.3	37.2	0.47

The pellet counts varied from 0.47 to 1.42 times larger than the known population. The "known" populations are thought to have been estimated accurately for these intensively-studied enclosed populations; variations in the ratios are then due almost entirely to the pellet counts. The amounts of the differences in the two values of DPSM suggest that other methods should be used to supplement these results.

Track and trail counts on transects may be made in snow or in ground vegetation to provide an index to the population. Roads may be used as the transects. If they are dragged at the same time twice each day, daily use can be measured. Trail counts provide an index to deer abundance with a minimal investment of man-days, and the results are useful for recognizing population changes from year to year and to relate to the results of other methods of estimation.

The use of late fall and early spring trail counts as indices to deer abundance in Wisconsin is described by McCaffery (1976). The results were positively related to other indices of deer abundance. Such trail counts also provide an index to habitat use when the numbers of trails encountered on transect lines are evaluated in relation to habitat types present along the lines.

Indirect population estimates are usually not good indicators of absolute population levels, and results of indirect estimates usually do not become meaningful until several years of data are obtained. Then, relative changes in indirect evidence may be used to draw conclusions on probable changes in the actual population. Sex and age ratios, reproductive data, and mortality data all become useful in making calculations of the likely numbers of animals, which in time may be rather reliable estimates.

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Eberhardt, L. and R. C. Van Etten. 1956. Evaluation of the pellet group count as a deer census method. J. Wildl. Manage. 20(1):70-74.

McCaffery, K. R. 1976. Deer trail counts as an index to populations and habitat use. J. Wildl. Manage. 40(2):308-316.

REFERENCES, UNIT 1.3

INDIRECT ESTIMATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	38--2	225	233	od--	meth, est deer pop, kill d	dasmann,rf	1952
JWMAA	20--1	75	78	od--	anal meths cens wintr-lost	robinette,wl; jo/	1956
JWMAA	26--1	50	55	od--	infl rain, pellet gr count	wallmo,oc; jacks/	1962
JWMAA	29--4	723	729	od--	error, pellet grou censusi	van etten,rc; ben	1965
JWMAA	32--3	592	596	od--	paint, marking pellet grou	kufeld,rc	1968
JWMAA	39--4	641	652	od--	dev distnc meth, pellet gr	batchelor,cl	1975
NAWTA	13---	431	441	od--	method measur od range use	mccain,r	1948
NAWTA	19---	511	525	od--	meths cens wintr-lost deer	robinette,wl; jo/	1954
NAWTA	21---	555	566	od--	large-scale dead deer surv	whitlock,sc; eber	1956
NAWTA	23---	411	425	od--	probl, pellet group counts	robinette,wl; fer	1958
NAWTA	24---	457	464	od--	deer drive vs track census	tyson,el	1959

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	90--1	29	36	odvi	est popul, mortal, 1970-72	king,dr	1976
CNSVA	28--5	36	38	odvi	deer pop, wildl rollercoas	severinghaus,cw	1974
JWMAA	4---1	15	18	odvi	meth censusing, sprng, sum	erickson,ab	194?
JWMAA	4---4	398	403	odvi	stud pop, pellet gr counts	bennett,lj; engl/	1940
JWMAA	7---2	203	216	odvi	on aransas refuge, texas	halloran,af	1943
JWMAA	16--2	121	131	odvi	hunt statis rang cond, pop	gunvalson,ve; er/	1952
JWMAA	20--1	70	74	odvi	evalua, pellet-group count	eberhardt,l; van	1956
JWMAA	23--2	187	197	odvi	highway mor, index pop cha	jahn,lr	1959
JWMAA	29--2	381	387	odvi	esti pop, automa colle dat	sittler,od	1965
JWMAA	33--4	871	880	odvi	harv est, sampl surv, mich	hawn,lj; ryel,la	1969
JWMAA	37--2	212	216	odvi	road kills show trends in	mccaffery,kr	1973
JWMAA	40--2	308	316	odvi	trail counts, pop, hab use	mccaffery,kr	1976
JWMAA	41--4	779	782	odvi	freq dist pell gr, indiana	stormer,fa; hoek/	1977
MDCRA	2352-	1	64	odvi	techn data, pellet grp sur	ryel,la	1961
MFNOA	89...	1	2	odvi	count pellet gr, mult-rand	krefting,lw; shiu	1960
NAWTA	3----	287	295	odvi	census, kill rec, lake sta	adams,he	1938
NAWTA	24---	201	215	odvi	food habits, everglades de	loveless,cm; liga	1959
NFGJA	7---1	80	82	odvi	persist, wint pell gro, ny	patric,ef; bernha	1960

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PCGFA	6----	1	15	odvi	estimat popula from tracks	tyson,el	1952
PCGFA	16---	29	31	odvi	track counts, meas pop siz	brunett,le; lambo	1962
PCGFA	19---	110	117	odvi	interp, trap data, alabama	lueth,fx	1965
PCGFA	21---	39	41	odvi	eval track census meth, se	harlow,rf; downin	1967
PCGFA	21---	69	73	odvi	determ unreport kill, tenn	legler,e,jr; hayn	1967
TNWSD	9----	1	5	odvi	che sta data, herd siz, nh	stevens,cl	1953
TNWSD	20---	1	37	odvi	gains & losses in pop, n y	free,s; hesselto/	1964
WSCBA	22--8	6	10	odvi	the deer unit: surv, manag	keener,jm; thomps	1957

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	25--1	66	68	odhe	fecal gro coun rel site fa	anderson,ae; med/	1972
JWMAA	7---1	123	124	odhe	counts, bucks vs shed antl	hickel,mr; swift,	1943
JWMAA	11--1	103	104	odhe	prob error, samp meas,kill	cronemiller,fp	1947
JWMAA	22--2	193	199	odhe	pel-gr coun, cens, ran use	rogers,g; juland/	1958
JWMAA	28--3	435	444	odhe	defecation rates of mule d	smith,ad	1964
JWMAA	32--3	585	591	odhe	comp plots, pellet gr dens	smith,rh	1968
JWMAA	33--4	895	905	odhe	frequen distr, fec gr coun	bowden,dc; ander/	1969
NAWTA	15---	644	649	odhe	determin pop from the kill	lauckhart,b	1950
NAWTA	21---	487	498	odhe	fluctuations, popul, calif	dasmann,rf	1956
NOSCA	34--4	118	126	odhe	differ range use, spruce-f	white,kl	1960
UASPA	17...	65	69	odhe	estim pop, diff huntg mort	kelker,gh	1940
UASPA	32...	59	64	odhe	weath, persis, pellet grou	ferguson,rb	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	29--2	406	407	ceel	determinat defecation rate	neff,dj; wallmo,/	1965
JWMAA	34--1	29	36	ceel	od, frequen distrib pel gr	mcconnell,br; smi	1970
JWMAA	39--4	641	652	ceel	dev dis meth, pellet group	batcheler,cl	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NCANA	95--5	1153	157	alal	det # pell grps, bed areas	desmeules,p	1969
QSFRA	8----	1	12	alal	cens taking sta, 1971, can	potvin,c; guilber	1973

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
ATRLA	21-15	217	222	ungu	est num in for by trac cou	dzieciolowski,r	1976
BIOKA	42--3	279	290		pop est, chng comp, removl	chapman,dg	1955
ECOLA	33--4	441	450		exp meths in popu dynamics	smith,fe	1952
ECOLA	39--1	147	150	anim	nearst-neighbr distnc meth	blacklith,re	1958
JFUSA	34--5	467	471	wldl	wildl cens meth, n england	hosley,nw	1936
JOMAA	22--2	148	157	mamm	techniqs study anim populs	blair,wf	1941
JOMAA	32--3	318	328	anim	new techniq of anim census	maclulich,da	1951
JWMAA	13--2	145	157	anim	strip census method, estim	hayne,dw	1949
JWMAA	29--2	392	395	anim	schnabel est, removl anims	overton,ws	1965
JWMAA	30--1	173	180		shnabel est, diff pop levl	chapman,dg; overt	1966
JWMAA	32--1	82	88		preliminar appr, line tran	eberhart,ll	1968
JWMAA	32--3	597	614	biga	pellet group coun tech for	neff,dj	1968
JWMAA	42--2	441	444	herb	dung ph to diff herb speci	hansen,rm	1978
NAWTA	3----	407	414	wldl	wildl cens, counts vs esti	mccutchen,aa	1938
NAWTA	4----	542	545	wldl	region 8 tech, wildl inven	ruff,fj	1939
NAWTA	10---	234	241	biga	meths deter numbers & rnge	hunter,gn	1945
UASPA	20...	189	198	wldl	formulas deter pop, sx rat	kelker,gh	1948
XARRA	170--	1	7		rec, comp summ, pellet dat	patton,dr; casner	1970

UNIT 1.4. OBSERVED POPULATION DYNAMICS

Descriptions of population dynamics are necessary for good long-range management decisions. Some species, such as white-tailed deer, are very abundant in some areas and population dynamics need to be understood in order to set up adequate harvests and prevent range deterioration. Other species are absent or rare in potentially good habitat, and restocking efforts and subsequent protection are necessary to establish populations.

Some population changes are dramatic. The rise and fall of caribou on St. Matthew Island (Klein 1968) illustrates how a primary consumer relates to range resources in a rather simplified system over a period of several years. Population changes in more heterogenous habitats may not be as dramatic, but the same principles apply. Certain components of natural population dynamics have been eliminated in post-settlement times. Natural predators such as wolves, bears, mountain lions, bobcats, and others have much more restricted distributions than in pre-settlement times. Changes in the vegetation are also dramatic as farming and forestry practices result in plant communities quite unlike those in which wild ruminants spent the last several thousand years.

The reproductive potential of white-tailed deer is well known. A herd in New York State grew from less than 40 animals in 1949 to over 2500 in 1957 after 8 years of protection within the Seneca Army Depot fence. The increase in numbers was accompanied by decreases in body weight and reproductive rates. The population was reconstructed by aging the deer harvested, beginning in the late 1950's, and numbers and reproductive rates used to calculate mortality. The analyses by Moen and Sauer (1977) demonstrated the importance of accurately aging the deer.

There are many papers containing descriptions of the population dynamics of different species of wild ruminants. These papers contain estimates of N in different sex and age classes, and data on natality and mortality rates, useful in relation to discussions in UNITS 1.1, 1.2, and 1.3 and to the next TOPIC. References to population growth after restocking may be found in the list of SERIALS at the end of this UNIT, and in CHAPTER 22. Some of the references listed contain brief descriptions of observed numbers, and some contain extensive descriptions of population dynamics. The references will be useful when using natality and mortality rates for population predictions in CHAPTER 19. First, however, sex, age, and weight structures are discussed in TOPIC 2.

LITERATURE CITED

Klein, D. R. 1968. The introduction, increase, and crash of reindeer on St. Matthew Island. J. Wildl. Manage. 32(2):350-367.

Moen, A. N. and P. Sauer. 1977. Population predictions and harvest simulations. Pages 26-36 In: Proc. Joint Northeast-Southeast Deer Study Group Meeting, Blackstone, Va.

REFERENCES, UNIT 1.4

OBSERVED POPULATION DYNAMICS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
MANJA	20--1	24	26	cerv	pop tren, licen rep, malay	khan,m; khan,m	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	44--1	51	72	od--	surviv, forag trend, calif	dasmann,wp; hjers	1958
CAGRA	10--5	9	14	od--	population dynamics of dee	longhurst,wm	1956
CFGGA	4....	1	139	od--	jawbone deer herd, califor	; riney,t; /	1951
CFGGA	6----	1	316	od--	surv herds; rnge, mgt prob	longhurst,wm; le/	1952
NAWTA	12---	193	203	od--	9 yr observtn, problm area	einarsen,as	1947

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMFOA	74--4	32		odvi	white-tails: success story	randall,ce	1968
AMNAA	61...	230	238	odvi	historic view, ranges, wis	christensen,em	1959
CNSVA	28--5	36	38	odvi	deer pop, wildl rollercoas	severinghaus,cw	1974
ECOLA	41--4	706	715	odvi	popula ecology, ne alabama	adams,wh,jr	1960
FLSCA	38...	157	167	odvi	populations, florida everg	schemnitz,sd	1974
ICNSA	7---4	30		odvi	deer survey, 1948, iowa	faber,lf	1948
ICNSA	12--1	101	101	odvi	iowa's early deer story	madson,j	1953
INHNA	34---	1	22	odvi	white-t deer popu, illinoi	pietsch,lr	1954
JWMAA	5---2	182	190	odvi	prelim report, study, texa	sanders,e	1941
JWMAA	9---3	237	242	odvi	in the great plains region	cook,fw	1945
JWMAA	11--3	263	266	odvi	the huron mounta deer herd	manville,rh	1947
JWMAA	17--2	166	176	odvi	necedah refuge deer irrupt	martin,fr; krefti	1953
JWMAA	29--4	706	716	odvi	die-off, cent min reg, tex	marburger,rg; tho	1965
MDCRA	2282.	1		odvi	estim vital statistcs herd	eberhardt,l	1960
MDCRA	2395-	1	143	odvi	pop dyna, econ impac, mich	mcneil,rj	1962
MGQPA	31...	194	218	odvi	popula dynam 1954-67, minn	petraborg,w; idst	1972
MOCOA	18--6	1	3	odvi	two decades of deer	robb,d	1957

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
MRLTA	31--3	43	44	odvi	introduced dee, se washing	swanson,cv	1950
MRYCA	1942-	6	8	odvi	worcester county deer herd	wilson,ka; vaughn	1942
NAWTA	3----	280	286	odvi	tagging & popul stud, minn	olson,hf	1938
NAWTA	14---	543	553	odvi	whitetail deer, us & canad	bartlett,ih	1949
NAWTA	17---	472	479	odvi	exti, resto, 60 yr, georgi	jenkins,jh	1952
NAWTA	21---	487	499	odhe	fluct, popul, calif chapar	dasmann,rf	1956
NAWTA	26---	448	459	odvi	deer, bad river indian res	cook,rs; hale,jb	1961
NAWTA	28---	422	430	odvi	10 yr, enclosed herd, mich	arnoldl,da; verme	1963
NFGJA	3---1	80	87	odvi	hist, man, ecol, allegh pk	severinghaus,cw	1956
NFGJA	3---2	129	167	odvi	history of w-t d in n york	severinghaus,cw;	1956
NFGJA	12--1	17	30	odvi	popul dynamics, senec army	hesselton,wt; se/	1965
NFGJA	16--1	19	26	odvi	minimum deer populatio, ny	severinghaus,cw	1969
NYCOA	12--4	19	19	odvi	seneca ordnanc deer, pt II	severinghaus,cw	1958
NYCOA	20--2	28	32	odvi	deer facts, seneca depot	hesselton,wt; se/	1965
PCGFA	5----	1	18	odvi	deer restoration, se u. s.	barick,fb	1951
PCGFA	21---	15	23	odvi	overpop, hunt, ft knox, ky	dechert,ja	1968
PCGFA	21---	42	50	odvi	herd dynamics, pioneer pop	urbston,df	1967
PCGFA	27---	297	301	odvi	obs die-off, smoky mts prk	fox,jr; pelton,mr	1974
PMACA	10...	411	416	odvi	prelim surv, dee yrds, mic	bartlett,ih; step	1928
PMACA	19...	567	570	odvi	deer populations, michigan	bartlett,ih	1933
RRFBA	19...	66	75	odvi	status of w-t dee, tenness	schultz,v	1955
SLUMA	173..	141	142	odvi	w-t d, forest crop, arkans	read,ra	1946
TISAA	62--2	135	140	odvi	herd pop dynamics, illinoi	hawkins,re; montg	1969
TNWSD	8----	1	17	odvi	some aspects, de herd, n j	sweet,jc; wright,	1952
TNWSD	9----	1	5	odvi	chec sta dat, herd siz, nh	stevens,cl	1953
TNWSD	16---	1	19	odvi	pop census, 1959, n jersey	wright,cw	1960
TSASA	62--1	67	79	odvi	prelim survey, deer, kansa	taylor,dl; elder,	1959
TWASA	35---	351	366	odvi	deer irruptions, wisconsin	leopold,a	1943
TWASA	42---	197	247	odvi	w-t dee in early wisconsin	schorger,aw	1953
TWASA	48---	49	56	odvi	forest cov, pop dens, wisc	habec,jr; curtis,	1959
UKMPA	39---	1	36	odvi	status of deer in kansas	anderson,dd	1964
VIWIA	29--4	10	21	odvi	northwes virgini deer herd	thornton,je	1968
VIWIA	29--5	8	9	odvi	vital statistcs of va herd	carpenter,m	1968
VJSCA	13...	1	16	odvi	allegheny cty herd, virgin	giles,rh,jr	1962

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
WLMOA	67---	1	53	odvi	populat dynam, captiv herd	woolf,a; harder,j	1979
WSCBA	8---8	3	11	odvi	deer eruptions	leopold,a	1943
WSCBA	8---8	11	19	odvi	deer today, tomorrow, wisc	feeney,ws	1943
WSCBA	18--1	3	10	odvi	and the browse came back	deboer,sg	1953
WSCBA	26--3	17	19	odvi	how many deer?	keener,j	1961
WSCBA	32--5	14	15	odvi	dee explosion in the south	owen,d	1967
XFNCA	39---	11	18	odvi	deer popula in the midwest	nixon,cm	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BISNA	23--2	113	114	odhe	kaibab deer incident, myth	burk,cj	1973
CAFGA	33--4	287	314	odhe	populatio, interstate herd	interst committee	1947
CAFGA	49--1	4	15	odhe	abundance, scarcity, calif	dasmann,wp; dasma	1963
CAFGA	50--3	132	145	odhe	study, redwoo-doug fir for	browning,bm; laup	1964
DRCWD	11---	1	24	odhe	hist, curr stat, popu east	kufeld,rc	1979
ECOLA	38--2	233	246	odhe	dynam, 3 natural populatio	taber,rd; dasmann	1957
JAZAA	5....	43	44	odhe	transplanted odhe in arizo	mcculloch,cy	1968
JWMAA	15--2	206	208	odhe	dynamics, mule de populati	cronemiller,fp	1951
NAWTA	4----	236	243	odhe	range, popul studies, utah	rasmussen,di	1939
NAWTA	21---	159	172	odhe	nutri, popu dynam, n calif	taber,rd	1956
UASPA	32...	59	64	odhe	weath, persis, pellet grou	ferguson,rb	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	91--2	130	133	ceel	alal, pop fluctuat, manito	rounds,rc	1977
EKPOA	17...	709	718	ceel	reproduc, dynamics, poland	serafinski,w	1969
JAECA	38--2	425	457	ceel	pop dynami, red d, on rhum	lowe,vpw	1969
JWMAA	13--1	127	134	ceel	irruption, riding mt, mani	banfield,awf	1949
JWMAA	24--1	15	21	ceel	roosevelt elk, afognak isl	troyer,wa	1960
JWMAA	29--2	406	407	ceel	determinat defecation rate	neff,dj; wallmo,/	1965
JWMAA	31--2	304	316	ceel	pop cha, gallatin, 1932-65	peek,jm; lovaas,/	1967
JWMAA	33--3	465	481	ceel	popul ecol, summ, jacks ho	martinka,cj	1969
JWMAA	38--2	161	174	ceel	popul analyses, north utah	kimball,jf; wolfe	1974

ceel continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	3----	388	389	ceel	ann n yellowsto herd count	alane,vh	1938
NAWTA	14---	513	526	ceel	american elk today	rasmussen,dj	1949
NZFSA	5....	235	249	ceel	erup, deter, decli, nelson	clarke,cmh	1976
VILTA	3--3	177	376	ceel	ecol investiga, scandinavi	ahlen,i	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
EKPOA	17...	709	718	alal	reproduc, dynamics, poland	seraffinski,w	1969
JEVSB	4---1	39	51	alal	comput sim model, wolf dyn	zarnoch,sj; turne	1974
JOMAA	49--2	325	326	alal	status, moose, nova scotia	telfer,es	1968
JWMAA	26--4	360	365	alal	studies, mountains, montan	peek,jm	1962
MABIA	26--3	267	281	alal	wolf, diff equat model rel	hausrath,ar	1975
NAWTA	14---	492	501	alal	status of moose in n ameri	hatter,j	1949
NCANA	101-1	1	8	alal	moose, yesteday, today, to	peterson,rl	1974
NCANA	101-1	559	593	alal	pop fluct, 1950-72, alaska	bishop,rh; rausch	1974
NCANA	101-1	605	613	alal	pop dynam, forests, e ussr	filonov,cp; zykov	1974
PASCC	8----	41	49	alal	dynamics, railbelt populat	rausch,ra	1957
TRVIA	108-1	110	112	alal	note on the moose, sweden	curry-lindahl,k	1961
ZOLZA	54--5	752	762	alal	mathemat modeli, pop dynam	galantsev,vp; ki/	1975
ZOOLA	41--3	105	118	alal	ecol, behav, popul dynamcs	denniston,rh,II	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATICA	14...	91	100	rata	pop dy, mackenzie, 1938-58	krebs,cj	1961
ATICA	27...	256	264	rata	ovmo, on banks island, nwt	kevan,pgK	1974
ATLPA	9---4	369	382	rata	pop dynam, reinde, svalbar	reimers,e	1977
BICOB	1---1	86	87	rata	caribo, southampt isl, nwt	macpherson,ah	1968
BPURD	1----	127	139	rata	alaska, u.s., canada herds	le resche,re	1975
BPURD	1----	155	161	rata	status, wild reindee, ussr	semenov-tian-shan	1975
BPURD	1----	162	169	rata	pop grow, movt pat, nelchi	hemming,je	1975
BPURD	1----	170	180	rata	popu status, nelchina herd	bos,gn	1975

rata continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	1----	221	227	rata	status, selkirk mt caribou	freddy,dj; ericks	1975
BPURD	3----	1	8	rata	hist, curren status, alask	davis,jl	1978
BPURD	3----	9	19	rata	pop status, caribou,nw-ter	calef,gw	1978
BYMOA	81--1	132	133	rata	the altai reindeer	sobanskii,gg	1976
CAFNA	89--3	299	310	rata	disapp, reintrod, cap bret	dauphine,tc,jr	1975
CWLSB	1419-	1	11	rata	coats isla carib surv 1970	parker,gr	1970
CWPNB	3----	1	5	rata	popul esti, bg car, canada	thomas,dc; parke/	1968
CWOPA	10---	1	9	rata	trends popul, canada, 20 y	parker,gr	1971
CWPNB	56...	1	10	rata	ovmo, crash, popul, par is	_____; thomas,dc/	1975
CWPNB	64---	1	13	rata	peary car popul, can arcti	thomas,dc; russe/	1976
CWPNB	80---	1	14	rata	2 popul, peary carib, arct	thomas,dc; russe/	1977
CWRSB	9----	1	44	rata	popul estimate, bg caribou	thomas,dc	1969
CWRSB	20---	1	93	rata	total numb, mortal, recrui	parker,gr	1972
CWRSB	31---	1	88	rata	biol kaminuriak pop bar-gr	miller,fl	1976
CWRSB	40---	1	55	rata	ovmo, dist, movement, numb	miller,fl; russe/	1977
FUNAA	22...	253	264	rata	range, popu size, svalbard	norderhaug,m	1969
JOMAA	39--4	560	573	rata	prelim study ungava caribo	banfield,awf; ten	1958
JWMAA	32--2	350	367	rata	introd, incr, crash, st ma	klein,dr	1968
JWMAA	38--4	757	770	rata	decl in n am aftr settlmnt	bergerud,at	1974
NAWTA	29---	445	453	rata	invest woodl caribo, nw us	evans,hf	1964
NCANA	83...	225	234	rata	hstry, dist, anal pop, mgt	moisan,g	1956
NPMEA	99...	132	139	rata	distribut, svalbard, 1960s	norderhaug,m	1970
NPOAA	1969-	70	79	rata	popul densit, svalbard rei	norderhaug,m	1970
NPOAA	1970-	53	58	rata	distr of svalbard reindeer	norderhaug,m	1972
NPOAA	1977-	243	248	rata	counts, popu est, svalbard	larsen,t	1976
PCZOA	16---	206		rata	prelim invest bar-gr carib	banfield,awf	1954
SYLVA	4----	17	23	rata	status, woodl carib, ontar	de vos, a	1948
WLMOA	25---	1	55	rata	popul dynam, newfound cari	bergerud,at	1971
WMBAA	10a--	1	79	rata	prelim invest, barren-gr c	banfield,awf	1954
WMBAA	10b--	1	112	rata	prelim invest, barr-gr, II	banfield,awf	1954
WMBAA	12---	1	147	rata	continued barre-gr studies	kelsall,jp	1957
WMBAA	15---	1	145	rata	co-op stud barr-gr 1957-58	kelsall,jp	1960
ZOLZA	50--1	117	125	rata	wild reindeer pop, novosib	kishchinskii,aa	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOMAA	25--1	43	46	anam	distrib, status in montana	beer,j	1944

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOMAA	48--1	145	146	bibi	present number, bison, tex	jackson,aw	1967
OFBIA	27---	29	32	bibi	plains bison, nort ontario	young,om	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
EXJOA	49...	17	28	ov--	wild sheep, brooks range	kilham,wh,jr	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CAFGA	43...	103	111	ovca	surv, santa rosa mts, cali	jones,fl; flittn/	1957
CAFGA	43--3	179	191	ovca	surv, santa rosa mts, cali	jones,fl; flittn/	1957
CGFPA	24---	1	11	ovca	liter review, popul dynami	streeter,rg	1970
JOMAA	27--1	3	28	ovca	ecol stud, rocky mt nat pa	packard,fm	1946
JWMAA	28--2	381	390	ovca	popul dynam, wildhorse isl	woodgerd,w	1964
JWMAA	31--4	693	706	ovca	populat, desert game range	hansen,cg	1967
SCBUB	35--6	29	76	ovca	survey of sierr nevad bigh	jones,fl	1950

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
EXJOA	46...	297	304	ovda	dall she count, mackenzies	kilham,wh,jr	1968
JWMAA	40--4	597	609	ovda	dall sh demog, murie, alas	murphy,ec; whitte	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
ATICA	30--1	52	60	obmo	s range, abund, e greenlan	ferns,pn	1977
CWPNB	33...	1	9	obmo	rata, prelimi surveys, nwt	miller,fl; russel	1973

obmo continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	39--3	398	408	obmo	distribu of muskox in cana	tener,js	1958
JOMAA	55--4	824	828	obmo	dist, numbers, arctic cana	miller,fl; russel	1974
JWMAA	35--1	103	108	obmo	pop char, jones sound, nwt	freeman,mmr	1971
MAMLA	22--1	168	174	obmo	the muskox, east greenland	vibe,c	1958
NPOAA	1974-	159	174	obmo	muskox populatio, svalvard	alendal,e	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	19--4	417	429	oram	two-year stud, crazy mount	lentfer,jw	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJZOA	2---1	9	65	anim	outlin of dynamics of pops	nicholson,aj	1954
AMBOC	7---3	130	131	many	endangered animals, sweden	anonymous	1978
ATICA	6....	91	148	seve	status of some arctic mamm	rausch,rl	1953
CWOPA	4----	1	50	game	queen eliz isl game survey	tener,js	1963
ECOLA	51--1	53	72	ungu	eruption of popultions, nz	caughley,g	1970
ECOLA	56--4	855	967		stabil, growth, pred, prey	tanner,jt	1975
FPWTA	32---	35	40	many	big gam mackenzie mts, nwt	simmons,nm	1968
MABIA	4---1	129	136		pop gro rat, lif cy pertur	demetrius,l	1969
NAWTA	12---	437	447	biga	status, big gam herds, mex	leopold,as	1947
NAWTA	15---	644	649	biga	determ, big game pop, kill	lauckhart,b	1950
NAWTA	43---	311	322	ungu	eval pop and range, b colu	bunnell,fl; elli/	1978
NAWTA	43---	351	357	ungu	popul in rel to wilderness	martinka,cj	1978
PZESA	15...	25	30	mamm	comp resp artif contro pop	batcheler,cl	1968
QRBIA	29--2	103	137		pop conseq, life hist phen	cole,lc	1954
SGGMA	40--4	321	331	many	stat, prosp, lrg mamm, can	anderson,rm	1924
XFWLA	342--	1	1	biga	inventory, u. s., 1950-51	us fish, wildl se	1952

TOPIC 2. POPULATION STRUCTURES

Sex and age structures of populations are very commonly represented in the literature as the two basic parameters of interest when evaluating population dynamics. Sex ratios are very important, of course, because the higher the fraction of parturient members in a population, the greater the potential for population growth The ratio of or fraction of females in the total population is especially important when considering the potential rate of increase.

Ages alone are not always good indicators of reproductive potentials because of the importance of body condition, which is a function of range conditions. Weight, or weight in relation to age is a better indicator of reproductive potentials than age alone. No measured data are available on weight structures of populations, however, so it is necessary to derive the weight structure from age and growth data.

Sex, age, and weight classes will be used in analyses that follow in this CHAPTER 18 and in CHAPTER 19. Terms used are described below, with their definitions and rationale for their use given.

First, classes are labeled with a small letter. The use of a letter avoids confusion with age classes which are represented by numbers. Think of a series of classes as:

a.
b.
c.
.
.
.
n.

This column is always to the left when compiling population data.

The column above may be expanded to include sex indentification by adding a hyphen for males and a second letter for females. Thus:

Males	Females
a-.	aa.
b-.	bb.
c-.	cc.
.	.
.	.
.	.
n-.	nn.

One further indentification may be added by using prefixes for the kind of class being considered: AC = age class and WC = weight class. Thus:

CLASS	
ACa-.	= age class of group a, males,
ACb-.	= " " " " b, " ,
ACc-.	= " " " " c, " , and
ACaa.	= age class of group a, females,
ACbb.	= " " " " b, " ,
ACcc.	= " " " " c, " .

Also,

CLASS	
WCa-.	= weight class of group a, males,
WCb-.	= " " " " b, " ,
WCc-.	= " " " " c, " , and
WCaa.	= weight class of group a, females,
WCbb.	= " " " " b, " ,
WCcc.	= " " " " c, " .

Age classes may be identified by the year interval (0-1, 1-2 . . .), by the mid-point (1/2, 1 & 1/2, 2 & 1/2 . . .), or by the age in days (AGDA = 1, 100, 365, 1519, etc.). Thus, using males classes as an example, age classes in year intervals (ACYI) are as follows:

CLASS	ACYI	
ACa-.	0-1	Includes all males from birth to their first birthday.
ACb-.	1-2	Includes all males from their first to second birthdays.
ACc-.	2 +	Includes all males from their second birthday on.

The mid-point age class designation is commonly used in the literature because animals are often aged in the fall at hunter checking stations when the animals are 1/2 year or older by one or more years. Thus, using female classes as an example, age classes by mid-point (ACMP) are as follows:

CLASS	ACMP	
ACaa.	1/2	Females one-half year of age.
ACbb.	1 & 1/2	Females one and one-half years of age.
ACcc.	2 & 1/2 +	Females two and one-half years of age and older.

Age classes divided by age in days (AGDA) may include any age interval selected. Thus:

CLASS	ACAD	
ACa-.	1 - 100	Includes all males age 1 to 100 days.
ACb-.	101 - 200	Includes all males age 101 to 200 days.
ACc-.	201 - 300	Includes all males age 201 to 300 days.
ACaa.	1 - 100	Includes all females age 1 to 100 days.
ACbb.	101 - 200	Includes all females age 101 to 200 days.
ACcc.	201 - 300	Includes all females age 201 to 300 days.

Different age classes will be chosen for different uses in the UNITS that follow. Analyses of populations throughout the year will use the year interval (ACYI), analyses of fall populations only will use the age classes by midpoint (ACMP). The age classes by age in day intervals (ACAD) will be used when estimating weights for the different age classes.

The following examples illustrate possible weight classes for use in later evaluations, where WCKI = weight class interval in kg.

CLASS	WCKI	
WCa-.	0 - 10	Weight class of males weighing 1 - 10 kg.
WCb-.	10 - 20	Weight class of males weighing 10 - 20 kg.
WCc-.	20 - 30	Weight class of males weighing 20 - 30 kg.

Weight classes could be identified by their mid-point weights (WCMP) too.

CLASS	WCMP	
WCaa.	5	Females closest to 5 kg.
WCbb.	25	Females closest to 25 kg.
WCcc.	45	Females closest to 45 kg.

Mid-point designations are really another way to express intervals; if WCMP = 1, 25, 45... , the intervals are 0 - 15, 15 - 35, 35 - 55, etc. Understand the logic of these sex, age, and weight identifications, and then begin using them in UNIT 2.1.

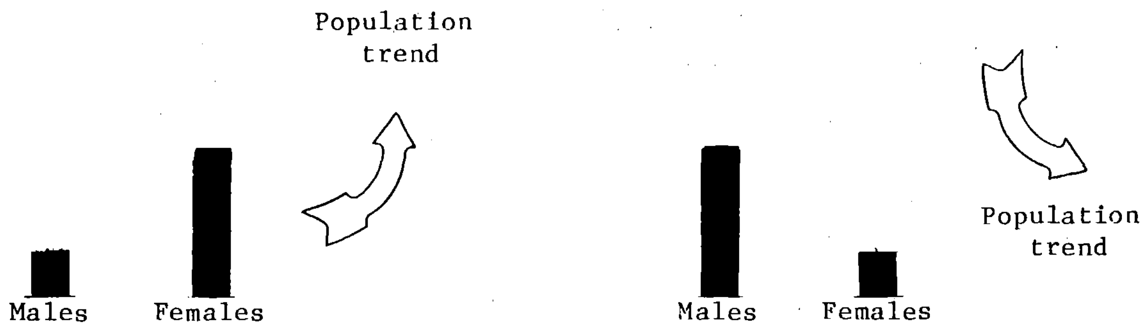
Sex and age structures, discussed in UNIT 2.1, form the bases for conversions to weight structures of populations. Different kinds of weight structures of populations are determined from estimates of individual weights and the distribution of weights in each sex and age class in a population in UNITS 2.2, 2.3, and 2.4. Metabolic structures are discussed in UNIT 2.5.

The several references to life tables of different wild ruminants in the literature are listed in UNIT 2.6. Life tables are discussed only briefly, however.

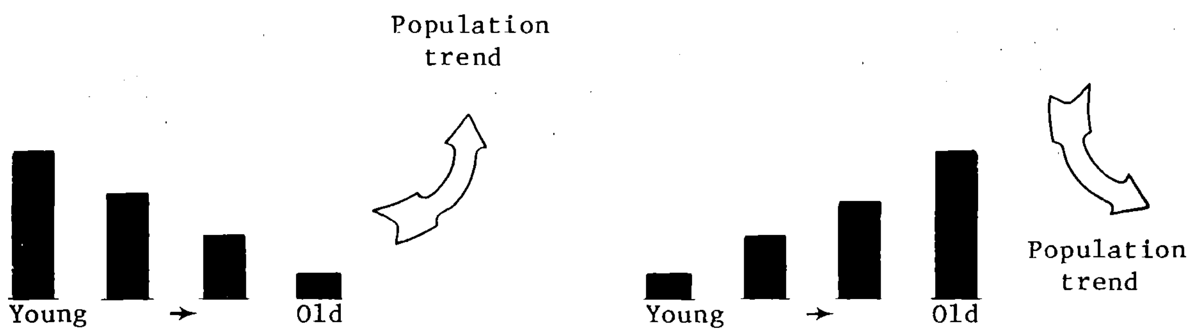
The discussions in the UNITS illustrate basic concepts and formats. Users are urged to consult the literature on selected species for specific data for WORKSHEET calculations.

UNIT 2.1: SEX AND AGE STRUCTURES

The breakdown of a population into sex and age classes reveals information that can be used to calculate the sex ratio, which is of importance when evaluating the potential parturient component of the population, and age ratios, which are of importance when evaluating the reproductive potential of a population over time. A sex ratio in favor of females indicates that a higher fraction of the population could produce young than when a sex ratio is in favor of males.



Age ratios in favor of the younger age groups indicate high reproduction in the immediate past. If sex and age ratios are in favor of young females, then a high reproductive potential exists for the near future when the young females mature and reproduce. Conversely, age ratios favoring the older classes indicate that reproduction has been depressed and as the animals age further, will likely go down even more. These relationships are illustrated below.



The representation of a population according to its sex and age structure, the usual population structures given in the literature, is fairly straight-forward if accurate sexing and aging techniques are available. Sex determination is straightforward in wild ruminants if the carcass is available for examination.

Sex may also be determined from skeletons; Taber (1956) examined the pelvic girdle of black-tailed and white-tailed deer, noting suspensary tuberosities for the attachment of penis ligaments in the male, but not in the female. Sexing of fetuses early in the gestation period before the external genetalia are present requires microscopic examination. Sex chromatin particles were found in nuclei of extra-embryonic membranes of female embryos, but not in those of males (Segelquist 1966).

Aging techniques for wild ruminants have been given considerable attention for many years because of the importance of age frequencies and distributions in population gowth. Some species--sheep and goats--may be conveniently aged by counting the "rings" that result from annualy-occurring periods of rapid horn growth (smooth areas) and of slower growth (ridges). Mountain goat horns are illustrated by Brandborg (1955) and Taber (1969:399). This technique offers the advantage of being able to determine age at death from skeletal remains.

Tooth replacement as a means of age determination of young deer was described by McLean in 1936. C. W. Severinghaus (1949) described and photographed jaws and teeth of known-age white-tailed deer and this effort resulted in the use of tooth-wear as a standard aging technique for many wild ruminants. Illustrations are included in the wildlife management techniques manual (Giles 1969). The extent of interest in teeth characteristics is indicated by the number of references in the SERIALS list in CHAPTER 2, UNIT 1.4.

Aging by tooth wear is not always accurate. Other methods have been tried in recent years. Eye lens weights have been evaluated in relation to age, especially in white-tailed deer and mule deer (see CHAPTER 2, UNIT 1.5). The relationship is good enough to be used as a predictor of age, but is not a very practical one. Aging is almost always done at hunter checking stations, and the removal of an eye lens is not an accepted practice.

Teeth may not only be examined but extracted at checking stations. A recently developed aging method, and apparently the most reliable one known at this time, involves microscopic examination of the annuli in a cross section of a tooth. The annuli are responses to seasonal metabolic rhyuthms, synchonized with changes in range conditions.

Comparisons of tooth-wear and annuli show that white-tailed deer aged by tooth wear are often thought to be younger than when aged by the more accurate annuli method (Moen and Sauer 1977). This has significant implications in predicting population dynamics since underaging does not give an individual credit for being in the population for the time between real age and estimated age, and also eliminates consideration of her offspring produced during that missing time. Thus the aging error has a multiplicative effect. In fact, underaging of deer at the Seneca Army Depot in New York resulted in too few deer estimated present to reproduce enough to even keep up with known mortality from controlled hunts (Moen and Sauer 1977).

Absolute numbers in sex and age classes are of interest with respect to a given population. If N is estimated or known, then N males and N females should also be estimated, if not known. If N is not known as an absolute number, and it seldom is, then estimated N's should be used to calculate ratios and weighted means for use in analyses and predictions.

A format for recording numbers in each sex and age class is shown on the next page. Mid-point data are used in this example. Numbers given are for the number in a prehunt population (NPHP) (see CHAPTER 19 - Page 1).

CLASS	ACMP	NMAC
ACa-.	1/2	50
ACb-.	1 1/2	38
ACc-.	2 1/2+	12
	SUM =	100 = TNMP

CLASS	ACMP	NFAC
ACaa.	1/2	44
ACbb.	1-1/2	34
ACcc.	2-1/2+	22
	SUM =	100 = TNFP

The male to female sex ratio may be added as shown below.

CLASS	ACMP	NMAC
ACa-.	1/2	50
ACb-.	1-1/2	38
ACc-.	2-1/2+	12
	SUM =	100 = TNMP

CLASS	ACMP	NFAC	NMAC/NFAC	=	MFSR
ACaa.	1/2	44	50 / 44	=	1.14
ACbb.	1-1/2	34	38 / 34	=	1.12
ACcc.	2-1/2+	22	12 / 22	=	0.55
	SUMS =	100 = TNFP			

Male and female fractions in each age class of the male and female populations may be added as shown below.

CLASS	ACMP	NMAC	NMAC/TNMP	=	FMPA
ACa-.	1/2	50	50 / 100	=	0.50
ACb-.	1-1/2	38	38 / 100	=	0.38
ACc-.	2-1/2+	12	12 / 100	=	0.12
	SUMS =	100 = TNMP			[1.00]

CLASS	ACMP	NFAC	NFAC/TNFP	=	FFPA
ACaa.	1/2	44	44 / 100	=	0.44
ACbb.	1-1/2	34	34 / 100	=	0.34
ACcc.	2-1/2+	22	22 / 100	=	0.22
	SUMS =	100 = TNFP			[1.00]

Population estimates may also be made from the numbers removed by hunting. In New York State, Age-Sex Multipliers are used to estimate the number of deer per square mile of each age and sex class from the buck take per square mile (Free et al. 1964). These multipliers have been determined empirically from calculated gains and losses in deer populations over a number of years. Thus, the number of deer in any age and sex class can be estimated by multiplying the buck take by the appropriate multiplier. An example is given below for Steuben County in western New York.

MULTIPLIERS

Males		Females		Total
Fawns	Adults	Fawns	Adults	Population
1.35	1.47	1.28	2.29	6.39

Steuben County buck take = 4775. Therefore:

4775 x 1.35 = 6447 = male fawn population,
4775 x 1.47 = 7019 = male adult population,
4775 x 1.28 = 6112 = female fawn population,
4775 x 2.29 = 10935 = female adult population, and
4775 x 6.39 = 30512 = total population.

Another method for estimating populations from numbers removed by hunting is a change-in-ratio (CIR) procedure (Shope 1978), developed from a paper by Selleck and Hart (1957). This method has an advantage over the multiplier method in that it incorporates annually all losses which alter age and sex ratios, not just average losses during several sample years. The method can be used only when there is differential mortality for sex and age groups, resulting in changes in the sex or age ratios of the population as a result of the loss.

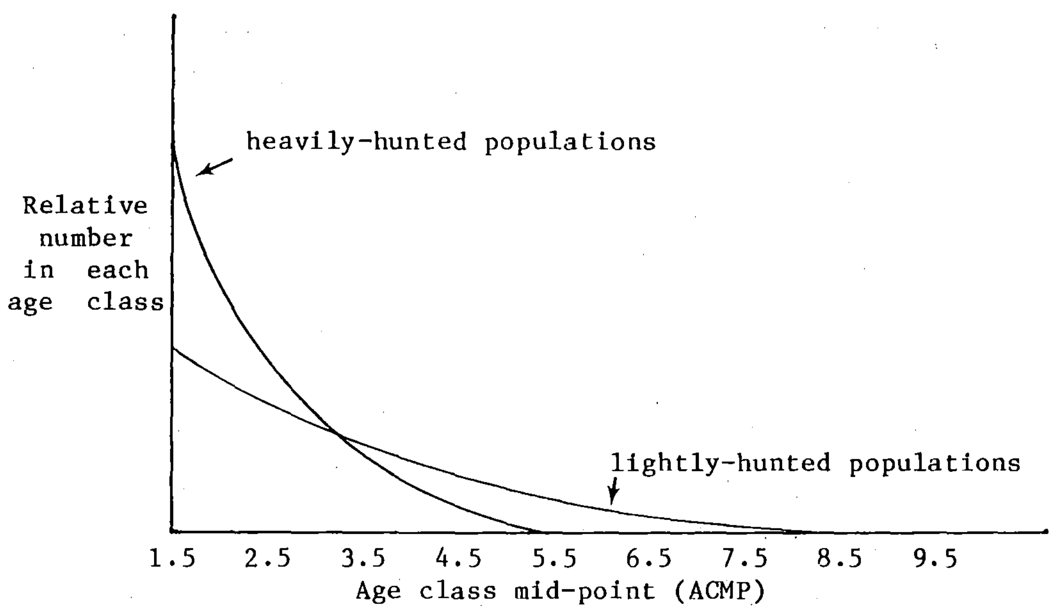
Seven steps are given by Shope (1978) for estimating a series of deer populations from which estimates of adult survival rates and minimum fawn production may be made. The estimations require the following information:

a. Prehunt adult males per 100 adult females,
b. Adult males harvested per 100 adult females, and
c. Posthunt adult males per 100 adult females.

The use of this information in making population estimates is described in WORKSHEET 2.1d.

Estimations of populations based on hunter kill data have a disadvantage in only accounting for losses from the calculated legal take, thereby underestimate the actual populations in the field. Severinghaus (1981) has estimated that actual populations may be at least 25% larger than those estimated by both the Age-Sex Multiplier and the Shope methods.

Suppose the age composition of a population was entirely unknown. There is evidence indicating that white-tailed deer age compositions can be represented with exponential equations, thereby permitting first approximations of the age composition when field data are not available. C. W. Severinghaus at Cornell's Wildlife Ecology Laboratory showed that the exponential curve was the best fit or very close to the best fit for deer populations in 10 different ecological zones in New York State. Variations in the intercept and slope depended on the hunting regimes in the different zones. Heavily-hunted populations had more younger and less older animals, and lightly-hunted populations had less younger and more older animals. The basic relationship is illustrated below.



First approximations of the age-structure may be made by estimating the relative number of yearlings and the maximum age; the exponential curve fills in the rest. Better estimates of the age structures of local populations are made by curve-fitting the numbers in each of the age classes.

The formats for dividing populations into any number of age classes are given as WORKSHEETS for your use in making population predictions in CHAPTER 19. There are several references in the SERIALS list for most species for use in these WORKSHEETS, or you may use your local or state data. Be sure to build the population tabulations in these step-wise fashions so you are familiar with the groups that may be used in both the arithmetic and exponential predictions in CHAPTER 19.

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Taber, R. D. 1956. Characteristics of the pelvic girdle in relation to sex in black-tailed and white-tailed deer. Calif. Fish and Game 42(1):5-21.

Taber, R. D. 1969. Criteria of sex and age. Chapter 20, Pages 325-401 In: R. H. Giles, Jr. (Ed.); Wildlife Management Techniques. The Wildlife Society, Washington, D. C. 623 p.

REFERENCES, UNIT 2.1

SEX AND AGE STRUCTURES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	17--1	95	97	od--	secondar sex ratio, odocoi	taber,rd	1953

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNSVA	24--2	18	19	odvi	incredible white deer herd	hesselton,wt	1969
JWMAA	18--4	482	495	odvi	deer management study: mud	hunt,rw; mangus,l	1954
JWMAA	29--4	884	885	odvi	unusual sex ratio, w-t dee	downing,rl	1965
JWMAA	38--3	563	565	odvi	seas diff sex ratio, trapp	mattfeld,gf; sag/	1974
JWMAA	40--3	454	463	odvi	group size, comp, flor key	hardin,jw; silv,/	1976
JWMAA	41--4	709	714	odvi	accur, sex, age ratio coun	downing,rl; mich/	1977
MDCRA	2282.	1		odvi	estim vital statistcs herd	eberhardt,l	1960
NAWTA	28---	422	430	odvi	10 yr obs, encl herd, mich	arnold,da; verme,	1963
NFGJA	1---1	98	109	odvi	warines, age comp hunt kil	maguire,hf; sever	1954
NFGJA	2---2	242	246	odvi	age compo data, sex ratios	severinghaus,cw;/	1955
NFGJA	16--1	19	26	odvi	minimum pop, moose riv, ny	severinghaus,cw	1969
NFGJA	26--1	14	19	odvi	sex ratios among fawns	clarke,sh; severi	1979
PMACA	47---	289	316	odvi	valid age determ mich deer	ryel,la; fay,ld;/	1961
TNWSD	1959.	1	6	odvi	rel matrn age, pren sex ra	mcdowell,rd	1959
WLMOA	15---	1	62	odvi	ecol, mgt llano basin, tex	teer,jg; thomas,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	38--2	211	224	odhe	food hab, prod, cond, cali	lassen,rw; ferre/	1952
CAFGA	39--2	177	186	odhe	reprod on 3 chapar cov typ	taber,rd	1953
CAFGA	40--3	215	234	odhe	de fora relat lassen-washo	dasmann,w; blaisd	1954
JWMAA	18--3	309	315	odhe	sex diff, mortal, young de	taber,rd; dasmann	1954
JWMAA	20--1	78	83	odhe	determ struct in populatio	dasmann,rf; taber	1956
JWMAA	21--1	1	16	odhe	diff mortal by sex and age	robinette,wl; ga/	1957
JWMAA	31--4	651	666	odhe	charac, herds, range, utah	richens,vb	1967
NAWTA	13---	409	430	odhe	ceel, sexing, airpla, colo	riordan,le	1948

odhe continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NEXAA	567--	1	32	odhe	ft stanton hrd, ecol, n mx	wood,je; bickle,/	1970
SWNAA	15--1	29	36	odhe	ind surv, repro fem, n mex	anderson,ae; sny/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	64...	40	42	ceel	produc, sex survi, alberta	green,hu	1950
CWRSB	11---	1	71	ceel	caus, impli sex diff, surv	flook,dr	1970
JWMAA	32--3	553	5457	ceel	differ distri by sex & age	peek,jm; lovaas,a	1968
JWMAA	38--4	789	791	ceel	preg rt; fall cow/clf rati	follis,tb; spille	1974
MRLTA	32--2	19	22	ceel	tech for age determination	swanson,cv	1951
NATUA	177--	488	489	ceel	propor fawns to hinds, n z	riney,t	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
EKPOA	17-37	709	718	alal	reprod, dynam, pop, poland	serafinski,w	1969
ELPLB	23--3	493	506	alal	pop char, range use, polan	morow,k	1975
JWMAA	24--1	162	170	alal	foo habs, mvmt, pops, mont	knowlton,ff	1960
JWMAA	26--4	360	365	alal	studies, mountns in montan	peek,jm	1962
JWMAA	34--3	645	646	alal	aerial sex, antlerless, bc	mitchell,hb	1970
NCANA	101-3	539	558	alal	annu yield sex, age, ontar	cumming,hg	1974
WLMOA	48---	1	65	alal	habitat select, forest mgt	peek,jm; urich,d/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	3----	1	30	rata	sympos, caribou popul ecol	klein,dr; white,r	1978
CWRSB	31---	1	88	rata	dentition, age and sex com	miller,fl	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	36--3	328	329	anam	calif antel repro potentia	chattin,je; lasse	1950
NAWTA	15---	627	644	anam	rang ecol, wichita mt, kan	buechner,hk	1960

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
JWMAA	35--1	103	108	obmo	pop char, jones sound, nwt	freeman,mmr	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	29--2	185	185	oram	mt goat age ratios, montan	petrides,ga	1948

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	112--	381	388		sex rat adj under food str	myers,jh	1978
JWMAA	7---1	11	13	biga	bag rec, sex rat, pop dens	baker,rh; siegler	1943
JWMAA	29--1	185	192		sex ratio, prod, surv data	wight,hm; heath,/	1965
JWMAA	34--4	690	703		det param, pop, struct mod	henny,cj; overto/	1970
SCIEA	179--	90	92	many	nat sel on par, sx rt offs	trivers,rl; willa	1973
UASPA	20...	189	198		sex ratio equatns, formula	kelker,gh	1944
WLMOA	9----	1	60	many	prod, abun, sex, age ratio	hanson,wr	1963

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
DRGBA	2---2	127	155	caca	analys danish pop, extermi	andersen,j	1953
LYNXA	14...	14	19	caca	sex indx in yg pops, ecosy	novakova,e; hanzl	1973
ZEJAA	1---2	65	69	caca	mark fawns, field id ag cl	wettstein,o	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	23--1	3	48	bibo	dyn, strc of pop in poland	krasinski,za	1978

CHAPTER 18, WORKSHEET 2.1a

Calculations of male to female sex ratios in each age class

The following format may be used to calculate male to female sex ratios (MFSR) in each age class. Space is provided for nine age classes, and an additional set of blanks is provided on the back of this page.

SPECIES: ______________________ REFERENCE: ______________________

LOCATION: ______________________ TIME PERIOD: ______________________

CLASS	ACMP	NMAC
ACa-.	1/2	____
ACb-.	1-1/2	____
ACc-.	2-1/2	____
ACd-.	3-1/2	____
ACe-.	4-1/2	____
ACf-.	5-1/2	____
ACg-.	6-1/2	____
ACh-.	7-1/2	____
ACi-.	8-1/2+	____
	SUM =	____ = TNMP

CLASS	ACMP	NFAC	NMAC/NFAC	=	MFSR
ACaa.	1/2	____	____/____	=	____
ACbb.	1-1/2	____	____/____	=	____
ACcc.	2-1/2	____	____/____	=	____
ACdd.	3-1/2	____	____/____	=	____
ACee.	4-1/2	____	____/____	=	____
ACff.	5-1/2	____	____/____	=	____
ACgg.	6-1/2	____	____/____	=	____
AChh.	7-1/2	____	____/____	=	____
ACii.	8-1/2+	____	____/____	=	____
	SUM =	____ = TNFP			

SPECIES: ____________ REFERENCE: ____________

LOCATION: ____________ TIME PERIOD: ____________

CLASS	ACMP	NMAC
ACa-.	1/2	____
ACb-.	1-1/2	____
ACc-.	2-1/2	____
ACd-.	3-1/2	____
ACe-.	4-1/2	____
ACf-.	5-1/2	____
ACg-.	6-1/2	____
ACh-.	7-1/2	____
ACi-.	8-1/2+	____

SUM = ____ = TNMP

CLASS	ACMP	NFAC	NMAC/NFAC	=	MFSR
ACaa.	1/2	____	____/____	=	____
ACbb.	1-1/2	____	____/____	=	____
ACcc.	2-1/2	____	____/____	=	____
ACdd.	3-1/2	____	____/____	=	____
ACee.	4-1/2	____	____/____	=	____
ACff.	5-1/2	____	____/____	=	____
ACgg.	6-1/2	____	____/____	=	____
AChh.	7-1/2	____	____/____	=	____
ACii.	8-1/2+	____	____/____	=	____

SUM = ____ = TNFP

CHAPTER 18, WORKSHEET 2.1b

Calculations of the male and female fractions in each age class of the total male and female populations

Calculations of the male and female fractions in nine age classes in relation to the total male and female populations may be made in the space provided below. A second set of spaces is provided on the back of this page.

SPECIES: ____________ REFERENCE: ____________

LOCATION: ____________ TIME PERIOD: ____________

CLASS	ACMP	NMAC	NMAC/TNMP	=	FMPA
ACa-.	1/2	____	____/____	=	____
ACb-.	1-1/2	____	____/____	=	____
ACc-.	2-1/2	____	____/____	=	____
ACd-.	3-1/2	____	____/____	=	____
ACe-.	4-1/2	____	____/____	=	____
ACf-.	5-1/2	____	____/____	=	____
ACg-.	6-1/2	____	____/____	=	____
ACh-.	7-1/2	____	____/____	=	____
ACi-.	8-1/2+	____	____/____	=	____
	SUMS =	____	= TNMP		[1.00]

CLASS	ACMP	NFAC	NFAC/TNFP	=	FFPA
ACaa.	1/2	____	____/____	=	____
ACbb.	1-1/2	____	____/____	=	____
ACcc.	2-1/2	____	____/____	=	____
ACdd.	3-1/2	____	____/____	=	____
ACee.	4-1/2	____	____/____	=	____
ACff.	5-1/2	____	____/____	=	____
ACgg.	6-1/2	____	____/____	=	____
AChh.	7-1/2	____	____/____	=	____
ACii.	8-1/2+	____	____/____	=	____
	SUMS =	____	= TNFP		[1.00]

SPECIES: ____________ REFERENCE: ____________

LOCATION: ____________ TIME PERIOD: ____________

CLASS	ACMP	NMAC	NMAC/TNMP	=	FMPA
ACa-.	1/2	____	____/____	=	____
ACb-.	1-1/2	____	____/____	=	____
ACc-.	2-1/2	____	____/____	=	____
ACd-.	3-1/2	____	____/____	=	____
ACe-.	4-1/2	____	____/____	=	____
ACf-.	5-1/2	____	____/____	=	____
ACg-.	6-1/2	____	____/____	=	____
ACh-.	7-1/2	____	____/____	=	____
ACi-.	8-1/2+	____	____/____	=	____
	SUMS =	____	= TNMP		[1.00]

CLASS	ACMP	NFAC	NFAC/TNFP	=	FFPA
ACaa.	1/2	____	____/____	=	____
ACbb.	1-1/2	____	____/____	=	____
ACcc.	2-1/2	____	____/____	=	____
ACdd.	3-1/2	____	____/____	=	____
ACee.	4-1/2	____	____/____	=	____
ACff.	5-1/2	____	____/____	=	____
ACgg.	6-1/2	____	____/____	=	____
AChh.	7-1/2	____	____/____	=	____
ACii.	8-1/2+	____	____/____	=	____
	SUMS =	____	= TNFP		[1.00]

CHAPTER 18, WORKSHEET 2.1c

First approximations of age class distributions

A first approximation of the age structure may be made by fitting two points, fraction of yearlings in the population and the fraction in the oldest age class present, with an exponential curve.

1. Determine the yearling fraction of the yearling and adult population and tabulate below.

2. Determine the oldest age class expected to have a minimum fraction of animals worth considering in the total population, add 1.0* to that number, and record 0.01 in that last age class. Tabulate below.

ACMP	FYAP
1.5	___
___*	0.01

*This is the oldest age class plus 1.0.

3. Use an exponential curve-fitting program for the above table to derive a first-approximation equation for age class distribution. Calculate the fraction in each age class.
   Review the concepts presented on Page 39 in relation to heavily-hunted and lightly-hunted populations.

Space is provided on the next page for tabulated (TBLD) fractions of the yearling and adult populations for data of your choosing for nine age classes. Derive the equation and determine the calculated (CALC) fractions of the yearling and adult populations in each age class. Then determine the differencee (DIFF) between tabulated and calculated values.

ACMP	TBLD FYAP	CALC FYAP	DIFF
1.5	____	____	____
2.5	____	____	____
3.5	____	____	____
4.5	____	____	____
5.5	____	____	____
6.5	____	____	____
7.5	____	____	____
8.5	____	____	____
9.5	____	____	____
SUM =	1.00	____	

The equation for your data is:

ACMP	TBLD FYAP	CALC FYAP	DIFF
1.5	____	____	____
2.5	____	____	____
3.5	____	____	____
4.5	____	____	____
5.5	____	____	____
6.5	____	____	____
7.5	____	____	____
8.5	____	____	____
9.5	____	____	____
SUM =	1.00	____	

The equation for your data is:

CHAPTER 18, WORKSHEET 2.1d

Estimations of sex and age ratios based on prehunt and posthunt change-in-ratios

A method described by Shope and modified by Severinghaus (1981) may be used to determine sex and age compositions of prehunt populations. The basic data needed are age ratios and harvest data from two consecutive years. The method is described below.

I. Inputs

1. PYM1 = percent of yearling males in the total yearling and adult male population, year 1.
2. PYF1 = percent of yearling females in the total yearling and adult female population, year 1.
3. PAM2 = percent of adult males in the total yearling and adult male population, year 2.
4. PAF2 = percent of adult females in the total yearling and adult female population, year 2.
5. PYM2 = percent of yearling males in the total yearling and adult male population, year 2.
6. PYF2 = percent of yearling females in the total yearling and adult female population, year 2.
7. NAMH = number of adult and yearling males harvested, year 1.
8. NAFH = number of adult and yearling females harvested, year 1.
9. NFFH = number of fawn females harvested, year 1.
10. MFSR = number of males per 1 female.

II. Other Symbols Used

1. PRAM = number of prehunt adult males/100 adult females. See equation #1.
2. AMHF = number of adult males harvested/100 adult females. See equation #2.
3. PSAM = number of posthunt adult males/100 adult females. See equation #3.
4. MHRT = male harvest rate. See equation #4.
5. NMAC = number of males in each age class.
6. TMFP = number of males and females in the population.
7. NFAC = number of females in each age class.

III. Outputs

NAMP =	number of	adult (2-1/2+ years)	males in the population.	
NYMP =	"	" yearling	" " "	".
NFMP =	"	" fawn	" " "	".
NAFP =	"	" adult (2-1/2+ years)	females in the population.	
NYFP =	"	" yearling	" " "	".
NFFP =	"	" fawn	" " "	".

IV. Equations

1. PRAM = (PYF1/PYM1) x MFSR x 100

2. AMHF = (NAMH/NAFH) x 100

3. PSAM = [(PAM2 x PYF2)/(PAF2 x PYM2)] x 100

4. MHRT = [AMHF x (PRAM - PSAM)]/[PRAM x (AMHF - PSAM)]

5. NYAM = NAMH/MHRT =
   number of yearling and adult males in the prehunt population

   a. NYMP = (PYM2 x NYAM)/100 = number of yearling males
   b. NAMP = (PAM2 x NYAM)/100 = number of adult males

6. NYAF = (NYAM x 100)/PRAM =
   number of yearling and adult females in the prehunt population

   a. NYFP = (PYF2 x NYAF)/100 = number of yearling females
   b. NAFP = (PAF2 x NYAF)/100 = number of adult females

7. NFFP = [(PYF2/PAF2) (NYAF - NAFH)] + NFFH =
   number of fawn females in the prehunt population

8. NFMP = NFFP X MFSR = number of fawn males in the prehunt population

9. The total number of males and females in the population (TMFP) equals:

   TMFP = NYMP + NAMP + NFMP + NYFP + NAFP + NFFP

A sample calculation is shown in the next WORKSHEET, and a format to be used for your calculations is given on page 44ee.

The number of individuals per square mile in each class or the total population can be determined by dividing the number in each class or the total population by the number of square miles of deer habitat (AREA).

The age compositions of the population or sex group may be determined by dividing the number in each age class by the total number in the population or sex group.

LITERATURE CITED

Shope, W. K. 1978. Estimating deer populations using CIR procedures and age structure data and harvest management decision making from CIR estimates. p. 28-35 In Trans. 14th Ann. NE Deer Study Group Meeting.

Severinghaus, C. W. 1981. Unpublished report #81-27 of the Wildlife Ecology Laboratory, Cornell University.

CHAPTER 18, WORKSHEET 2.1e

Sample calculation of sex and age ratios
based on prehunt and posthunt change-in-ratios

A sample calculation for Allegany County, N.Y., 1978 and 1979, is shown below. Each blank is filled with the data indicated by the symbol in brackets underneath it. Input data are given at the top.

INPUT DATA	Age Ratio Data				Harvest Data			
	PYM	PAM	PYF	PAF	NAMH	NAFH	NFFH	MFSR
year 1	75		35		2555	266	209	1.15
year 2	79	21	38	62				

1. (35 / 75) x 1.15 x 100 = 53.67 = PRAM
[PYF1] [PYM1] [MFSR]

2. (2555 / 266) x 100 = 960.53 = AMHF
[NAMH] [NAFH]

3. [(21 x 38) / (62 x 79)] x 100 = 16.29 = PSAM
[PAM2] [PYF2] [PAF2] [PYM2]

4. [960.53 x (53.67 - 16.29)] / [53.67 x (960.53 - 16.29)] = 0.71 = MHRT
[AMHF] [PRAM] [PSAM] [PRAM] [AMHF] [PSAM]

5. 2555 / 0.71 = 3598.59 = NYAM
[NAMH] [MHRT]

6. (3598.59 x 100) / 53.67 = 6705.03 = NYAF
[NYAM] [PRAM]

7. [(38 / 62) (6705.03 - 266)] + 209 = 4155.50 = NFFP
[PYF2] [PAF2] [NYAF] [NAFH] [NFFH]

ACMP	MALE	NMAC	FEMALE	NFAC
1/2	(4155.50 x 1.15) [NFFP] [MFSR]	=4779 =NFMP		4156 =NFFP
1-1/2	(3598.59 x 79) / 100= [NYAM] [PYM2]	2843 =NYMP	(6705.03 x 38) / 100= [NYAF] [PYF2]	2548 =NYFP
2-1/2+	(3598.59 x 21) / 100= [NYAM] [PAM2]	756 =NAMP	(6705.03 x 62) / 100= [NYAF] [PAF2]	4157 =NAFP

Totals: # OF MALES= 8378 =TNMP # OF FEMALES= 10861 =TNFP

Total Population = 8378 + 10861 = 19239 = TMFP
[TNMP] [TNFP]

Fill in the blanks as indicated by the symbols in brackets underneath. If only one year of data is available, use it twice. Input data are to be tabulated at the top.

INPUT DATA	Age Ratio Data				Harvest Data			
	PYM	PAM	PYF	PAF	NAMH	NAFH	NFFH	MFSR
year 1	______		______		______	______	______	______
year 2	______	______	______	______				

1. (______ / ______) x ______ x 100 = ______ = PRAM
   [PYF1] [PYM1] [MFSR]

2. (______ / ______) x 100 = ______ = AMHF
   [NAMH] [NAFH]

3. [(______ x ______) / (______ x ______)] x 100 = ______ = PSAM
   [PAM2] [PYF2] [PAF2] [PYM2]

4. [______ x (______ - ______)] / [______ x (______ - ______)] = _____ = MHRT
   [AMHF] [PRAM] [PSAM] [PRAM] [AMHF] [PSAM]

5. ______ / ______ = ______ = NYAM
   [NAMH] [MHRT]

6. (______ x 100) / ______ = ______ = NYAF
   [NYAM] [PRAM]

7. [(______ / ______) (______ - ______)] + ______ = ______ = NFFP
   [PYF2] [PAF2] [NYAF] [NAFH] [NFFH]

ACMP	MALE	NMAC	FEMALE	NFAC
1/2	(______ x ______) [NFFP] [MFSR]	=______=NFMP		______ =NFFP
1-1/2	(______ x ______) / 100= [NYAM] [PYM2]	______=NYMP	(______ x ______) / 100= [NYAF] [PYF2]	______=NYFP
2-1/2+	(______ x ______) / 100= [NYAM] [PAM2]	______=NAMP	(______ x ______) / 100= [NYAF] [PAF2]	______=NAFP
Totals:	# OF MALES=	______=TNMP	# OF FEMALES=	______=TNFP

Total Population = ______ + ______ = ______ = TMFP
[TNMP] [TNFP]

UNIT 2.2. LIVE-WEIGHT STRUCTURES

Compilation of the weight structures of populations is important for those species which have the potential for major ecological impacts on the range. All wild ruminants have this potential as their number, biomass, and metabolic requirements may build up to levels that affect the stability of the forage resources necessary to support them. Populations of many other organisms--song birds, for example--do not build up to levels that have such potentially major, long-term, widespread impacts on the ecosystem.

Weights generally increase as animals grow older, with seasonal variations contributing to a sequence of weights through time for each individual as well as differences between individuals. Weight equations were presented in CHAPTER 1, and the results of calculations with those equations, using information on the sex and age structures discussed in UNIT 1.1, can now be used to determine the weight structure of a population.

The basic format for displaying the weight structure of a population is the same as that for the age structure. Weight classes replace age classes for each sex, and the numbers in each, fractions of the total number in each, and the weighted mean for a population are all recorded and determined as described for age structures in UNIT 2.1.

The format for determining weight structures follows for both females and males. Be sure to work through the simplified example to verify your ability to represent a population by its weight structure.

CLASS	WCKI	NMWC	
WCa-.	40-50	____	
WCb-.	50-60	____	
WCc-.	60-70+	____	
	SUM =	____	= TNMP

CLASS	WCKI	NFWC	
WCaa.	40-50	____	
WCbb.	50-60	____	
WCcc.	60-70+	____	
	SUM =	____	= TNFP

Ratios may be added to the format as shown below.

CLASS	WCKI	NMWC
WCa-.	40-50	35
WCb-.	50-60	44
WCc-.	60-70+	21
	SUM =	100 = TNMP

CLASS	WCKI	NFWC	NMWC/NFWC	=	MFSR
WCaa.	40-50	50	35 / 50	=	0.70
WCbb.	50-60	43	44 / 43	=	1.02
WCcc.	60-70+	7	21 / 7	=	3.00
	SUM =	100 = TNFP			

Ratios could also be derived for each class as a fraction of the total if that sex. Thus the male fraction of the total number of both males and females (TNMF) in each ACMP could be determined as follows:

CLASS	WCKI	NMWC	NMWC/TNMP	=	FMPW
WCa-.	40-50	35	35 / 100	=	0.35
WCb-.	50-60	44	44 / 100	=	0.44
WCc-.	60-70+	21	21 / 100	=	0.21
	SUMS =	100	= TNMP		[1.00]

CLASS	WCKI	NFWC	NFWC/TNFP	=	FFPW
WCaa.	40-50	50	50 / 100	=	0.50
WCbb.	50-60	43	43 / 100	=	0.43
WCcc.	60-70+	7	7 / 100	=	0.07
	SUMS =	100	= TNFP		[1.00]

The above formats for weight classes are used when weights are available and frequency-tabulations can be made. The occurrence of individuals in different weight classes are evaluated just as the age classes were, resulting in the number of animals in each of the weight classes, after which ratios of males to females or of males or females in relation to the total number in each age class can be calculated.

Measured weights of live or field-dressed animals (field-dressed weights can be converted to live weights) are seldom available throughout the year. Age class data may be used to estimate age in days (AGDA), and AGDA used to calculate live weights (See CHAPTER 1, TOPIC 1). The resulting calculated live weights in kg (CLWK) represent estimated average weights for each age class rather than weight distributions in the population. The weights may be used, however, in calculating reproductive rates, ecological metabolism, weights of forage reached, and other weight-dependent variables.

The formats for tabulating calculated live weights in kg for males and females in each of the age classes are shown below.

CLASS	ACYI	JDAY	AGDA	CLWK
ACa-.	0-1	____	____	____
ACb-.	1-2	____	____	____
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
ACn-.	____	____	____	____

CLASS	ACYI	JDAY	AGDA	CLWK
ACaa.	0-1	____	____	____
ACbb.	1-2	____	____	____
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
ACnn.	____	____	____	____

Weighted mean live weights for male and female populations (WLMP and WLFP) are calculated next by multiplying the class weight by the fraction of the males or females in that class. The sums of the weighted mean weights for each age class are the weighted mean population weights.

MALES

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	x	____	=	____
.	.	.	.	.	.		.		.
.	.	.	.	.	.		.		.
.	.	.	.	.	.		.		.
ACn-.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP			[1.00]		[____] WLMP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NMAC = number of males in each age class,
CLWK = calculated live weight in kg,
FMPA = fraction of the male population in each age class (NMAC/TNMP),
WMLA = weighted mean live weight of the age class,
SUMS = sums,
TNMP = total number of males in the population, and
WLMP = weighted-mean live weight of the male population.

A sample calculation is shown below. All the blanks are filled in to demonstrate the sequence of the calculations. The format is repeated in WORKSHEET 2.2a for your use with a species of your choice.

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	1/2	310	160	50	45	x	0.50	=	22.5
ACb-.	1-1/2	310	525	38	70	x	0.38	=	26.6
ACc-.	2-1/2+	310	890	12	85	x	0.12	=	10.2
			SUMS =	[100] TNMP			[1.00]		[59.3] WLMP

The format for determining the weighted-mean live weight of the female population is shown below.

FEMALES

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLA
ACaa.	___	___	___	___	___	x	___	=	___
ACbb.	___	___	___	___	___	x	___	=	___
.	.	.	.	.	.		.		.
.	.	.	.	.	.		.		.
.	.	.	.	.	.		.		.
ACnn.	___	___	___	___	___	x	___	=	___
			SUMS =	[___] TNFP			[1.00]		[___] WLFP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NFAC = number of females in each age class,
CLWK = calculated live weight in kg,
FFPA = fraction of the female population in each age class (NFAC/TNFP),
WMLW = weighted mean live weight of the age class,
SUMS = sums,
TNFP = total number of females in the population, and
WLFP = weighted-mean live weight of the female population.

Sample calculations are shown below. All the blanks are filled in to demonstate the sequence of the calculations, and the format is repeated in WORKSHEET 2.2b for your use with a species of your choice.

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLW
ACaa.	1/2	310	160	44	42	x	0.44	=	18.5
ACbb.	1-1/2	310	525	34	56	x	0.34	=	19.0
ACcc.	2-1/2+	310	890	22	62	x	0.22	=	13.6
			SUMS =	[100] TNFP			[1.00]		[51.2] WLFP

The calculation of WEIGHT STRUCTURES in this UNIT 2.2 leads to calculations of METABOLIC WEIGHT STRUCTURES in UNIT 2.4. This is useful for calculating ecological metabolism (see CHAPTER 7), with the use of metabolic weight in the equations for ELMD.

The metabolic weight structure of the population is determined by adding a few columns to the right side of the format for the weight structure.

REFERENCES, UNIT 2.2

LIVE-WEIGHT STRUCTURES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NFGJA	20--2	77	107	odvi	comp physc cond, sev indic	hesselton,wt; sau	1973

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	52--1	147	152	alal	biomass dynamics, populati	jordan,pa; botki/	1971

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
MAMLA	34--3	363	393	herb	est biomass large herbivor	mentis,mt	1970

CHAPTER 18, WORKSHEET 2.2a

Determining live weight population structures - males

Calculations of the live weight structures of populations of males in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP			[1.00]		[____] WLMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP			[1.00]		[____] WLMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP			[1.00]		[____] WLMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	x	FMPA	=	WMLA
ACa-.	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP			[1.00]		[____] WLMP

CHAPTER 18, WORKSHEET 2.2b

Determining live weight population structures - females

Calculations of the live weight structures of populations of females in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLA
ACaa.	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP			[1.00]		[____] WLFP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLA
ACaa.	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP			[1.00]		[____] WLFP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLA
ACaa.	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP			[1.00]		[____] WLFP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	x	FFPA	=	WMLA
ACaa.	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP			[1.00]		[____] WLFP

UNIT 2.3: INGESTA-FREE WEIGHT STRUCTURES

Ingesta-free weight structures are determined from the live-weight structures by multiplying live weights by the appropriate fractions representing ingesta-free weights (See CHAPTER 1, UNIT 1.5). The formats below look very familiar; they are identical to those in UNIT 2.2, with the addition of a column for IFWK. The formats are presented separately because some calculations are based on live weight (height of forage reached, for example), some on ingesta-free weight (body composition, for example), and some on metabolic weights (See UNIT 2.4).

MALES

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.	____	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	____	x	____	=	____
.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.		.		.
ACn-.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP				[1.00]		[____] WIMP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NMAC = number of males in each age class,
CLWK = calculated live weight in kg,
IFWK = ingesta-free weight in kg,
FMPA = fraction of the male population in each age class (NMAC/TNMP),
WMIA = weighted mean ingesta-free weight of the age class,
SUMS = sums,
TNMP = total number of males in the population, and
WIMP = weighted mean ingesta-free weight of the population.

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.	1/2	310	160	50	45	40.5	x	0.50	=	20.3
ACb-.	1-1/2	310	525	38	70	63.0	x	0.38	=	23.9
ACc-.	2-1/2+	310	890	12	85	76.5	x	0.12	=	9.2
			SUMS =	[100] TNMP				[1.00]		[53.4] WIMP

FEMALES

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	x	____	=	____
.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.		.		.
ACnn.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP				[1.00]		[____] WIFP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NFAC = number of females in each age class,
CLWK = calculated live weight in kg,
IFWK = ingesta-free weight in kg,
FFPA = fraction of the female population in each age class (NFAC/TNFP),
WMIA = weighted mean ingesta-free weight of the age class,
SUMS = sums,
TNFP = total number of females in the population, and
WIFP = weighted mean ingesta-free weight of the population.

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	1/2	310	160	44	42	37.8	x	0.44	=	16.6
ACbb.	1-1/2	310	525	34	56	50.4	x	0.34	=	17.1
ACcc.	2-1/2+	310	890	22	62	55.8	x	0.22	=	12.3
			SUMS =	[100] TNFP				[1.00]		[46.0] WIFP

REFERENCES, UNIT 2.3

INGESTA-FREE WEIGHT STRUCTURES

SERIALS

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

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

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

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

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

Determining ingesta-free weight population structures - males

Calculations of the ingesta-free weight structures of populations of males in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.	____	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP				[1.00]		[____] WIMP

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.	____	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP				[1.00]		[____] WIMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.							x		=	
ACb-.							x		=	
ACc-.							x		=	
ACd-.							x		=	
ACe-.							x		=	
ACf-.							x		=	
ACg-.							x		=	
ACh-.							x		=	
ACi-.							x		=	
			SUMS =	[ ] TNMP				[1.00]		[ ] WIMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	x	FMPA	=	WMIA
ACa-.							x		=	
ACb-.							x		=	
ACc-.							x		=	
ACd-.							x		=	
ACe-.							x		=	
ACf-.							x		=	
ACg-.							x		=	
ACh-.							x		=	
ACi-.							x		=	
			SUMS =	[ ] TNMP				[1.00]		[ ] WIMP

CHAPTER 18, WORKSHEET 2.3b

Determining ingesta-free weight population structures - females

Calculations of the ingesta-free weight structures of populations of females in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP				[1.00]		[____] WIFP

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP				[1.00]		[____] WIFP

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP				[1.00]		[____] WIFP

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	x	FFPA	=	WMIA
ACaa.	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP				[1.00]		[____] WIFP

UNIT 2.4: METABOLIC WEIGHT STRUCTURES

Metabolic weight structures are used when estimating metabolism. The formats below include a column for metabolic weight in kg (MWKG) in addition to those included in UNIT 2.3. The weighted mean metabolic weights derived in the samples below will be used when calculating the weighted mean metabolic structure illustrated in UNIT 2.5.

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.	___	___	___	___	___	___	___	x	___	=	___
ACb-.	___	___	___	___	___	___	___	x	___	=	___
.	.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.	.		.		.
ACn-.	___	___	___	___	___	___	___	x	___	=	___
			SUMS =	[___] TNMP					[1.00]		[___] WMMP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NMAC = number of males in each age class,
CLWK = calculated live weight in kg,
IFWK = ingesta-free weight in kg,
MWKG = metabolic weight in kg,
FMPA = fraction of the male population in each age class (NMAC/TNMP),
WMMA = weighted mean metabolic weight of the age class,
SUMS = sums,
TNMP = total number of males in the population, and
WMMP = weighted mean metabolic weight of the population.

A sample calculation follows.

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.	1/2	310	160	50	45	40.5	16.1	x	0.50	=	8.1
ACb-.	1-1/2	310	525	38	70	63.0	22.4	x	0.38	=	8.5
ACc-.	2-1/2+	310	890	12	85	76.5	25.9	x	0.12	=	3.1
			SUMS =	[100] TNMP					[1.00]		[19.7] WMMP

FEMALES

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	____	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	____	x	____	=	____
.	.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.	.		.		.
.	.	.	.	.	.	.	.		.		.
ACnn.	____	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP					[1.00]		[____] WMFP

Definitions of the symbols are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NFAC = number of females in each age class,
CLWK = calculated live weight in kg,
IFWK = ingesta-free weight in kg,
MWKG = metabolic weight in kg,
FFPA = fraction of the female population in each age class (NFAC/TNFP),
WMMA = weighted mean ingesta-free weight of the age class,
SUMS = sums,
TNFP = total number of females in the population, and
WMFP = weighted mean ingesta-free weight of the population.

A sample calculation follows.

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	1/2	310	160	44	42	37.8	15.2	x	0.44	=	6.7
ACbb.	1-1/2	310	525	34	56	50.4	18.9	x	0.34	=	6.4
ACcc.	2-1/2+	310	890	22	62	55.8	20.4	x	0.22	=	4.5
			SUMS =	[100] TNFP					[1.00]		[17.6] WMFP

The reasons for determining weighted mean weights and weighted mean metabolic weights are probably not apparent yet. Completion of weighted mean live weights and ingesta-free weights greatly simplifies predictions of populations in CHAPTER 19. Weighted mean metabolic weights are used in calculating metabolic structures in the next UNIT (2.5), which is used in calculations of carrying capacity in CHAPTER 20.

Select species for which the necessary age and weight data are available and complete WORKSHEETS on the weight structures of the populations. The simplicity of population predictions and carrying capacity calculations will then be demonstrated in the next two chapters.

REFERENCES, UNIT 2.4

METABOLIC WEIGHT STRUCTURES

SERIALS

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

odvi

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

odhe

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

ceel

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

alal

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

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

CHAPTER 18, WORKSHEET 2.4a

Determining metabolic weight population structures - males

Calculations of the metabolic weight structures of populations of males in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.								x		=	
ACb-.								x		=	
ACc-.								x		=	
ACd-.								x		=	
ACe-.								x		=	
ACf-.								x		=	
ACg-.								x		=	
ACh-.								x		=	
ACi-.								x		=	
			SUMS =	[____] TNMP					[1.00]		[____] WMMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.								x		=	
ACb-.								x		=	
ACc-.								x		=	
ACd-.								x		=	
ACe-.								x		=	
ACf-.								x		=	
ACg-.								x		=	
ACh-.								x		=	
ACi-.								x		=	
			SUMS =	[____] TNMP					[1.00]		[____] WMMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.	____	____	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP					[1.00]		[____] WMMP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	x	FMPA	=	WMMA
ACa-.	____	____	____	____	____	____	____	x	____	=	____
ACb-.	____	____	____	____	____	____	____	x	____	=	____
ACc-.	____	____	____	____	____	____	____	x	____	=	____
ACd-.	____	____	____	____	____	____	____	x	____	=	____
ACe-.	____	____	____	____	____	____	____	x	____	=	____
ACf-.	____	____	____	____	____	____	____	x	____	=	____
ACg-.	____	____	____	____	____	____	____	x	____	=	____
ACh-.	____	____	____	____	____	____	____	x	____	=	____
ACi-.	____	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNMP					[1.00]		[____] WMMP

CHAPTER 18, WORKSHEET 2.4b

Determining metabolic weight population structures - females

Calculations of the metabolic weight structures of populations of females in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	____	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP					[1.00]		[____] WMFP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	____	____	____	____	____	____	____	x	____	=	____
ACbb.	____	____	____	____	____	____	____	x	____	=	____
ACcc.	____	____	____	____	____	____	____	x	____	=	____
ACdd.	____	____	____	____	____	____	____	x	____	=	____
ACee.	____	____	____	____	____	____	____	x	____	=	____
ACff.	____	____	____	____	____	____	____	x	____	=	____
ACgg.	____	____	____	____	____	____	____	x	____	=	____
AChh.	____	____	____	____	____	____	____	x	____	=	____
ACii.	____	____	____	____	____	____	____	x	____	=	____
			SUMS =	[____] TNFP					[1.00]		[____] WMFP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	___	___	___	___	___	___	___	x	___	=	___
ACbb.	___	___	___	___	___	___	___	x	___	=	___
ACcc.	___	___	___	___	___	___	___	x	___	=	___
ACdd.	___	___	___	___	___	___	___	x	___	=	___
ACee.	___	___	___	___	___	___	___	x	___	=	___
ACff.	___	___	___	___	___	___	___	x	___	=	___
ACgg.	___	___	___	___	___	___	___	x	___	=	___
AChh.	___	___	___	___	___	___	___	x	___	=	___
ACii.	___	___	___	___	___	___	___	x	___	=	___
			SUMS =	[____] TNFP					[1.00]		[____] WMFP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	x	FFPA	=	WMMA
ACaa.	___	___	___	___	___	___	___	x	___	=	___
ACbb.	___	___	___	___	___	___	___	x	___	=	___
ACcc.	___	___	___	___	___	___	___	x	___	=	___
ACdd.	___	___	___	___	___	___	___	x	___	=	___
ACee.	___	___	___	___	___	___	___	x	___	=	___
ACff.	___	___	___	___	___	___	___	x	___	=	___
ACgg.	___	___	___	___	___	___	___	x	___	=	___
AChh.	___	___	___	___	___	___	___	x	___	=	___
ACii.	___	___	___	___	___	___	___	x	___	=	___
			SUMS =	[____] TNFP					[1.00]		[____] WMFP

UNIT 2.5: METABOLIC STRUCTURES

Metabolic structures of populations are calculated from the JDAY and from the sex, age, weight, and reproductive-rate structures presented earlier by using equations for ecological metabolism (ELMD) given in CHAPTER 7. ELMD is easily determined by multiplying base-line metabolism (a function of weight; CHAPTER 1) by the multiple of base-line metabolism (MBLM), a function of sex, JDAY, and reproductive rate. The previous tabulations of population characteristics are used in determining the metabolic structure of a population, and the format for tabulating the necessary parameters is an extension of the formats used before. The formats for both males and females are shown here, along with sample with calculations, and are also set up as WORKSHEETS for different species at the end of this UNIT.

MALES

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLMx	BLMD=	ELMDx	FMPA=	WEMA
ACa-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACb-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
ACn-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
			SUMS =	[____] TNMP							[1.00]	[____] WEMP

Definitions are:

- AGCL = age class,
- JDAY = julian day,
- AGDA = age in days,
- NMAC = number of males in each age class,
- CLWK = calculated live weight in kg,
- IFWK = ingesta-free weight in kg,
- MWKG = metabolic weight in kg,
- MBLM = multiple of base-line metabolism,
- BLMD = base-line metabolism per day,
- ELMD = ecological metabolism per day,
- FMPA = fraction of the male population in each age class (NMAC/TNMP),
- WEMA = weighted mean ecological metabolism of the age class,
- SUMS = sums,
- TNMP = total number of males in the population, and
- WEMP = weighted mean ecological metabolism of the population.

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLMx	BLMD=	ELMDx	FMPA=	WEMA
ACa-.	1/2	310	160	50	45	40.5	16.1	2.5 x	1127 =	2818 x	0.50 =	1409
ACb-.	1-1/2	310	525	38	70	63.0	22.4	2.5 x	1568 =	3920 x	0.38 =	1490
ACc-.	2-1/2+	310	890	12	85	76.5	25.9	2.5 x	1813 =	4533 x	0.12 =	544
		SUMS =		[100] TNMP							[1.00]	[3443] WEMP

FEMALES

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.	____	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACbb.	____	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
ACnn.	____	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
		SUMS =		[____] TNFP								[1.00]	[____] WEFP

Definitions are:

AGCL = age class,
JDAY = julian day,
AGDA = age in days,
NFAC = number of females in each age class,
CLWK = calculated live weight in kg,
IFWK = ingesta-free weight in kg,
MWKG = metabolic weight in kg,
RERT = reproductive rate,
MBLM = multiple of base-line metabolism,
BLMD = base-line metabolism per day,
ELMD = ecological metabolism per day,
FFPA = fraction of the female population in each age class (NFAC/TNFP),
WEMA = weighted mean ecological metabolism of the age class,
SUMS = sums,
TNFP = total number of females in the population, and
WEFP = weighted mean ecological metabolism of the population.

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.	1/2	310	160	44	42	37.8	15.2	0.10	2.5 x	1064 =	2660 x	0.44 =	1170
ACbb.	1-1/2	310	525	34	56	50.4	18.9	0.90	3.0 x	1323 =	3969 x	0.34 =	1349
ACcc.	2-1/2+	310	890	22	62	55.8	20.4	1.60	3.2 x	1428 =	4570 x	0.22 =	1005
		SUMS =		[100] TNFP								[1.00]	[3525] WEFP

REFERENCES, UNIT 2.5

METABOLIC STRUCTURES

SERIALS

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

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

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

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

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

ovça

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

CHAPTER 18 - WORKSHEET 2.5a

Determining the weighted mean ecological metabolism of a population - males

Calculations of the weighted mean ecological metabolism of populations of males in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLMx	BLMD=	ELMDx	FMPA=	WEMA
ACa-.								x	=	x	=	
ACb-.								x	=	x	=	
ACc-.								x	=	x	=	
ACd-.								x	=	x	=	
ACe-.								x	=	x	=	
ACf-.								x	=	x	=	
ACg-.								x	=	x	=	
ACh-.								x	=	x	=	
ACi-.								x	=	x	=	
		SUMS =		[____] TNMP							[1.00]	[____] WEMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLM	BLMD	ELMDx	FMPA=	WEMA
ACa-.								x	=	x	=	
ACb-.								x	=	x	=	
ACc-.								x	=	x	=	
ACd-.								x	=	x	=	
ACe-.								x	=	x	=	
ACf-.								x	=	x	=	
ACg-.								x	=	x	=	
ACh-.								x	=	x	=	
ACi-.								x	=	x	=	
		SUMS =		[____] TNMP							[1.00]	[____] WEMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLMx	BLMD=	ELMDx	FMPA=	WEMA
ACa-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACb-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACc-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACd-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACe-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACf-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACg-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACh-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACi-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
		SUMS =	[____] TNMP								[1.00]	[____] WEMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLMx	BLMD=	ELMDx	FMPA=	WEMA
ACa-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACb-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACc-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACd-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACe-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACf-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACg-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACh-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
ACi-.	____	____	____	____	____	____	____	____ x	____ =	____ x	____ =	____
		SUMS =	[____] TNMP								[1.00]	[____] WEMP

CHAPTER 18 - WORKSHEET 2.5b

Determining the weighted mean ecological metabolism of a population - females

Calculations of the weighted mean ecological metabolism of populations of females in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.									x	=	x	=	
ACbb.									x	=	x	=	
ACcc.									x	=	x	=	
ACdd.									x	=	x	=	
ACee.									x	=	x	=	
ACff.									x	=	x	=	
ACgg.									x	=	x	=	
AChh.									x	=	x	=	
ACii.									x	=	x	=	

SUMS = [____] TNFP   [1.00] [____] WEFP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.									x	=	x	=	
ACbb.									x	=	x	=	
ACcc.									x	=	x	=	
ACdd.									x	=	x	=	
ACee.									x	=	x	=	
ACff.									x	=	x	=	
ACgg.									x	=	x	=	
AChh.									x	=	x	=	
ACii.									x	=	x	=	

SUMS = [____] TNFP   [1.00] [____] WEFP

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.									x	=	x	=	
ACbb.									x	=	x	=	
ACcc.									x	=	x	=	
ACdd.									x	=	x	=	
ACee.									x	=	x	=	
ACff.									x	=	x	=	
ACgg.									x	=	x	=	
AChh.									x	=	x	=	
ACii.									x	=	x	=	

SUMS = [____] TNFP [1.00] [____] WEFP

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RERT	MBLMx	BLMD=	ELMDx	FFPA=	WEMA
ACaa.									x	=	x	=	
ACbb.									x	=	x	=	
ACcc.									x	=	x	=	
ACdd.									x	=	x	=	
ACee.									x	=	x	=	
ACff.									x	=	x	=	
ACgg.									x	=	x	=	
AChh.									x	=	x	=	
ACii.									x	=	x	=	

SUMS = [____] TNFP [1.00] [____] WEFP

UNIT 2.6: LIFE TABLES

The tables here have been prepared for many different populations, so this unit includes a brief description of a life table and lists of references in SERIALS that may be consulted by the interested user.

Life tables deal with mortality and survival. The traditional life table consists of a series of columns giving the age at the beginning of intervals, the number of survivors of the cohorts at each age, the number of mortalities in each age class, the mortality rate of each age class, the survival rate of each class (1.0 - mortality rate), and the average life expectancy at each age. The columns are often arranged as shown below.

x	l_x	d_x	q_x	L_x	e_x

Column headings are:

x = age at beginning of interval.
l_x = number of survivors of the cohort at age X.
d_x = number of individuals dying between ages X and (X + 1).
q_x = probability of the L_x individuals dying before age (X + 1).
L_x = average number of survivors between ages X and (X + 1).
e_x = expectation of further life at age X.

The customary age-classes used are years; X = 1. The age-specific mortality rate, (q_x) is the ratio of the number of deaths of individuals between the ages of x and (x+1) to the number alive at age X. It is the probability that an individual attaining age X will die within the next year. Such probabilities are of direct interest to persons working with human populations.

Life tables were originally devised by actuaries calculating insurance and annuity premiums, reserves, and dividends. Such tables are based on averages, with rates reflecting long-term mortality and survivorship curves for members of the human population dying of ordinary natural causes. The effects of catastrophes are not included; insurance policies often exclude payments of benefits to survivors if the deceased died as a result of large-scale perturbations, such as war, or singular catastrophes, such as airplane crashes. The exclusion of such deviations from the calculations used to derive human life tables illustrates that the usefulness of life tables is limited to the factors considered in deriving the average values in the table.

When life tables are adapted by ecologists for use on free-ranging populations, the effects of transient perturbations, which can affect population dynamics for years to come, should be included. Ecological life tables are used for accurately describing population characteristics and probabilities of survival for different classes. Insurance-oriented life tables for humans are designed for accurately predicting payments to survivors so the firm can show a profit, or at least remain solvent. This subtle difference is very important when using, interpreting, and applying the life-table format in population analyses.

Life tables provide a format for recording some essential characteristics of classes in a population, but natality rates, which are of distinct ecological importance and they are also available, are omitted. They are most useful for human populations with constraints on the individuals considered (war casualities not considered, for example), and Allee et al. (1949) use known data to illustrate life tables, even though the book is directed toward animal ecology. Life tables are most useful when working with known populations over time, with individuals followed from birth to death. This is an unlikely situation for most wildlife biologists to find themselves in. Some populations may be studied intensively enough to construct a life table describing what happens. Controlled deer hunts in enclosures make this possible. Rather than direct more efforts here to the characteristics and uses of life tables, descriptions in Allee et al. (1949), Eberhardt (1969), and Tanner (1978) should be consulted for further information.

The discussion now turns to predicting populations in CHAPTER 19, while there are many problems involved in sampling, estimating, and describing populations, the need for these evaluations must be emphasized. Working with population data, especially in predictive ways, helps one understand the factors contributing to population dynamics, thereby increasing understanding of what is possibly occurring in the field.

LITERATURE CITED

Allee, W. C., A. E. Everson, O. Park, T. Park, and K. P. Schmidt. 1949. Principles of Animal Ecology. W. B. Saunders Company, Philadelphia. 837 p.

Eberhardt, L. L. 1969. Population Analysis. Chapter 22 In R. H. Giles, Jr. (Ed.), Wildlife Management Techniques. The Wildlife Society, Washington, D. C. 625 p.

Tanner, J. T. 1978. Guide to the Study of Animal Populations. The University of Tennessee Press. Knoxville, TN. 186 p.

REFERENCES, UNIT 2.6

LIFE TABLES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	11--2	177	183	od--	computing rate of increase	kelker,g	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	33--4	1027	1028	odvi	longevity records, female	ozoga,jj	1969
VIWIA	29--5	8	9	odvi	vital statistics, dee herd	carpenter,m	1968

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
FUNAA	25...	84	96	alal	the moose in norway, 1970	myrberget,s	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	33...	143	147	rata	provis life table, b g car	banfield,awf	1955

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
MUOXD	17...	32	37	obmo	musk-ox on baffin island	harington,cr	1975
NPOAA	1976-	159	174	obmo	musk-ox pop, svalbard, nor	alendal,e	1976

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
EVOLA	19--3	395	420		F-stats, mating sys, struc	wright,s	1965
JWMAA	35--4	658	663		rate of increase	caughley,g; birch	1971
NAWTA	23---	426	442		est eff exploit by lif tab	quick,hf	1963
QRBIA	22--4	283	314	anim	life tables, naturl populs	deevey,es,jr	1947

CLOSING COMMENTS - CHAPTER EIGHTEEN

Population structures are very important when analyzing population dynamics. The sequential approach illustrated in CHAPTER 18 makes it easy to compile population structures and to derive weighted-mean values for different population characteristics. Uses of these weighted-means are illustrated in CHAPTERS 19 and 20; the utility of weighted-means will be evident as population predictions and calculations of carrying capacity are made.

Aaron N. Moen
June 2, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER EIGHTEEN

ACa- = Age class - males
ACaa = Age class - females
ACAD = Age class by age in day intervals
ACMP = Age class by mid-point
ACYI = Age class in year intervals
AGCL = Age class
AGDA = Age in days
AMHF = Number of adult males harvested per 100 females
APGP = Average number of pellet groups per plot

BLMD = Base-line metabolism per day

CALC = Calculated
CLWK = Calculated live weight in kilograms

DIFF = Differencae
DPSM = Deer per square mile
DYLF = Days since leaf fall

ELMD = Ecological metabolism per day

*FFP = Number of female fawns
FFPA = Fraction of the female population in each age class
FFPO (2) = Fraction of adult females in 2-1/2+ year age class, year 2
FFPW = Fraction of the female population in each weight class
FFPY (1) = Fraction of adult females in 1-1/2 year age class, year 1
FFPY (2) = Fraction of adult females in 1-1/2 year age class, year 2
*FMP = Number of male fawns
FMPA = Fraction of the male population in each age class
FMPO (2) = Fraction of adult males in 2-1/2+ year class, year 2
FMPW = Fraction of the male population in each weight class
FMPY (1) = Fraction of adult males in 1-1/2 year class, year 1
FMPY (2) = Fraction of adult males in 1-1/2 year class, year 2
FYAP = Fraction of yearlings and adults in the population

IFWK = Ingesta-free weight in kilograms

JDAY = Julian day

KNPL = Known population

MBLM = Multiple of base-line metabolism
MFSR = Male to female sex ratio
MWKG = Metabolic weight in kilograms

NAFH = Number of adult females harvested
NAMH = Number of adult males harvested
NFAC = Number of females in each age class
NFWC = Number of females in each weight class
NMAC = Number of males in each age class
NMPO = Number in the population
NMWC = Number of males in each weight class
NPHP = Number in the prehunt population
NUAC = Number in the age class

*OFP = Number of females in 2-1/2+ year class
*OMP = Number of males in 2-1/2+ year class

PAFP = Prehunt adult female population
PAMF = Prehunt adult males per 100 females
PAMP = Prehunt adult male population
PECO = Pellet-count estimates
PSMF = Post-hunt adult males per 100 females

RERT = Reproductive rate
RTIO = Ratio of PECO/KNPL

SERA = Sex ratio at birth (number of males per 1 female)
SUMS = Sums

TBLD = Tabulated
TNFP = Total number of females in the population
TNMF = Total of both males and females
TNMP = Total number of males in the population

WCa- = Weight class - males
WCaa = Weight class - females
WCKI = Weight class in kilogram intervals
WCMP = Weight class by mid-point
WEMA = Weighted mean ecological metabolism of the age class
WEFP = Weighted mean ecological metabolism of the female population
WEMP = Weighted mean ecological metabolism of the male population
WIFP = Weighted mean ingesta-free weight of the female population
WIMP = Weighted mean ingesta-free weight of the male population
WLFP = Weighted mean live weight of the female population
WLMP = Weighted mean live weight of the male population
WMIA = Weighted mean ingesta-free weight of the age class
WMLA = Weighted mean live weight of the age class
WMFP = Weighted mean metabolic weight of the female population
WMMA = Weighted mean metabolic weight of the age class
WMMP = Weighted mean metabolic weight of the male population

*YFP = Number of females in 1-1/2 year class
*YMP = Number of males in 1-1/2 year class

AJZOA Australian Journal of Zoology
AMBOC Ambio
AMFOA American Forests
AMNAA American Midland Naturalist
AMNTA American Naturalist
ATICA Arctic (Canada)
ATLPA Arctic and Alpine Research
ATRLA Acta Theriologica (Poland)

BFRNA British Columbia Forest Service Research Notes
BICOB Biological Conservation
BIOKA Biometrika
BISNA Bioscience
BPURD Biological Papers of the University of Alaska Special Report
BYMOA Byulletin Moskovskago Obshchestva Ispyrtatalei Prirody Otdel Biologicheskii (USSR)

CAFGA California Fish and Game
CAFNA Canadian Field Naturalist
CAGRA California Agriculture
CFGGA California Department of Fish and Game, Game Bulletin
CGFPA Colorado Division of Game, Fish, and Parks Special Report
CJZOA Canadian Journal of Zoology
CNSVA Conservationist
CWLSB Canadian Wildlife Service
CWOPA Canadian Wildlife Service Occassional Paper
CWPNB Canadian Wildlife Service Progress Notes
CWRSB Canadian Wildlife Service Report and Management Bulletin Series

DRCWD Colorado Division of Wildlife Division Report
DRGBA Danish Review of Game Biology

ECOLA Ecology
EKPOA Ekologia Polska Seria A
EVOLA Evolution (US)
EXJOA Explorer's Journal

FLSCA Florida Science
FPWTA Transactions of the Federal-Provincial Wildlife Conference
FUNAA Fauna (Oslo)

ICNSA Iowa Conservationist
INHNA Illinois Natural History Survey, Biological Notes

JAECA Journal of Animal Ecology
JAZAA Journal of the Arizona Academy of Science
JEVSB Journal of Environmental Systems
JFUSA Journal of Forestry

JOMAA	Journal of Mammalogy
JRMGA	Journal of Range Management
JWMAA	Journal of Wildlife Management
LYNXA	Lynx (Czechoslovakia)
MABIA	Mathematical Biosciences
MAMLA	Mammalia
MANJA	Malayan Nature Journal
MDCRA	Michigan Department of Conservation Game Division Report
MFNOA	Minnesota Forestry Notes
MGQPA	Minnesota Department of Natural Resources Game Research Project Quarterly Progress Report
MOCOA	Missouri Conservationist
MRLTA	Murrelet, The
MRYCA	Maryland Conservationist
MUOXD	Musk-ox
NATUA	Nature (England)
NAWTA	North American Wildlife and Natural Resources Conference, Transactions of the,
NCANA	Naturaliste Canadien, Le
NEXAA	New Mexico Agricultural Experiment Station Bulletin
NFGJA	New York Fish and Game Journal
NOSCA	Northwest Science
NPMEA	Norsk Polarinstitutt Meddelelser
NPOAA	Norsk Polarinstituut Arbok
NYCOA	New York State Conservationist
NZFSA	New Zealand Journal of Forest Science
OFBIA	Ontario Field Biologist
OUOKA	Outdoor Oklahoma
PASCC	Proceedings of the Alaskan Scientific Conference
PCGFA	Proceedings of the Southeastern Association of Game and Fish Commissioners
PCZOA	Proceedings of the International Congress of Zoology
PMACA	Papers of the Michigan Academy of Sciences, Arts and Letters
PNSIA	Proceedings of the Nova Scotian Institute of Science
PSAFA	Proceedings of the Society of American Foresters
PZESA	Proceedings of the New Zealand Ecological Society
QRBIA	Quarterly Review of Biology
QSFRA	Quebec Service de la Faune Rapport
RRFBA	Report Reelfoot Lake Biological Station of the Tennessee Academy of Science
SCBUB	Sierra Club Bulletin
SCIEA	Science
SGGMA	Scottish Geographical Magazine
SLUMA	Southern Lumberman
SWNAA	Southwestern Naturalist
SYLVA	Sylva

TISAA	Transactions of the Illinois State Academy of Science
TNWSD	Transactions of the Northeast Section, The Wildlife Society
TRVIA	Terre Vie (La Terre et la Vie)
TSASA	Transactions of the Kansas Academy of Science
TWASA	Transactions Wisconsin Academy of Sciences, Arts, and Letters
UASPA	Proceedings of the Utah Academy of Sciences, Arts and Letters
UKMPA	University of Kansas Museum of Natural History Miscellaneous Publication
VILTA	Viltrevy
VIWIA	Virginia Wildlife
VJSCA	Virginia Journal of Science
WCDBA	Wisconsin Department of Natural Resources Technical Bulletin
WLMOA	Wildlife Monographs
WMBAA	Wildlife Management Bulletin (Ottowa) Series 1 (Canada)
WSCBA	Wisconsin Conservation Bulletin
XARRA	U S Forest Service Research Note RM
XFNCA	U S Forest Service Research Paper NC
XFWLA	U S D I Fish and Wildlife Service, Wildlife Leaflet
ZEJAA	Zeitschrift fuer Jagdwissenschaft
ZOLZA	Zoologicheskii Zhurnal
ZOOLA	Zoologica (New York)

LIST OF PUBLISHERS - CHAPTER EIGHTEEN

amel	American Elsevier Publ. Co., Inc.	New York	nyny
hapr	Hafner Press	New York	nyny
jwis	John Wiley and Sons, Inc.	New York, NY	nyny
olbo	Oliver and Boyd	Edinburgh, Scotland	edsc
psup	Pennsylvania State University Press	University Park, PA	uppa
saco	Saunders Publishing Co.	Philadelphia, PA	phpa
uchp	Univ. of Chicago Press	Chicago, IL	chil
utnp	Univ. Tennesse Press	Knoxville, TN	kntn
whfr	W. H. Freeman Co.	San Francisco, CA	sfca
wiso	Wildlife Society, The	Washington, D.C.	wadc

LIST OF WORKSHEETS - CHAPTER EIGHTEEN

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER NINETEEN

POPULATION RATES AND PREDICTIONS

by

Aaron N. Moen

Professor of Wildlife Ecology

Department of Natural Resources

College of Agriculture and Life Sciences

Cornell University

Ithaca, N.Y. 14853

and

Certified Wildlife Biologist

(The Wildlife Society)

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POPULATION RATES AND PREDICTIONS

CHAPTER 19. POPULATION RATES AND PREDICTIONS

An understanding of the characteristics and productive potentials of individual animals should be logically followed by an understanding of the characteristics and productive potentials of groups or populations of individuals. Since wild ruminants can have definite impacts on the resources of agricultural, forested, and natural systems, accurate population predictions are very desirable, and approaching necessity.

There are two basic approaches to the analysis of populations. One, observed changes in the population as a whole may be represented mathematically and the results correlated with observed conditions, and two, productivity characteristics of individuals may be used to evaluate causes of changes in the population as a whole. The former is applicable to species with little differences in individuals, or to very large populations. Insect populations often meet these criteria. The latter is applicable to long-lived animals that are larger in mass and fewer in number. Such animals, and wild ruminants are among them, usually go through 2 or 3 annual growth cycles before reproducing, with large differences in weight between the younger, immature individuals and the older, mature ones. Their roles in population dynamics are different; younger animals are consumers only, while older animals are both consumers and producers.

Population predictions may be of two types. One, time-specific summations of the next one, two, or three or more year's populations based on current conditions, and two, overall population predictions of the total number for as many years as the natality rates and the mortality rates are expected to apply. Both are useful. The former gives one insight into population changes throughout the year based on summations of recruitment and removal, and the latter, a long-range outlook based on the cumulative effects of removal and recruitment over one to several years.

This CHAPTER describes the logic and the steps necessary to calculate natality and mortality rates and make population predictions easily and quickly with arithmetic summations and exponential predictions. Such predictions may be made for one or more years at a time. They may also be made for time periods within the year. Such time periods should be of logical lengths, with beginning and ending points coinciding with processes rather than arbitary dates.

The following time periods are suggested as reasonable and logical, with flexibility in the JDAYs marking the beginnings and ends of each of the periods. The periods are:

```
     PSPP                PSUP                 PFAP           PHUP PWNP
       ↓                   ↓                    ↓               ↓    ↓
 WNTR  |       SPRN        |        SUMR        |      FALL     |HUNT|  WNTR
1                                   182                                  365
JDAY→
```

The designations of seasons represent time periods that coincide with biological functions and range conditions. They are:

PHUP: prehunt population.
HUNT: the period in the fall when the hunting season is open.
PWNP: prewinter population.
WNTR: the period following the hunt when winter conditions prevail.
PSPP: prespring population.
SPNG: the period when winter conditions have waned and new plant growth begins. The last third of gestation.
PSUP: presummer population.
SUMR: the period following parturition and through weaning.
PFAP: prefall population.
FALL: the period of weight recovery following weaning of the young and up to the hunt.

JDAYs marking the beginnings and ends of these periods vary between species, places, and years.

Population predictions are only as accurate as the natality and mortality data entered into the equations, of course. The demonstrated ease with which populations may be predicted mathematically should encourage field biologists to collect the best natality and mortality information possible. Once collected, the use of the data for predicting populations is very simple with the WORKSHEETS described here.

REFERENCES, CHAPTER 19

POPULATION RATES AND PREDICTIONS

BOOKS

TYPE	PUBL	CITY	PGES	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
edbo	olbo	edsc	152		numbers of man and animals	cragg,jb,ed; piri	1955
aubo	meth	loen	191		uniqueness of the individu	medawar,pb	1957
aubo	dove	nyny	291		genetc theory of nat selec	fisher,ra	1958
aubo	uchp	chil	281		intro to study of anim pop	andrewartha,hg	1961
edbo	wiso	wadc	419		wildlf invest tech, 2nd ed	mosby,hs,ed	1963
edbo	saco	phpa	388		readin in pop, commun ecol	hazen,we,ed	1964
aubo	amel	nyny	183		quantitv and dynam ecology	kershaw,ka	1964
aubo	jwis	nyny	200		the biology of populations	macarthur,rh; con	1966
aubo	prup	prnj	307		adaptation and natur selec	williams,gc	1966
aubo	isup	amia	277		of predation and life	errington,pl	1967
edbo	blsp	oxen	308	herb	study of produc lg herbivs	golley,fb,ed; bue	1968
aubo	acpr	loen		herb	ecol cond aff prod, grassl	de vos,a	1969
aubo	meth	loen	231	mamm	ecol reprod, wild & domest	sadleir,rmfs	1969
edbo	oost	neth	611		dynam of numb in pop, proc	boer,pjd,ed; gra/	1970
edbo	umpr	aami	207		pred contrl, report to ceq	cain,sa,ed	1971
edbo	acpr	loen	358		applied biology, volume 1	cosher,th,ed	1976
edbo	ualb	edal	714		high arctc ecosystm, canad	bliss,lc,ed	1977
aubo	whfr	sfca	416		wildlife management	giles,rh,jr	1978
aubo	utnp	knte	186		guide to stud, anim popula	tanner,jt	1978

TOPIC 1. AGE-RELATED REPRODUCTIVE AND MORTALITY RATES

Reproductive potentials of a population, fundamental considerations in population ecology, are related to three factors. One, there are genetic limits to the rates of reproduction. Two, reproductive potentials depend on the vigor of the females and young as range conditions, pathogens, parasites, and predators exert their influence. Three, reproductive potentials drop as animals age beyond their prime.

The term "reproductive potential" is used here rather than "reproductive rate" to clarify a biological concept. The number of fertilized eggs in relation to the number of females is usually thought of as a conception rate. It is also a reproductive potential; that many young could potentially be born to that many females. The difference between the birth rate and the conception rate represents <u>in utero</u> mortality. The difference between the weaning rate and the birth rate represents mortality during the suckling period. Mortality removes individuals at different periods from conception to maturity. Such removals result in reproductive potentials not being reached. The concept of reproductive potentials should be understood first, and mortality data for different periods during the reproductive cycle used to identify natality and mortality rates.

The reproductive potential of a species is genetically controlled, as there are characteristic numbers of young born to females of different species. The adult females in good physical condition of some wild ruminants characteristically have two young--white-tailed deer, for example--while female elk and moose seldom have two young.

The genetic histories of individual animals in wild ruminant populations are not known, nor can they be controlled by selective breeding. Thus one cannot do much to alter the genetic potential of wild populations. Age structures are affected by hunting pressures, with heavily-hunted populations having younger age structures than lightly or unhunted ones. Animals of the same age, however, may have different reproductive rates if one group is on good range and another on poor range. Those on good range will be heavier and have higher reproductive potentials than those on poor range.

Reproductive data in the literature are almost always presented in relation to age. A general relationship between age and reproductive rate exists as immature females bear no young, first-year reproducers only one, and mature females of some species of wild ruminants bear two or even more young. While there is a general relationship between age and reproductive rate, females of the same age may have very different weights, and these differences are reflections of body condition. Since there is no human-controlled selective breeding in wild populations, reproductive rates of different populations are related to the condition of individual females, which is modified most by range conditions. Yearling white-tailed deer on western New York ranges, for example, have higher reproductive rates than yearlings in the Catskills, and those in the Catskills have higher reproductive rates than those in the central Adirondacks. These differences are due to the effects of differences in range conditions, and not to age *per se*. Reproductive rates of the different species of wild ruminants are given in the references in the SERIALS list at the end of UNIT 1.1 and also in CHAPTER 1, UNIT 3.4.

Mortality rates are also presented for age classes, though mortality is often modified by the conditions of different ranges. The use of age as the input variable into calculations of population growth, as a reflection of natality and mortality rates, is often necessary due to a lack of data on other input variables. The effects of weights on natality and mortality are usually not given in the literature.

Age-related natality rates are discussed in UNIT 1.1, and age-related mortality rates in UNIT 1.2.

UNIT 1.1. AGE-RELATED REPRODUCTIVE RATES

Reproductive rates generally increase as females grow older, reaching a maximum when the animals are physically mature and all production can be directed to the reproductive process. Smaller ruminants, such as white-tailed deer, reach maximum body size earlier than larger ruminants, such as moose. They also reach potential maximum reproductive rates sooner. Maximum reproductive rates are maintained until old age, when a decline occurs, unless range conditions depress reproduction. Relatively few animals may reach old age in hunted populations, but there could be many in non-hunted populations, depending on the amounts of predation and on the effects of parasites and diseases.

Nearly all of the published data presents natality rates in relation to age classes, usually for hunter-killed animals examined in the fall. They can be aged by one-year intervals beginning with 1/2. The data may be tabulated in the blanks indicated below, where ACMP = age class at the midpoint and CORT = conception rate.

CLASS	ACMP	CORT
ACaa.	1/2	___
ACbb.	1-1/2	___
.	.	.
.	.	.
.	.	.
ACnn.	n-1/2	___

Age-related natality rates may be organized with the format below. Columns are added for recording the fractions of the female population represented by each age class, with the multiplications and summations necessary for determining weighted mean natality and mortality rates. These are used later in the predictions of populations using the table of b values in the exponential predictions discussed in UNIT 4.2.

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	___	___	x	___	=	___
ACbb.	1-1/2	___	___	x	___	=	___
.							
.							
.							
ACnn.	n-1/2	___	___	x	___	=	___
	SUMS =	[___] = TNFP			[1.00]		[___] = WCRP

Definitions of the column headings are:

ACMP = age class at the midpoint,
NFAC = number of females in the age class,
CORT = conception rate,
FFPA = fraction of the female population in the age class,
WCRA = weighted mean conception rate for each age class,
SUMS = sums,
TNFP = total number of females in the populatin, and
WCRP = weighted mean conception rate of the population.

A sample calculation follows, illustrating the calculation of a single weighted mean conception rate for use in exponential population predictions.

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	44	0.12	x	0.44	=	0.05
ACbb.	1-1/2	34	0.95	x	0.34	=	0.32
ACcc.	2-1/2+	22	1.65	x	0.22	=	0.36
	SUMS =	[100] = TNFP			[1.00]		[0.73] = WCRP

A similar format may be used to tally birth rates rather than conception rates. The difference in the formats is in the age class heading from ACMP to age class by end of year (ACEY) intervals and in the change in the conception rate (CORT) column to a birth rate (BIRT) heading, and the weighted mean birth rate (WBRA).

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1	____	____	x	____	=	____
ACbb.	2	____	____	x	____	=	____
.							
.							
.							
ACnn.	n	____	____	x	____	=	____
	SUMS =	[____] = TNFP			[1.00]		[____] = WBRP

Additional definitions are:

ACEY = age class by end of year intervals,
BIRT = birth rate,
WBRA = weighted mean birth rate for each age class, and
WBRP = weighted mean birth rate for the population.

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1	44	0.10	x	0.44	=	0.04
ACbb.	2	34	0.90	x	0.34	=	0.31
ACcc.	3+	22	1.60	x	0.22	=	0.35
	SUMS =	[100] = TNFP			[1.00]		[0.70] = WBRP

One more format may be used to tally weaning rates by changing the age class to the midpoint designation with the youngest age class weaning their own young at age 1-1/2, and by changing the CORT or BIRT headings to weaning rate (WERT). The format is:

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1-1/2	____	____	x	____	=	____
ACbb.	2-1/2	____	____	x	____	=	____
.							
.							
.							
ACnn.	n-1/2	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WWRP

Additional definitions are:

WERT = weaning rate,
WWRA = weighted mean weaning rate for each age class, and
WWRP = weighted mean weaning rate for the population.

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1-1/2	44	0.06	x	0.44	=	0.03
ACbb.	2-1/2	34	0.70	x	0.34	=	0.24
ACcc.	3-1/2+	22	1.30	x	0.22	=	0.29

SUMS = [100] = TNFP [1.00] [0.56] = WWRP

The three formats given above provide different options for recording reproductive rates, depending on the time when the rates were determined. WORKSHEETS follow for each format.

REFERENCES, UNIT 1.1

AGE-RELATED REPRODUCTIVE RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	22--1	43	44	od--	replacement teeth, age det	mclean,dd	1936

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
COVEA	39--3	282	291	odvi	corpora lutea, ovulat, fer	cheatum,el	1949

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	41--4	706	715	odvi	popul ecol, northeast alab	adams,wh jr	1960
JOMAA	23--4	411	421	odvi	analys reprod pattern, tex	illige,d	1951
JOMAA	32--3	267	280	odvi	notes on fecundity, maine	palmer,rs	1951
JOMAA	32--4	411	421	odvi	analy repro patt, so texas	illige,d	1951
JOMAA	40--1	108	113	odvi	breeding, captivity, alaba	haugen,ao	1959
JOMAA	43--1	112	113	odvi	fecundity in a michig w-td	verme,lj	1962
JOMAA	43--3	414	414	odvi	quadruplet fetuses, ontari	trodd,ll	1962
JOMAA	45--1	151	151	odvi	unusual pregnancy	hesselton, wt; t/	1964
JOMAA	56--1	151	159	odvi	repro performance wtd iowa	haugen,ao	1975
JWMAA	10--3	242	248	odvi	region diff, breedng potnl	morton,gh; cheatu	1946
JWMAA	12--1	78	86	odvi	product, yield, george res	o'roke,ec; hamers	1948
JWMAA	14--3	290	295	odvi	breeding records, michigan	haugen,ao; davenp	1950
JWMAA	15--1	73	80	odvi	producti, mortal, coralled	severinghaus,cw	1951
JWMAA	20--3	286	292	odvi	reg diff size & prod, w va	gill,j	1956
JWMAA	26--4	409	411	odvi	x-ray, determining pregnan	verme,lj; fay,ld/	1962
JWMAA	29--1	74	79	odvi	reprod studies, penned w-t	verme,lj	1965
JWMAA	29--3	634	636	odvi	fertility, buck fawn	silver,h	1965
JWMAA	31--1	114	123	odvi	reproductive biol, maintob	ransom,ab	1967
JWMAA	32--1	130	141	odvi	range, ondition, fertility	allen,eo	1968
JWMAA	33--3	708	711	odvi	fertility in male fawns	follmann,eh; klim	1969
JWMAA	33--4	881	887	odvi	reproduct patterns, nutrit	verme,lj	1969
JWMAA	34--1	23	28	odvi	product, crab orch nat ref	roseberry,jl; kli	1970
JWMAA	36--3	868	875	odvi	reproductive physiol, male	lambiase,jt;amann	1972
JWMAA	37--2	179	182	odvi	fertiliza rates, sout texa	barron,jc; harwel	1973
JWMAA	38--4	808	814	odvi	prod, bruce penin, ontario	mansell,wd	1974
JWMAA	41--4	700	708	odvi	natal mortality, michigan	verme,lj	1977
MDCRA	2253-	1	7	odvi	radiog (x-ray), productivi	verme,lj; fay,ld/	1959
NAWTA	15---	170	190	odvi	fertility, range	cheatum,el; sever	1950
NAWTA	26---	448	459	odvi	deer, bad rivr indn reserv	cook,rs; hale,jb	1961
NAWTA	32---	405	420	odvi	experim diets, reproductio	verme,lj	1967
NFGJA	11--1	13	27	odvi	product, growth, adirondac	severinghaus,cw;/	1964
NFGJA	21--2	135	152	odvi	repro rates of wt-d in nys	hesselton,w; jack	1974
NYCOA	1---5	18	18	odvi	white-tail fertility	cheatum,el	1947
OJSCA	71--4	217	225	odvi	productivi of w-td in ohio	nixon,cm	1971
PCGFA	10---	47	51	odvi	ferti, reari succes, virgi	davey,sp	1956
PCGFA	14---	53	60	odvi	wtd produc stud in mississ	noble,re	1960
PCGFA	16---	24	28	odvi	x-ray stud, produc, tennes	lewis,jc	1962
PCGFA	20---	123	130	odvi	breeding season, louisiana	roberson,jh jr; /	1966
PCGFA	21---	62	68	odvi	reproduct studies, alabama	lueth,fx	1967
PCGFA	25---	53	60	odvi	characs reprod in arkansas	wilson,sn; seala/	1971

odvi continued on the next page

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
PIAIA	69---	231	238	odvi	ovar anal, corp lutea chng	haugen,ai; traine	1962
QJFAA	35--4	165	170	odvi	repro rates wt-d, florida	harlow,rf	1972
TNWSD	30---	299	326	odvi	status of reprod rates, ny	hesselton,wt; jac	1973
WLMOA	15---	1	62	odvi	ecol, manage, l basin, tex	teer,jg; thomas,/	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANREA	122--3	335	340	odhe	quadruplets in mule deer	sears,hs; browman	1955
BIREB	21--5	1099	1104	odhe	age at frst concepti, b-td	mueller,cc; sadle	1979
CAFGA	34--1	25	31	odhe	br seas, produc, calif, or	chattin,je	1948
CAFGA	39--2	177	186	odhe	reproduction, chaparral	taber,rd	1953
CAFGA	44--3	253	259	odhe	prod, californi deer herds	bischoff,ai	1958
CAFGA	50--3	132	147	odhe	deer study, redw-dougl fir	browning,bm; laup	1964
JOMAA	38-1	116	120	odhe	gestat, breedng fawnng per	golley,fb	1957
JOMAA	39--1	155	155	odhe	failur of to wean offsprng	hanson,wr	1958
JWMAA	14--4	457	469	odhe	prod, breedng, fawning per	robinette,wl; gas	1950
JWMAA	17--2	225	225	odhe	initial proof, fawns breed	crane,hs; jones,d	1953
JWMAA	19--1	115	136	odhe	fertility, utah mule deer	robinette,wl; ga/	1955
JWMAA	19--4	503	503	odhe	rocky mount, high reproduc	jensen,w; robine/	1955
JWMAA	21--1	62	65	odhe	ovarian anal, repr perform	golley,fb	1957
JWMAA	23--2	234	235	odhe	fetal recoveries, mule dee	hudson,p	1959
JWMAA	25--1	54	60	odhe	rela sum rang cond, reprod	julander,o; robin	1961
JWMAA	32--2	344	349	odhe	prod, nat bison rang, mont	nellis,ch	1968
NAWTA	9----	156	161	odhe	studies of productiv, utah	robinette,wl; ol/	1944
NAWTA	15---	589	596	odhe	productiv, mule d, colorad	tolman,cd	1950
SWNAA	15--1	29	36	odhe	ind repro surv fema, n mex	anderson,ae; sny/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	64--1	40	42	ceel	productiv, survival, banff	green,hu	1950
JBLPA	8....	69	72	ceel	ferti, postnat mort, young	brna,j	1969
JOMAA	18--1	62	66	ceel	life hist, roos elk, calif	orr,rt	1937
JOMAA	44--1	111	112	ceel	evid yrlng pregn, roosevlt	batchelor,r	1963
JOMAA	47--2	332	334	ceel	fetus resorption in elk	haugen,ao	1966

ceel continued on the next page

CODEN	VO-NO	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRPFA	54--2	325	334	ceel	factrs aff reprod red deer	guinness,fe; alb/	1978
JWMAA	9---4	295	319	ceel	roosevelt elk, washington	schwartz,je; mitc	1945
JWMAA	17--2	177	184	ceel	reproduction of yellowston	kittams,wh	1953
JWMAA	17--2	223	223	ceel	a pregnant yearlng cow elk	coffin,al; reming	1953
JWMAA	24--3	297	307	ceel	ovar char, knwn breed hist	morrison,ja	1960
JWMAA	27--3	411	414	ceel	captive elk herd, missouri	murphy,da	1963
JWMAA	32--2	368	376	ceel	exp stud, controlled repro	greer,kr; hawkin/	1968
JWMAA	38--4	789	791	ceel	wintr preg rt, cow:clf rat	folllis,tb; spill	1974
JWMAA	39--1	92	100	ceel	repro, erly clf mort, norw	wegge,p	1975
NAWTA	20---	560	567	ceel	increas natal, lowered pop	buechner,hk; swan	1955
NAWTA	21---	545	554	ceel	post conception ovulation	halazon,gc; buech	1956
PZESA	9----	31	33	ceel	herd compo, effec reproduc	miers,kh	1962

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
EKIAA	1---2	100	101	alal	fertility, ussr	priklonskii,sg; c	1970
EKIAA	4---1	81	88	alal	dynami, productiv, estonia	ling,hi	1973
JWMAA	22--3	261	268	alal	reproduction in a populatn	edwards,ry; ritce	1958
JWMAA	23--4	381	401	alal	reprod & produc, newfoundl	pimlott,dh	1959
JWMAA	29--4	740	750	alal	reproduc, product, ontario	simkin,dw	1965
JWMAA	37--4	535	544	alal	reproductn, shiras, montan	schladweiler,p; s	1973
JWMAA	38--3	571	572	alal	late pregnancy, alaska	coady,jw	1974
NCANA	101-3	517	526	alal	reproduction, productivity	simkin,dw	1974
NCANA	101-3	527	537	alal	evolut, reproduc potential	geist,v	1974
TISAA	69--2	151	152	alal	triplets, isle-royale	moll,d; moll,bk	1976
VILTA	6---3	127	299	alal	reproduct of moose, sweden	markgren,g	1969

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATICA	14...	91	100	rata	popul dynam, mach deta her	krebs,cj	1961
CJZOA	50--1	43	46	rata	reproduction	mcewan,eh; whiteh	1972
JOMAA	52--2	479	479	rata	twinning in caribou	mcewan,eh	1971
JOMAA	54--3	781	781	rata	twinning in reindeer	nowasad,rf	1973
JWMAA	28--3	477	480	rata	det partur rates, newfnlnd	bergerud,at	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AJANA	125-2	217	231	anam	reproduction, female	ogara,bw	1969
CAFGA	36--3	328	329	anam	calif reproduct potentials	chattin,je; lasse	1950
JAVMA	134..	562	564	anam	vibriosis, factor, reprodu	trueblood,ms; pos	1959
JOMAA	48--3	489	490	anam	minimum breeding age, pron	mithcell,gj	1967
JWMAA	26--1	100	101	anam	minimum breeding age	wright,pl; dow,sa	1962
JWMAA	34--3	570	582	anam	forage, water, productivit	beale,dm; smith,a	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ISJRA	49--1	1	8	bibi	reproducti in plains bison	haugen,ao	1974
SWNAA	13--1	23	26	bibi	produc, wichi mt ref, okla	halloran,af	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	24--1	1	11	ovca	life hist, tarryall mt, co	spencer,c	1943
JOMAA	46--4	685	687	ovca	records, mount sheep, utah	egoscue,jh	1965
JWMAA	9---2	155	156	ovca	non-breeding in bighorn sh	pulling,ars	1945
JWMAA	30--1	207	207	ovca	twinning in bighorn sheep	spalding,dj	1966
JWMAA	38--4	771	774	ovca	lamb prod, surv, mort, col	woodward,tn; guti	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	92--3	292	293	ovda	twinning in dall sheep	hoefs,m	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	52--1	238	238	obmo	1st verified case twinning	wilkinson,pf	1971
JWMAA	35--1	103	108	obmo	pop characs, nrth wst terr	freeman,mmr	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	51...	588	601		age specifici, ecol theory	emlen,jm	1970
JFUSA	50--3	206	207	biga	yiel tabls for big ga hrds	kelker,gh	1952
NAWTA	15---	581	588	biga	vital statistics, big game	cowan,im	1950
TLPBA	2---3	339	354		intrins grow, bir, dea rat	goodman,la	1971
WLMOA	9----	1	60	many	prod, surv, abun, sex, age	hanson,wr	1963

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
VILTA	7---2	121	149	caca	mort, repro, 1948-69, swed	borg,k	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	36--3	471	473	dada	releas, disper, repro, neb	packard,rl	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	1....	333	376	bibo	reproduc of european bison	jaczewski,z	1958
ATRLA	12-20	333	334	bibo	resul, breed, postwar pola	landowski,j; woli	1967
ATRLA	12-29	407	444	bibo	repro biol on res and free	krasinski,z; racz	1967

CHAPTER 19, WORKSHEET 1.1a

Formats for determining weighted mean conception rates

The nine age classes listed below may be used to tally conception rates for determining the weighted mean conception rate for the population. Note that the age class is designated by the midpoint, the approximate time when conception occurs.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACMP	NFAC	CORT	x	FFPA	=	WCRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

CHAPTER 19, WORKSHEET 1.1b

Formats for determining weighted mean birth rates

The nine age classes listed below may be used to tally birth rates for determining the weighted mean birth rate for the population. Note that the age class is designated by the end of year, the approximate time when birth occurs.

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WBRP

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WBRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WBRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACEY	NFAC	BIRT	x	FFPA	=	WBRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WBRP

CHAPTER 19, WORKSHEET 1.1c

Formats for determining weighted mean weaning rates

The nine age classes listed below may be used to tally weaning rates for determining the weighted mean weaning rate for the population. Note that the age class is designated by the midpoint, the approximate time when weaning occurs.

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WWRP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WWRP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WWRP

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	ACMP	NFAC	WERT	x	FFPA	=	WWRA
ACaa.	1/2	____	____	x	____	=	____
ACbb.	1-1/2	____	____	x	____	=	____
ACcc.	2-1/2	____	____	x	____	=	____
ACdd.	3-1/2	____	____	x	____	=	____
ACee.	4-1/2	____	____	x	____	=	____
ACff.	5-1/2	____	____	x	____	=	____
ACgg.	6-1/2	____	____	x	____	=	____
AChh.	7-1/2	____	____	x	____	=	____
ACii.	8-1/2+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WWRP

UNIT 1.2: AGE-RELATED MORTALITY RATES

There is a general relationship between age and mortality rates, especially at the two extremes. The mortality rates of the very young and the very old are higher than the rates of the age classes betwen these two extremes. This is especially true for factors related to such natural causes as predation and the effects of storms. Very young and very old animals do not have the resources or resiliency to withstand as much stress, and the very young do not have the beneficial effects of a lifetime of learning. They are inexperienced and less able to cope with predators than older animals, for example. On the other hand, old animals have less strength and endurance to escape predators, and lessened neurological capabilities for detecting them in the first place. Thus it is often concluded that predators take the older, diseased, and less fit animals.

Mortality rates given in the published literature are almost always expressed in relation to age classes. Sample formats and definitions for tabulating mortality data are given below.

CLASS	ACYI	NMAC	NBMO	MORT
ACa-.	____	____	____	____
ACb-.	____	____	____	____
.				
.				
.				
ACn-.	____	____	____	____
	SUMS =	____	= TNMP	

Weighted means of age-related mortality may be determined with the format given below. Males and females are kept on separate formats. The male format is:

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA
ACa-.	0-1	____	____	____	x	____	=	____
ACb-.	1-2	____	____	____	x	____	=	____
.								
.								
.								
ACn-.	____	____	____	____	x	____	=	____
	SUMS =	____	= TNMP	[____]		[1.00]		____ = MWMP

where ACYI = age class by yearly intervals,
NMAC = number of males in each age class,
NBMO = number of mortalities,
MORT = mortality rate,
TNMP = total number of males in the population,
FMPA = fraction of the male population in each age class,
MWMA = weighted mean mortality rate of each age class, and
SUMS = sums
MWMP = weighted mean mortality rate of the male population.

A sample calculation is illustrated below.

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA
ACa-.	0-1	50	10	0.20	x	0.50	=	0.10
ACb-.	1-2	38	3	0.08	x	0.38	=	0.03
ACc-.	2-3+	12	1	0.08	x	0.12	=	0.01
	SUMS =	100	= TNMP			[1.00]		0.14 = MWMP

The format for determining the weighted mean mortality for females in each age class is the same as for males, with the appropriate changes in column headings. A sample format is shown below.

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA
ACa-.	0-1	___	___	___	x	___	=	___
ACb-.	1-2	___	___	___	x	___	=	___
.								
.								
.								
ACn-.	___	___	___	___	x	___	=	___
	SUMS =	___	= TNMP			[1.00]		___ = FWMP

where ACYI = age class by yearly intervals,
NFAC = number of females in each age class,
NBMO = number of mortalities,
MORT = mortality rate,
FFPA = fraction of the female population in each age class,
FWMA = female weighted mortality rate of each age class, and
SUMS = sums
FWMP = weighted mortality rate of the female population.

A sample calculation is illustrated below. WORKSHEETS are given for both males and females.

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA
ACa-.	0-1	44	12	0.27	x	0.44	=	0.12
ACb-.	1-2	34	3	0.09	x	0.34	=	0.03
ACc-.	2-3+	22	1	0.05	x	0.22	=	0.01
	SUMS =	100	= TNMP			[1.00]		0.16 = FWMP

Note that the age class need not be the one-year interval as indicated above. Age classes could be age in days intervals during the year. The five biological periods discussed at the beginning of this CHAPTER 19 are also likely possiblities, resulting in five mortality periods during the year, each with its own rate for each age class. Data are not often available for so many time-periods, however; the option is mentioned because it could be used to trace population changes through the year as well as from year to year.

REFERENCES, UNIT 1.2

AGE-RELATED MORTALITY RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CAFNA	90--1	29	36	odvi	est pop and mort, ce ontar	king,dr	1976
JWMAA	11--4	317	323	odvi	die-offs, edwrds plat, tex	taylor,wp; hahn,h	1947
JWMAA	15--1	73	80	odvi	prod and mort coralled dee	severinghaus,cw	1951
JWMAA	33--4	1027	1028	odvi	longev recrds, femal, mich	ozoga,jj	1969
JWMAA	35--1	47	56	odvi	mort, young fawns, s texas	cook,rs; white,m/	1971
JWMAA	38--4	799	807	odvi	factors, highway mortality	publisi,mj; lind/	1974
JWMAA	40--2	317	325	odvi	deer-car accidents, michig	allen,re; mccullo	1976
JWMAA	41--1	63	69	odvi	fac af neo-na fwn surv, tx	carroll,bk; brown	1977
JWMAA	41--4	700	708	odvi	assess natal mort, up mich	verme,lj	1977
NAWTA	12---	212	223	odvi	weather, winter mort, adir	severinghaus,cw	1947
NFGJA	2--1	1	15	odvi	mort of fwns, senec ar dep	o'pezio,jp	1978
PCGFA	23---	188	191	odvi	fawn mortal, confin va hrd	mcginnes,bs; down	1970
TNWSD	9----	1	12	odvi	anal kil-curvs of fem deer	gill,j	1953
TNWSD	30---	345	361	odvi	eval fawn mort, army depot	o'pezio,jp	1973
WDABB	3---4	160	165	odvi	radiotel, fawn mortal stud	cook,rs; white,m/	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JOMAA	39--1	155	155	odhe	failur of to wean offsprng	hanson,wr	1958
JWMAA	21--1	1	16	odhe	difrtnl mor by age and sex	robinette,w; gas/	1957
JWMAA	24--1	80	88	odhe	natural mortali, se alaska	olson,st	1960
JWMAA	31--4	651	666	odhe	char of herds, range, utah	richens,vb	1967
JWMAA	43--3	657	665	odhe	fac affe surv desert fawns	smith,rh; lecount	1979
MRLTA	35--3	39	42	odhe	summer mort, juvenil, wash	brigham,jh	1954

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JAECA	47--3	817	832	ceel	factors affect calf mortal	guinness,fe; clu/	1978
JOMAA	47--2	332	334	ceel	fetus resorption in elk	haugen,ao	1966
JRPFA	54--2	325	334	ceel	factrs aff reprod red deer	guinness,fe; alb/	1978
JWMAA	39--1	92	100	ceel	repro, erly clf mort, norw	wegge,p	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	32--4	953	956	alal	spring-fall calf mort, ala	leresche,re	1968
JWMAA	40--2	336	339	alal	marrow fat, mortal, alaska	franzmann,aw; arn	1976
NCANA	101-5	737	754	alal	num road kil, laur pk, que	grenier,pa	1974
WLMOA	48---	1	65	alal	habitat select, forest mgt	peek,jm; urich,d/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	87--1	21	25	rata	mater behav, morta, stress	miller,fl; brough	1973
CWRSB	26---	1	25	rata	calf mort, 1970, kaminuria	miller,fl; brough	1974
JOMAA	42--4	550	551	rata	post natal mortal, b-gr ca	pruitt,wd	1961
JWIDA	9---4	311	313	rata	lightning, central alaska	shaw,ge; neiland,	1973
JWIDA	9---4	376	378	rata	mort due to meningeal worm	trainer,do	1973
NOSCA	50--2	97	101	rata	threats to surv, koote, bc	johnson,dr	1976
NPOAA	1976-	249	270	rata	survivorship, svalbard rei	de bie,s	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	30--3	488	496	anam	die-off in trans-pecos, tx	hailey,tl; thoma/	1966
JWMAA	31--4	843	843	anam	orphaned pronghorns surviv	bromley,pt; o'gar	1967
JWMAA	37--3	343	352	anam	morta, fawns, western utah	beale,dm; smith,a	1973

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	38--4	771	774	ovca	lamb prod, surv, mort, col	woodward,tn; gut/	1974

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	35--3	456	456	obmo	muskox longevity	buckley,jl; spen/	1954
JWMAA	35--1	103	108	obmo	pop characs, nrth wst terr	freeman,mmr	1971

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	105--	137	156		age-specif selection; r, k	king,ce; anderson	1971
AMNTA	106--	14	31		concept of r-, k-selection	gadgil,j; solbrig	1972
JTBIA	12--1	12	45		moulding of senese, nat se	hamilton,wd	1966
SCIEA	206--	1101	1103	ungu	inbreedng, juvenile mortal	ralls,k; brugger/	1979

CHAPTER 19, WORKSHEET 1.2a

Determining weighted mean mortality rate of a population - males

Calculations of the weighted mean mortality rates of populations of males in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES:______________ TIME PERIOD:______________

LOCATION:______________ REFERENCE:______________

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA
ACa-.	0-1	____	____	____	x	____	=	____
ACb-.	1-2	____	____	____	x	____	=	____
ACc-.	2-3	____	____	____	x	____	=	____
ACd-.	3-4	____	____	____	x	____	=	____
ACe-.	4-5	____	____	____	x	____	=	____
ACf-.	5-6	____	____	____	x	____	=	____
ACg-.	6-7	____	____	____	x	____	=	____
ACh-.	7-8	____	____	____	x	____	=	____
ACi-.	8-9+	____	____	____	x	____	=	____
	SUMS =	____	= TNMP			[1.00]		____ = MWMP

SPECIES:______________ TIME PERIOD:______________

LOCATION:______________ REFERENCE:______________

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA
ACa-.	0-1	____	____	____	x	____	=	____
ACb-.	1-2	____	____	____	x	____	=	____
ACc-.	2-3	____	____	____	x	____	=	____
ACd-.	3-4	____	____	____	x	____	=	____
ACe-.	4-5	____	____	____	x	____	=	____
ACf-.	5-6	____	____	____	x	____	=	____
ACg-.	6-7	____	____	____	x	____	=	____
ACh-.	7-8	____	____	____	x	____	=	____
ACi-.	8-9+	____	____	____	x	____	=	____
	SUMS =	____	= TNMP			[1.00]		____ = MWMP

SPEClES: ____________________   TIME PERIOD: ____________________

LOCATION: ____________________   REFERENCE: ____________________

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA	
ACa-.	0-1	___	___	___	x	___	=	___	
ACb-.	1-2	___	___	___	x	___	=	___	
ACc-.	2-3	___	___	___	x	___	=	___	
ACd-.	3-4	___	___	___	x	___	=	___	
ACe-.	4-5	___	___	___	x	___	=	___	
ACf-.	5-6	___	___	___	x	___	=	___	
ACg-.	6-7	___	___	___	x	___	=	___	
ACh-.	7-8	___	___	___	x	___	=	___	
ACi-.	8-9+	___	___	___	x	___	=	___	
	SUMS =	___	= TNMP			[1.00]		___	= MWMP

SPECIES: ____________________   TIME PERIOD: ____________________

LOCATION: ____________________   REFERENCE: ____________________

CLASS	ACYI	NMAC	NBMO	MORT	x	FMPA	=	MWMA	
ACa-.	0-1	___	___	___	x	___	=	___	
ACb-.	1-2	___	___	___	x	___	=	___	
ACc-.	2-3	___	___	___	x	___	=	___	
ACd-.	3-4	___	___	___	x	___	=	___	
ACe-.	4-5	___	___	___	x	___	=	___	
ACf-.	5-6	___	___	___	x	___	=	___	
ACg-.	6-7	___	___	___	x	___	=	___	
ACh-.	7-8	___	___	___	x	___	=	___	
ACi-.	8-9+	___	___	___	x	___	=	___	
	SUMS =	___	= TNMP			[1.00]		___	= MWMP

CHAPTER 19, WORKSHEET 1.2b

Determining weighted mean mortality rate of a population - females

Calculations of the weighted mean mortality rates of populations of females in nine age classes may be made in the spaces provided below. Two more sets of spaces are provided on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA	
ACaa.	0-1	____	____	____	x	____	=	____	
ACbb.	1-2	____	____	____	x	____	=	____	
ACcc.	2-3	____	____	____	x	____	=	____	
ACdd.	3-4	____	____	____	x	____	=	____	
ACee.	4-5	____	____	____	x	____	=	____	
ACff.	5-6	____	____	____	x	____	=	____	
ACgg.	6-7	____	____	____	x	____	=	____	
AChh.	7-8	____	____	____	x	____	=	____	
ACii.	8-9+	____	____	____	x	____	=	____	
	SUMS =	____	= TNMP			[1.00]		____	= FWMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA	
ACaa.	0-1	____	____	____	x	____	=	____	
ACbb.	1-2	____	____	____	x	____	=	____	
ACcc.	2-3	____	____	____	x	____	=	____	
ACdd.	3-4	____	____	____	x	____	=	____	
ACee.	4-5	____	____	____	x	____	=	____	
ACff.	5-6	____	____	____	x	____	=	____	
ACgg.	6-7	____	____	____	x	____	=	____	
AChh.	7-8	____	____	____	x	____	=	____	
ACii.	8-9+	____	____	____	x	____	=	____	
	SUMS =	____	= TNMP			[1.00]		____	= FWMP

SPECIES:____________________ TIME PERIOD:____________________

LOCATION:____________________ REFERENCE:____________________

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA	
ACaa.	0-1	____	____	____	x	____	=	____	
ACbb.	1-2	____	____	____	x	____	=	____	
ACcc.	2-3	____	____	____	x	____	=	____	
ACdd.	3-4	____	____	____	x	____	=	____	
ACee.	4-5	____	____	____	x	____	=	____	
ACff.	5-6	____	____	____	x	____	=	____	
ACgg.	6-7	____	____	____	x	____	=	____	
AChh.	7-8	____	____	____	x	____	=	____	
ACii.	8-9+	____	____	____	x	____	=	____	
	SUMS =	____	= TNMP			[1.00]		____	= FWMP

SPECIES:____________________ TIME PERIOD:____________________

LOCATION:____________________ REFERENCE:____________________

CLASS	ACYI	NFAC	NBMO	MORT	x	FFPA	=	FWMA	
ACaa.	0-1	____	____	____	x	____	=	____	
ACbb.	1-2	____	____	____	x	____	=	____	
ACcc.	2-3	____	____	____	x	____	=	____	
ACdd.	3-4	____	____	____	x	____	=	____	
ACee.	4-5	____	____	____	x	____	=	____	
ACff.	5-6	____	____	____	x	____	=	____	
ACgg.	6-7	____	____	____	x	____	=	____	
AChh.	7-8	____	____	____	x	____	=	____	
ACii.	8-9+	____	____	____	x	____	=	____	
	SUMS =	____	= TNMP			[1.00]		____	= FWMP

TOPIC 2. WEIGHT-RELATED REPRODUCTIVE AND MORTALITY RATES

The relationships between weights and reproductive rates are generally better than the relationship between ages and reproductive rates as females of a given age who are in very good physical condition weigh more and have higher reproductive rates than lighter-weight age-mates.

Weights at given ages are reflections of range conditions, of course. The higher the quality of the range, the faster the rate of growth. Free-ranging animals, dependent on their own foraging activity for the ingestion of nutrients, will hardly overdo ingestion to the point of obesity and subsequent reproductive depression. Thus weight is a good indicator of physical and reproductive condition. There are, however, very limited data on the relationship between female weights and reproductive rates for wild ruminants.

Variations in reproductive rates for different age classes may be the result of variations in weights at different ages. A three-year old animal on poor range may weigh about the same as a two-year old one on good range, and they may have similar reproductive rates. The use of weight as the independent variable and reproductive rate as the dependent variable seems to be biologically sound, and simplifies the use of reproductive data since reproductive rates would not have to be determined for age classes of animals on different ranges in different geographical areas, but rather, weights alone could be measured. Weights, of course, are harder to determine under field conditions than ages, although ages cannot always be accurately determined without laboratory preparations of tooth sections. The use of weights as the independent variable is favored for conceptual reasons rather than practical ones. Calculations are illustrated in UNIT 3.1.

Mortality rates in relation to weights are very useful since weight is a good indicator of animal condition, at least within age classes. The heavier-than-average individuals in a particular age class have survival and production advantages that the lighter-than-average ones do not have. These are discussed in UNIT 3.2.

UNIT 2.1: WEIGHT-RELATED REPRODUCTIVE RATES

Reproductive rates are almost always expressed in relation to age, even though weight is a better indicator of condition and an animal's capacity to reproduce than age. A large, healthy two-year-old whitetail will likely bear two fawns, while a small, undernourished three-year-old will likely bear a single fawn. Since published reproductive rates are so often expressed in relation to age, conversions from age to weight are necessary in order to use the more reasonable biological approach of weight-related natality rates. The discussions and techniques described in CHAPTER 1, UNITS 1.3 and 1.4 for adult and seasonal weight calculations need to be used for these age-to-weight conversions.

What time of year should be chosen for the weight-dependent calculation of reproductive rate? Peak fall weights are the most logical, with adjustments back to predicted peak fall weights when reproductive data are collected on animals in their weight decline. Adjustment back to peak fall weights for all individuals allows one to collect data from animals collected throughout the gestation period.

Adjustments backward to peak fall weights may be made by simple multipication. Suppose a 2-1/2 year-old deer weighing 50 kg was examined on January 31 and found to carry two fetuses. If the peak weight of a deer of that age is predicted to be 58 kg, and the calculated weight on January 31 is predicted to be 48 kg, then the ratio of 58/48 = 1.21 is applied to the deer examined. Her predicted peak weight is (50)(1.21) = 60.5, and x = 60.5, y = 2.0 in a regression calculation.

One unpublished report by Hesselton and Saur (1972; P-R Project W-89-R-15) describes the relationship between weight and reproductive rate (fawns *in utero*) for deer killed by cars in January in New York State. The weight:reproductive rate relationship was expressed as a linear regression equation. Their equation overestimated the reproductive rates of larger females, so I derived the following logarithmic equation as a better estimate over a wide range of weights:

$$\text{FEPF} = 2.79\ (\ln \text{CLWK}) - 9.78$$

where CLWK = calculated maximum live weight at JDAY 16, and
FEPF = fetuses per female.

Threshold weights for the first conception and for conception of two or three fawns may be calculated from this equation. First conception becomes possible when CLWK is 33 kg. Deer weighing 48 kg are expected to bear singles, and 68 kg, twins. Such an equation is useful when there are no reproductive rate data available but data on or estimates of weights are. The concept should be applied to deer in other areas and to other species too.

The formats for tabulating weight-related reproductive rates are the same as for age-related rates, except that the rates are functions of the weights rather than the ages of the animals. Since most of the published data are based on ages, both age and weight columns are included, permitting one to estimate weight from age first, if necessary, and then natality and mortality from weight.

CLASS	WCMP	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
.	.	.	.		.		.
.	.	.	.		.		.
.	.	.	.		.		.
WCnn.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

Definitions of the column headings are:

WCMP = weight class at the midpoint,
NFWC = number of females in each weight class,
CORT = conception rate,
FFPW = fraction of the female population in this weight class,
WCRW = weighted mean conception rate for each weight class,
SUMS = sums,
TNFP = total number of females in the population, and
WCRP = weighted mean conception rate of the population.

A sample calculation follows, illustrating the calculation of a single weighted mean conception rate for use in exponential predictions.

CLASS	WCMP	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	35	____	____	x	____	=	____
WCbb.	45	____	____	x	____	=	____
WCcc.	55+	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

REFERENCES, UNIT 2.1

WEIGHT-RELATED REPRODUCTIVE RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	22--1	43	44	od--	replacement teeth, age det	mclean,dd	1936
NAWTA	21---	159	172	od--	nutrit & pop dynams, calif	taber,rd	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	32--3	267	280	odvi	tomhegan comps, maine, fec	palmer,rs	1951
JWMAA	10--3	242	248	odvi	regio dif in bre potnl, ny	morton,gh; cheatu	1946
JWMAA	12--1	78	86	odvi	produ, yield, george resrv	o'roke,ec; hamers	1948
JWMAA	14--3	290	295	odvi	breeding records, michigan	haugen,ao; davenp	1950
JWMAA	20--3	286	292	odvi	regio dif in sze, prod, wv	gill,j	1956
JMWAA	33--4	881	887	odvi	reproduction, plane nutrit	verme,lj	1969
NAWTA	15---	170	190	odvi	fertility, range condition	cheatum,el; sever	1950
NAWTA	31---	129	138	odvi	effect of dietary protein	murphy,da; coates	1966
NAWTA	32---	405	420	odvi	experim diets, wtd reprodu	verme,lj	1967
NFGJA	11--1	13	27	odvi	prod, grwth, adirndcks, ny	severinghaus,cw;/	1964
NYCOA	1---5	18	18	odvi	white-tail fertility	cheatum,el	1947
PCGFA	13---	62	69	odvi	mast abund, weight, reprod	harlow,rf; tyson,	1959
PCGFA	14---	53	60	odvi	prog rep deer prod studies	noble,re	1950
PCGFA	21---	62	68	odvi	reprod studies, alabam hrd	lueth,fx	1967
PCGFA	25---	53	65	odvi	characs reprod in arkansas	wilson,sn; seala/	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	34--1	25	31	odhe	breeding season, productiv	chattin,je	1948
CAFGA	38--2	211	224	odhe	food habs, product, condit	lassen,rw; ferre/	1952
CAFGA	39--2	177	186	odhe	reprod 3 chaparr cvr types	taber,rd	1953
JOMAA	39--1	155	155	odhe	failur of to wean offsprng	hanson,wr	1958
JWMAA	17--2	225	225	odhe	initial proof, fawns breed	crane,hs; jones,d	1953
JWMAA	19--4	503	503	odhe	high reproductive rate	jansen,w; robinet	1955
JWMAA	21--1	62	65	odhe	ovarian anal, repr perform	golley,fb	1957
NAWTA	9----	156	161	odhe	studies product, cent utah	robinette,wl; ols	1944
NAWTA	15---	589	596	odhe	productivity, colorado	tolman,cd	1950

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	64--1	40	42	ceel	productiv, survival, banff	green,hu	1950
JOMAA	18--1	62	66	ceel	life hist, roos elk, calif	orr,rt	1937
JOMAA	47--2	332	334	ceel	fetus resorption in elk	haugen,ao	1966
JWMAA	9---4	295	319	ceel	roosevelt elk, washington	schwartz,je; mitc	1945
ZEJAA	3---4	145	153	ceel	reprodu rates, body weight	krowing,f; vorre	1957

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	36--3	328	329	anam	calif antel reprod potentl	chattin,je; lasse	1950
JWMAA	34--3	570	582	anam	productivity, forage, wate	beale,dm; smith,a	1970

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	24--1	1	11	ovca	life hist, tarryall mt, co	spencer,c	1943
JWMAA	9---2	155	156	ovca	non-breeding in bighorn sh	pulling,ars	1945
JWMAA	38--4	771	774	ovca	lamb produc, survi, mortal	woodard,tn; guti/	1974

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
NAWTA	15---	581	588	biga	vital statistics, big game	cowan,im	1950

CHAPTER 19, WORKSHEET 2.1a

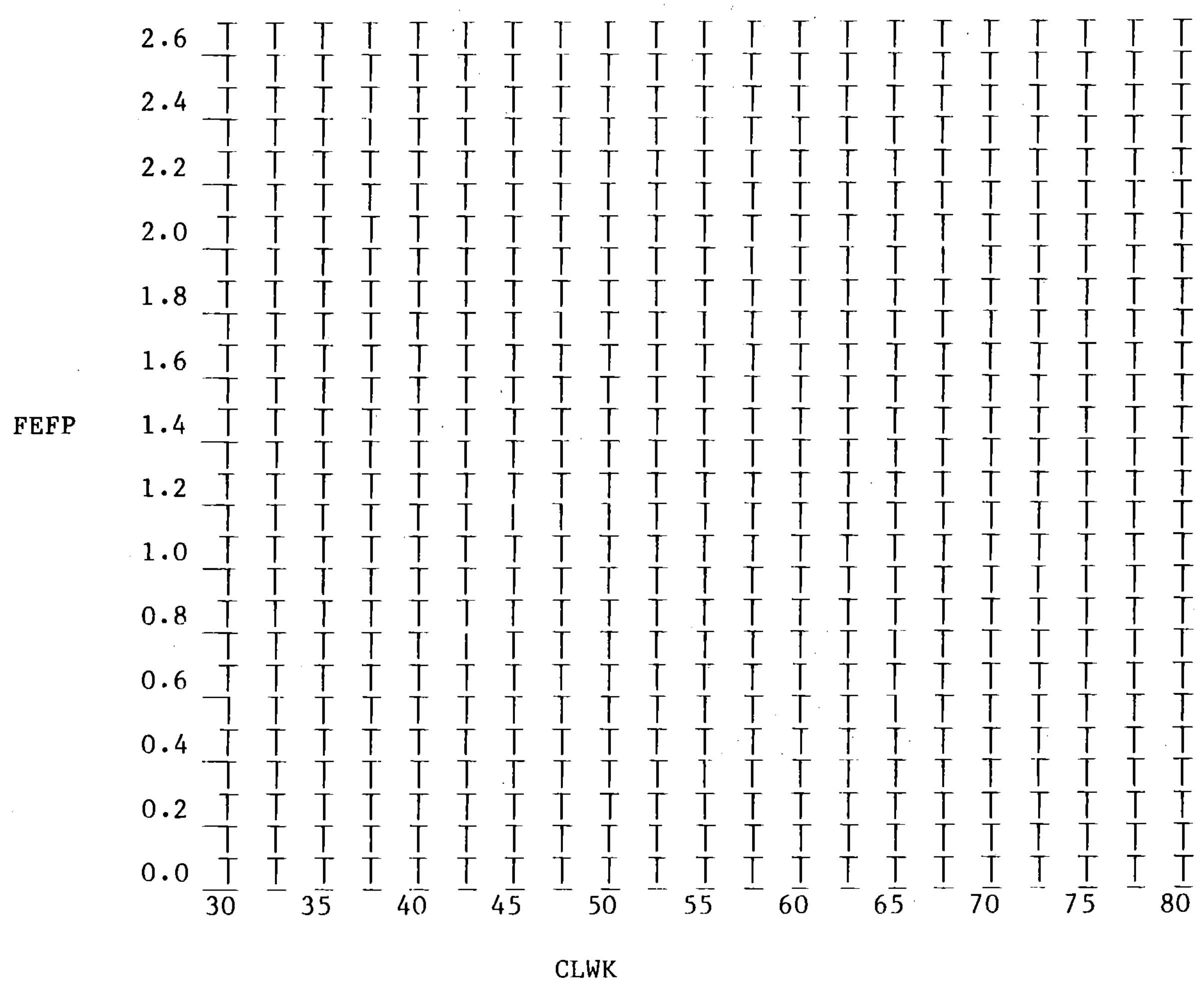
Estimations of the conception rate of white-tailed deer
from annual fall maximum weights

An equation was given in this UNIT as a first approximation of the conception rate of white-tailed deer in relation to their maximum weights in the fall. The equation is:

$$FEPF = 2.79 (\ln CLWK) - 9.78$$

where CLWK = calculated maximum live weight and
FEPF = fetuses per female.

Plot FEPF in the grid below in relation to the range of weights given.



CHAPTER 19, WORKSHEET 2.1b

Weight-related conception rates

The two sets of nine weight classes listed below may be used to tally conception rates for determining the weighted mean conception rate for the population. Select the appropriate classes for the species being considered. Two more sets are included on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WCKI	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WCKI	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ______ ____________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WCKI	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WCKI	NFWC	CORT	x	FFPW	=	WCRW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = WCRP

UNIT 2.2: WEIGHT-RELATED MORTALITY RATES

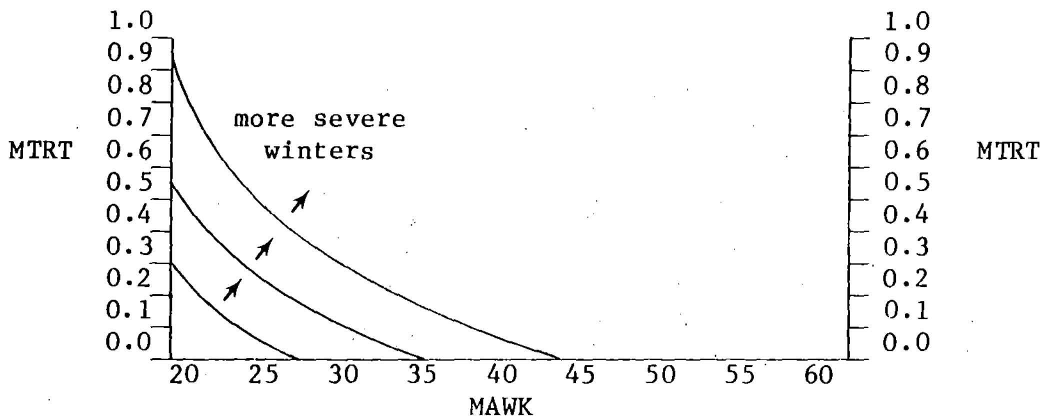
Mortality rates are almost always given for age classes, just as reproductive rates are. Mortality rates may also be more weight-dependent than age-dependent, however. Young of the year, for example, may be born early or late, yet both extremes are members of the same age class. The early-born animals may be considerably larger than the late-born ones by winter. Their chances of surviving harsh winter conditions are considerably better as their larger mass contains more fat reserves, they have a larger skeleton with which to cope with mechanical effects of snow as a barrier to movement, and they are also able to reach higher for forage. The larger young of the year will likely be socially dominant over the smaller young of the year too because of the several advantages they have over their smaller age-class peers.

A study of weight-related mortality of newborn white-tailed deer fawns is reported by Verme (1977). An eight-year study of mortality in relation to predicted birth weights showed that the lighter the fawns at birth, the greater their mortality risk is. The yearly data, rounded to two decimal places, are tabulated below and fit with a logarithmic regression analysis for natal mortality rate (NTMR) and natal survival rate (NTSR) in relation to the expected birth weight in kg (BIWK). The equations below the tabulated data represent very good fits.

YEAR	Predicted BIWK	Estimated NTMR	Calculated NTMR	Estimated NTSR	Calculated NTSR
1968	3.22	0.12	0.10	0.88	0.90
1969	2.75	0.33	0.35	0.67	0.65
1970	2.90	0.25	0.26	0.75	0.74
1971	2.50	0.50	0.50	0.50	0.50
1972	2.27	0.68	0.66	0.32	0.34
1973	3.24	0.10	0.09	0.90	0.91
1974	2.78	0.32	0.33	0.68	0.67
1975	2.61	0.43	0.43	0.43	0.57

$$NTMR = 1.9665 - 1.5982 \ln(BIWK); \quad R^2 = 0.99$$
$$NTSR = 1.5982 \ln(BIWK) - 0.9665; \quad R^2 = 0.99$$

The illustration above is a good example of weight-related mortality rates. Similar analyses can be made for other causes of weight-related mortality if data are available. Mortality rates of whitetail fawns during their first winter, for example, may have the pattern illustrated on the next page.



Note that the mortality rate (MTRT) is higher as the the maximum weight in kg (MAWK) is lower. Note also that in more severe winters, the mortality rate curve is shifted upward and to the right, toward higher MAWK.

The formats for determining weight-related mean mortality rates are similar to the age-related formats except for column changes as weight data replace age data, or are derived from age data. Sample formats for both males and females follow.

MALES

CLASS	WCKI	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	____	____	____	x	____	=	____
WCb-.	____	____	____	x	____	=	____
.							
.							
.							
WCn-.	____	____	____	x	____	=	____

SUMS = [____] = TNMP [1.00] [____] = MWMP

Definitions of the the column headings are:

WCKI = weight class by kg intervals,
NMWC = number of males in each weight class,
MTRT = mortality rate,
FMPW = fraction of the male population in this weight class,
MWMW = weighted mean mortality rate for each weight class,
SUMS = sums,
TNMP = total number of males in the population, and
MWMP = weighted mean mortality rate of the population.

CLASS	WCKI	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	40-50	35	0.20	x	0.35	=	0.07
WCb-.	50-60	44	0.08	x	0.44	=	0.04
WCc-.	60-70+	21	0.08	x	0.21	=	0.02

SUMS = [100] = TNMP [1.00] [0.13] = MWMP

FEMALES

CLASS	WCKI	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
.							
.							
.							
WCnn.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = FWMP

Definitions of the the column headings are:

WCKI = weight class by kg intervals,
NFWC = number of females in each weight class,
MTRT = mortality rate,
FFPW = fraction of the female population in this weight class,
FWMW = weighted mean mortality rate for each weight class,
SUMS = sums,
TNFP = total number of females in the population, and
FWMP = weighted mean mortality rate of the population.

CLASS	WTCL	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	40-50	50	0.27	x	0.50	=	0.14
WCbb.	50-60	43	0.09	x	0.43	=	0.04
WCcc.	60-70+	7	0.05	x	0.07	=	0.01

SUMS = [100] = TNFP [1.00] [0.19] = FWMP

LITERATURE CITED

Verme, L. J. 1977. Assessment of natal mortality in upper Michigan deer. J. Wildl. Manage. 41(4):700-708.

REFERENCES, UNIT 2.2

WEIGHT-RELATED MORTALITY RATES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	21---	159	172	od--	nutrit & pop dynams, calif	taber,rd	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	35--1	47	56	odvi	mortalit, young fawns, tex	cook,rs; white,m/	1971
JWMAA	38--4	799	807	odvi	factors, highway mortality	puglisi,mj; lind/	1974
JWMAA	40--2	317	325	odvi	deer-car accidents, michig	allen,re; mccullo	1976
NAWTA	12---	212	223	odvi	weath, wint mort, popu, ny	severinghaus,cw	1947

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	18--3	309	315	odhe	sex differ mortal, yg deer	taber,rd; dasmann	1954
JWMAA	21--1	1	16	odhe	differ mortal by sex & age	robinette,wl; ga/	1957
JWMAA	24--1	80	88	odhe	natur mortal patter, alask	klein,dr; olson,s	1960
JWMAA	31--4	651	666	odhe	charact, herds, rang, utah	richens,vb	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CWRSB	11---	1	71	ceel	caus, implic sex dif surviv	flook,dr	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--2	336	339	alal	marrow fat, mortal, alaska	franzmann,aw; ar	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	87--1	21	25	rata	behav, mort, stress, ba gr	miller,fl; brough	1973
CWRSB	26---	1	25	rata	1970 kaminuri calv gr mort	miller,fl; brough	1974

rata continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWIDA	9---4	311	313	rata	electrocu, lightnin, alask	shaw,ge; neiland,	1973
JWIDA	9---4	376	378	rata	carib mort, meningeal worm	trainer,dc	1973
NOSCA	50--2	97	101	rata	threats, mt carib surv, bc	johnson,dr	1976
NPOAA	1976-	249	270	rata	svalbard reind, survivorsh	de bie,s	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31	843	843	anam	orphaned pronghorns surviv	bromley,pt; o'gar	1967
JWMAA	37	343	352	anam	mortality, fawns, wes utah	beale,dm; smith,a	1973

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	38--4	771	774	ovca	lamb produc, survi, mortal	woodard,tn; guti/	1974

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			

CHAPTER 19, WORKSHEET 2.2a

Determining weighted mean weight-related mortality rates - males

The two sets of nine weight classes listed below may be used to tally mortality rates for determining the weighted mean mortality rates for two male populations. Select the appropriate classes for the species being considered. Two more sets are included on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	____	____	____	x	____	=	____
WCb-.	____	____	____	x	____	=	____
WCc-.	____	____	____	x	____	=	____
WCd-.	____	____	____	x	____	=	____
WCe-.	____	____	____	x	____	=	____
WCf-.	____	____	____	x	____	=	____
WCg-.	____	____	____	x	____	=	____
WCh-.	____	____	____	x	____	=	____
WCi-.	____	____	____	x	____	=	____

SUMS = [____] = TNMP [1.00] [____] = MWMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	____	____	____	x	____	=	____
WCb-.	____	____	____	x	____	=	____
WCc-.	____	____	____	x	____	=	____
WCd-.	____	____	____	x	____	=	____
WCe-.	____	____	____	x	____	=	____
WCf-.	____	____	____	x	____	=	____
WCg-.	____	____	____	x	____	=	____
WCh-.	____	____	____	x	____	=	____
WCi-.	____	____	____	x	____	=	____

SUMS = [____] = TNMP [1.00] [____] = MWMP

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	WTCL	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	____	____	____	x	____	=	____
WCb-.	____	____	____	x	____	=	____
WCc-.	____	____	____	x	____	=	____
WCd-.	____	____	____	x	____	=	____
WCe-.	____	____	____	x	____	=	____
WCf-.	____	____	____	x	____	=	____
WCg-.	____	____	____	x	____	=	____
WCh-.	____	____	____	x	____	=	____
WCi-.	____	____	____	x	____	=	____

SUMS = [____] = TNMP [1.00] [____] = MWMP

SPECIES: ______________________ TIME PERIOD: ______________________

LOCATION: ______________________ REFERENCE: ______________________

CLASS	WTCL	NMWC	MTRT	x	FMPW	=	MWMW
WCa-.	____	____	____	x	____	=	____
WCb-.	____	____	____	x	____	=	____
WCc-.	____	____	____	x	____	=	____
WCd-.	____	____	____	x	____	=	____
WCe-.	____	____	____	x	____	=	____
WCf-.	____	____	____	x	____	=	____
WCg-.	____	____	____	x	____	=	____
WCh-.	____	____	____	x	____	=	____
WCi-.	____	____	____	x	____	=	____

SUMS = [____] = TNMP [1.00] [____] = MWMP

CHAPTER 19, WORKSHEET 2.2b

Determining weighted mean weight-related mortality rates - females

The two sets of nine weight classes listed below may be used to tally mortality rates for determining the weighted mean mortality rates for two female populations. Select the appropriate classes for the species being considered. Two more sets are included on the back of this page.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = FWMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = FWMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = FWMP

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	WTCL	NFWC	MTRT	x	FFPW	=	FWMW
WCaa.	____	____	____	x	____	=	____
WCbb.	____	____	____	x	____	=	____
WCcc.	____	____	____	x	____	=	____
WCdd.	____	____	____	x	____	=	____
WCee.	____	____	____	x	____	=	____
WCff.	____	____	____	x	____	=	____
WCgg.	____	____	____	x	____	=	____
WChh.	____	____	____	x	____	=	____
WCii.	____	____	____	x	____	=	____

SUMS = [____] = TNFP [1.00] [____] = FWMP

TOPIC 3. INDICES OF NATALITY AND MORTALITY RATES

Knowledge of natality and mortality rates is difficult, time-consuming, and expensive to obtain, just as censuses of entire populations are. Population estimates are often replaced by indices; changes from year to year are easier to determine than are absolute numbers.

Indices of natality and mortality rates may sometimes be derived from easily-collected field data. The use of teat length as an indicator of the nursing of young is an example of a rather simple technique that can yield significant biological information (see UNIT 1.1). Antler beam diameters of white-tailed deer are indicators of range conditions. Such an indicator may be related to female reproductive rates since both males and females respond to the range conditions present (see UNIT 2.1).

The two UNITS in this TOPIC are examples of the kinds of indices that may be used to estimate absolute rates. The evaluation of these two indices for other species may prove to be worthwhile, and other indices may also be added.

UNIT 3.1: TEAT LENGTH AS AN INDEX OF NATALITY RATES

The use of teat length as an indicator of previous suckling of young is a common-sense procedure. Only recently, however, has the technique been described and used for determining reproductive rates. Sauer and Severinghaus (1977) examined hunter-killed yearling does for teat lengths and the presence of milk in the udder, indicating that the doe had been bred as a fawn. This indicator permits one to calculate the percent of fawns breeding.

There was minimal overlap in teat lengths between the bred and unbred groups of does. The fawn breeding rate can be used to predict yearling and adult reproductive rates. Equations given by Sauer and Severinghaus (1977:82), based on data from the Seneca Army Depot in western New York, are:

$$YERR = 1.28 + 1.06\ FARR;\ r = 0.821 \text{ and } SE = 0.19$$

$$ADRR = 1.79 + 0.41\ FARR;\ r = 0.757 \text{ and } SE = 0.10$$

where YERR = yearling reproductive rate,
FARR = fawn reproductive rate, and
ADRR = adult reproductive rate.

These equations may be used to estimate the reproductive rates of three important age groups in white-tailed deer populations. The rates are used when making the population predictions described in TOPIC 4.

LITERATURE CITED

Sauer, P. R. and C. W. Severinghaus. 1977. Determination and application of fawn reproductive rates from yearling teat lengths. Page 81-88, 84a and 84b. In Proceedings, Joint Northeast-Southeast Deer Study Group Meeting. September 6-8, 1977. 149 p.

REFERENCES, UNIT 3.1

TEAT LENGTH AS AN INDEX OF NATALITY RATES

SERIALS

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

odvi

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

odhe

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

ceel

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

alal

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

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

UNIT 3.2: ANTLER BEAM DIAMETER AS AN INDEX OF NATALITY RATES

Antler beams are expected to be larger on animals on good range than on poor range. Antler beam diameters can be predicted from live or dressed weights. Dressed weight and antler beam diameter data from five regions of New York State were analyzed by C. W. Severinghaus (See 1981 citation) and the following linear regression equation proposed as a first approximation:

$$YABD = 3.21 + 0.29\ YDWK; \quad R^2 = 0.97$$

where:

YABD = yearling antler beam diameter in mm, and
YDWK = yearling dressed weight in kg.

The equation above has been modified to be used with live weights (dressed weight : live weight conversion equation for New York deer from CHAPTER 1, page 26a). The live weight : antler beam diameter relationship is:

$$YABD = 2.83 + 0.23\ YLWK$$

where YABD = yearling antler beam diameter in mm, and
YLWK = yearling calculated live weight in kg.

Antler beam diameters in yearling white-tailed deer may be used to predict yearling reproductive rates. Linear regression of antler beam diameter and reproductive rate data from the Seneca Army Depot and several regions of New York State has been prepared by C. W. Severinghaus (1981), and the following equation for YERR proposed:

$$YERR = -1.187 + 0.14\ YABD; \quad R^2 = 0.93$$

where YERR = yearling reproductive rate, and
YABD = yearling antler beam diameter in mm.

Adult reproductive rates (ADRR) and fawn reproductive rates (FARR) can also be determined from the yearling antler beam diameter with the following equations from Severinghaus (1981):

$$ADRR = 0.765 + 0.056\ (YABD)$$

$$FARR = -0.700 + 0.054\ (YABD)$$

where:

ADRR = adult reproductive rate,
YABD = yearling antler beam diameter, and
FARR = fawn reproductive rate.

LITERATURE CITED

Severinghaus, C. W. 1981. The predictive relationships of dressed weights to antler beam diameters of yearling males and yearling antler beam diameters to reproductive rates of 1 year, 2 year and 3 year and older female white-tailed deer in New York State. Unpublished report, Wildlife Ecology Laboratory, Cornell University. 7 p.

REFERENCES, UNIT 3.2

ANTLER BEAM DIAMETER AS AN INDEX OF NATALITY RATES

SERIALS

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

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

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

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

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

CHAPTER 19, WORKSHEET 3.2a

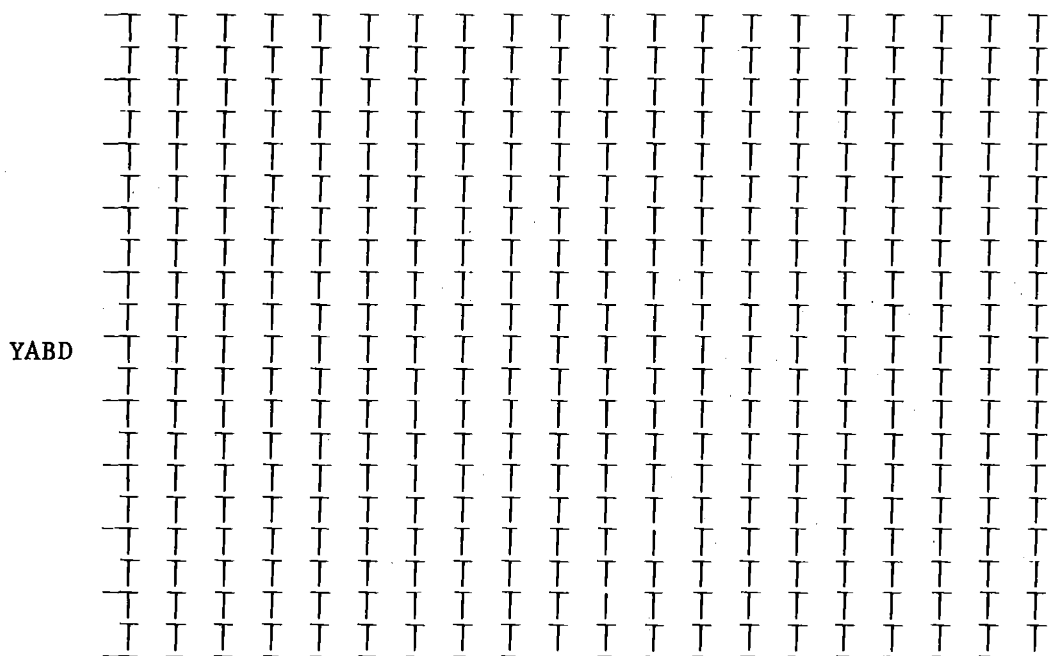
Predicting antler beam diameters from dressed weights

Yearling antler beam diameters can be predicted from dressed weight in kilograms (YDWK) using the following equation proposed by Severinghaus (1981) for New York deer:

$$YABD = 3.21 + 0.29\ YDWK; \quad R^2 = 0.97$$

where YABD = yearling antler beam diameter in mm, and
YDWK = yearling dressed weight in kg.

Using yearling dressed weights from your area or from the literature (see CHAPTER 1, UNIT 1.5), calculate antler beam diameters and plot on the grid below.



LITERATURE CITED

Severinghaus, C. W. 1981. The predictive relationships of dressed weights to antler beam diameters of yearling males and yearling antler beam diameters to reproductive rates of 1 year, 2 year and 3 year and older female white-tailed deer in New York State. Unpublished report 80-07, Wildlife Ecology Laboratory, Cornell University. 7 p.

CHAPTER 19, WORKSHEET 3.2b

Predicting antler beam diameters from live weights

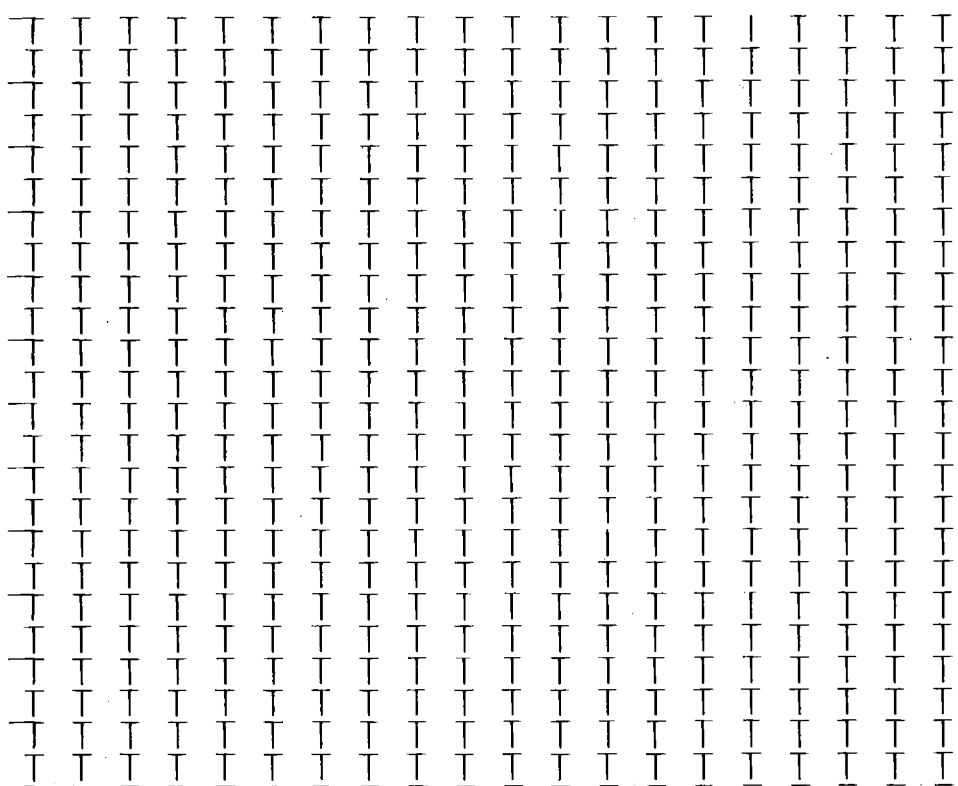
Yearling antler beam diameters can be predicted from live weight in kg (YLWK) using the equation below. This is a modified version of the equation found on the previous WORKSHEET, with live weights being calculated from dressed weights using conversion equations from CHAPTER 1, UNIT 1.5 of this book. The live weight : antler beam diameter relationship is:

$$YABD = 2.83 + 0.23\ YLWK$$

where YABD = yearling antler beam diameter in mm, and
YLWK = yearling live weight in kg.

Using live weights from your area or from the literature, calculate antler beam diameters and plot on the grid below.

YABD



YLWK

CHAPTER 19, WORKSHEET 3.2c

Predicting reproductive rates from antler beam diameters

Reproductive rates of yearling, adults, and fawns are correlated with yearling antler beam diameters, and may be predicted from them using the following equations from Severinghaus (1981):

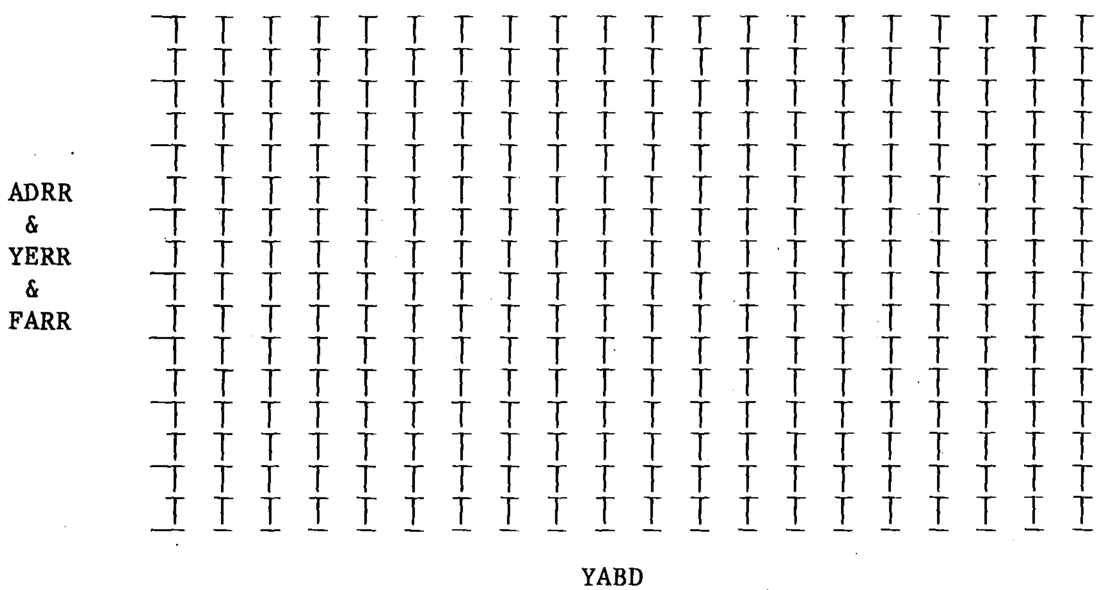
$$YERR = -1.187 + 0.140\ YABD; \quad R^2 = 0.93$$

$$ADRR = 0.765 + 0.056\ YABD; \quad R^2 = 0.69$$

$$FARR = -0.700 + 0.054\ YABD; \quad R^2 = 0.59$$

where YERR = yearling reproductive rate,
YABD = yearling antler beam diameter in mm,
ADRR = adult reproductive rate, and
FARR = fawn reproductive rate.

Using antler beam diameter from your area, from WORKSHEETS 3.2a or 3.2b, or from the literature, calculate reproductive rates for yearlings, adults, and fawns, and plot on the grid below.



LITERATURE CITED

Severinghaus, C. W. 1981. The predictive relationships of dressed weights to antler beam diameters of yearling males and yearling antler beam diameters to reproductive rates of 1 year, 2 year and 3 year and older female white-tailed deer in New York State. Unpublished report 80-07, Wildlife Ecology Laboratory, Cornell University. 7 p.

CHAPTER 19, WORKSHEET 3.2d

Conversion of yearling antler beam diameters to yearling dressed weights and reproductive rates for fawn, yearling and adult female white-tailed deer in New York State

The following equations from Severinghaus (1981) were used to set up the following table which can be used to predict yearling antler beam diameter (YABD), yearling dressed weight in pounds (YDWP), or reproductive rates of fawns (FARR), yearlings (YERR), and adults (ADRR) if one of the five variables is known:

$$YABD = 1.865 + 0.147\ YDWP; \quad R^2 = 0.90$$
$$YDWP = -12.627 + 6.791\ YABD; \quad R^2 = 1.00$$
$$FARR = -0.700 + 0.054\ YABD; \quad R^2 = 0.59$$
$$YERR = -1.187 + 0.140\ YABD; \quad R^2 = 0.93$$
$$ADRR = 0.765 + 0.056\ YABD; \quad R^2 = 0.69$$

where YABD = yearling beam diameter in mm,
YDWP = yearling dressed weight in pounds,
FARR = fawn reproductive rate,
YERR = yearling reproductive rate, and
ADRR = adult reproductive rate.

Yearling Antler Beam Diameter (mm)

	12	13	14	15	16	17	18	19	20	21	22
YDWP	69.0	75.6	82.4	89.2	96.0	102.8	109.6	116.4	123.2	130.0	136.8
FARR	0.00	0.00	0.60	0.11	0.16	0.22	0.27	0.33	0.38	0.43	0.49
YERR	0.49	0.63	0.77	0.91	1.05	1.19	1.33	1.47	1.61	1.75	1.89
ADRR	1.44	1.49	1.55	1.61	1.66	1.72	1.77	1.83	1.89	1.94	2.00

LITERATURE CITED

Severinghaus, C. W. 1981. The predictive relationships of dressed weights to antler beam diameters of yearling males and yearling antler beam diameters to reproductive rates of 1 year, 2 year and 3 year and older female white-tailed deer in New York State. Unpublished report 80-07, Wildlife Ecology Laboratory, Cornell University. 7 p.

TOPIC 4. POPULATION PREDICTIONS

Population predictions are based on the initial number of animals in the population, the reproductive potential of the animals, and on the mortality at different times during the reproductive process and in the classes within the population.

Reproductive potentials represent the ultimate number of young that can be produced. This is highest when expressed as a conception rate (CORT). In utero mortality results in fewer births than conceptions; the birth rate (BIRT) is an expression of realized natality. Mortality of neonates is often high in free-ranging populations, so the weaning rate (WERT) is an even better ecological expression of recruitment of individuals into a population. Then, the number of females that survive to reproduce is the best estimate of the reproductive potential of a population, since it is at that level of individual survival that productivity once again enters into population dynamics.

The compiling of N into sex and age classes is the first consideration when preparing to make population predictions. Knowing the reproductive rates of those present to reproduce is the beginning of the potential population predictions. Mortalities are then considered, representing depressants of productivity, resulting in realized populations that are less than the potential ones.

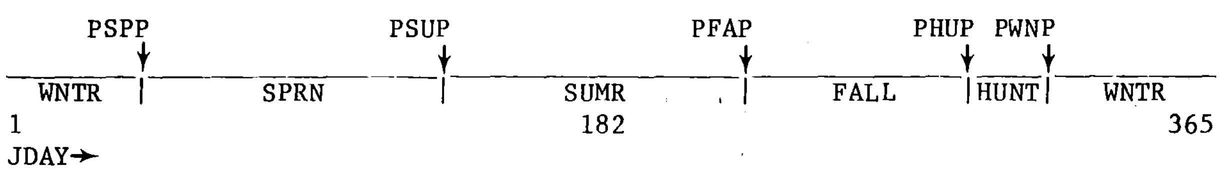
Two methods of population predictions are described in UNITS 4.1 and 4.2. Arithmetic functions are described in UNIT 4.1, using additions to and subtractions from the total population by each class. This approach requires considerable arithmetic. Exponential predictions are described in UNIT 4.2, using a short equation to make the predictions for each age or weight class, or after weighted mean natality and mortality rates have been determined for the population.

UNIT 4.1. ARITHMETIC SUMMATIONS

The basic idea behind arithmetic summations of recruitment of individuals to and removal from a population is very simple. Individuals are added to the population at birth and subtracted from the population at death. It is necessary to move survivors from one age class to the next at the completion of each annual cycle. When weight classes are used, the numbers in each weight class need to be adjusted too, of course, as survivors increase in weight. If range conditions deteriorate and weights do not increase as expected, then the distibution of numbers in weight classes will not be in proportion to age changes.

The summations must begin at some point in the annual cycle. The pre-hunt population is a good starting point as there are many estimates of fall, prehunt populations available in the literature.

The annual cycle was divided into functional rather than arbitrary periods of time at the beginning of this CHAPTER. The hunting season (HUNT) is one on those functional periods, a time of specific mortality. The winter season (WNTR) is another time of specific kinds of mortality. The time from the end of winter to parturition (SPNG) is another logical period in the annual cycle as animals move from winter range to summer range, dispersing for the reproductive season. The time period from parturition through weaning of the young (SUMR) is another logical period as the females are responsible for themselves and their young, and the survival of the young determines the number recruited into the population. The fall season (FALL), occurring after the young are weaned or at least not dependent on the dam for milk, and a time of weight recovery for the dam, is the fifth period in the annual cycle. It is at the beginning of this period that the young from the previous summer move to the 1/2 year old class, and all other age classes move up one year.



Some mortality factors are present throughout the year and need to be considered during each time period. Road kills, for example, may occur at any time, but rates vary in relation to the presence of roads and traffic, and to the movement patterns of the animals. They are usually higher during the period from the end of winter to parturition when animals are dispersing, for example.

A simplified diagram of population decrements and increments in three age classes for each sex is illustrated on the next page. The initial number in the class is subject to mortality, and the number of mortalities in the class (NBMO) is subtracted from NUAC. The number surviving in the class (NSAC) produces a number of young per female (NYPF), which combine to become the recruitment into the first (0-1) age class in the next prehunt population. Note that the number of females (NFER) is added to the 0-1 AGCL for females, and the number of males is added to the 0-1 male AGCL. The calculations for males involve only mortality, of course.

CLASS	ACYI	
ACa-.	0-1	NUAC - NBMO = NSAC
ACb-.	1-2	NUAC - NBMO = NSAC
ACc-.	2-3+	NUAC - NBMO = NSAC

	ACYI			
ACaa.	0-1	NUAC - NBMO = NSAC → NYPF		NFER
ACbb.	1-2	NUAC - NBMO = NSAC → NYPF	→ MFSR	
ACcc.	2-3+	NUAC - NBMO = NSAC → NYPF		NMAR

The definitions are:

ACYI = age class by year intervals,
NUAC = number in the age class,
NBMO = number of mortalities,
NSAC = number surviving in each age class,
NYPF = number of young per female,
MFSR = male to female sex ratio,
NFER = number of females recruited into the population, and
NMAR = number of males recruited into the population.

Note how the arrows show a beginning N followed by mortality which leads to the number of survivors. These survivors reproduce, and the young are recruited into the population. When the young of the year are recruited into the pre-hunt population, all older members move up one year to reflect the annual cycle from one pre-hunt population to the next.

The oldest age class accumulates all the survivors over 2 years old in the above example. Wild ruminant populations may be divided into several age classes, and smaller numbers are usually observed in the older age classes up to the last one, especially in populations that are exposed to hunting.

The flow of information illustrated should be clearly understood before going on to further divisions of the population into more age classes or of the annual cycle into smaller time periods. When further divisions are made, the format remains the same but the number of repetitious steps necessary for the completion of an annual cycle increases.

AGE-RELATED SUMMATIONS

Arithmetic summations for age-related population data provide a fairly simple approach to population predictions, and are based on the division of the population into age classes. The format for completing a sequence of summations is shown below.

CLASS	ACYI	NUAC	NBMO	NSAC
ACa-.	0-1	50	- 10	= 40
ACb-.	1-2	38	- 3	= 35
ACc-.	2-3+	12	- 1	= 11

CLASS	ACYI	NUAC	NBMO	NSAC	NYPF	NYPC	MFSR	NMAR	NFER
ACaa.	0-1	44	- 12	= 32	x 0.06	= 1.92	1.1:1.0	1.00	0.92
ACbb.	1-2	34	- 3	= 31	x 0.70	= 21.7	1.1:1.0	11.3	10.4
ACcc.	2-3+	22	- 1	= 21	x 1.30	= 27.3	1.1:1.0	14.2	13.1

The numbers illustrate the sequence and results of the calculations. To repeat another cycle, move the NSAC from the first year to the next age class as indicated by the dashed lines, as the number surviving in each age class (NSAC) becomes the number in the next higher age class; one year's outputs become the next year's inputs.

The use of such a format makes it possible to keep track of changes in the causes of mortality. The total number of mortalities (NBMO) in each class is determined by adding together the mortalities from different causes such as hunting, poaching, winter effects, predation, road kills, etc. over the period being considered. Suppose 100 animals were subject to the following mortalities:

```
NUAC = 100
                    - 16 (hunting)
                    -  2 (crippling loss)
                    -  4 (poaching)
                    -  3 (predation)
                    -  6 (winter losses)
                    -  8 (road kills)
                    -  1 (other causes)
                    ----
                      40 = NBMO
NSAC =  60
```

Some of the mortality factors above are compensatory. If hunting mortality is low, winter mortality may be high. If hunting mortality is high, winter mortality may be low. The amount of compensation depends on hunting regulations and on other factors, such as weather and range conditions. The possibilities of compensations should not be overstated as an argument of ecological certainty.

Reproductive rates--NYPF in this example--are derived from observed values, from age or weight data, or from indices to these rates (See TOPIC 1,2, and 3). The use of arithmetic summations forces one to estimate biological factors such as reproductive rates, and that is good mental excercise.

The number of mortalities may be expressed as a rate or ratio in relation to the initial number in the age class. In the example above, the 40 mortalities are expressed as 40/100 = 0.40 = MORT. If mortality rates rather than numbers are used, then the format on the next page is used. The use of reproductive rates and mortality rates rather than the number of mortalities is much more customary since absolute numbers of both the population and mortalities are seldom known. Rates allow one to keep all of the evaluations together on a relative basis.

CLASS	ACYI	MORT	x NUAC	= NBMO	NSAC
ACa-.	0-1	0.20			
			x 50	= 10	
				− 10	= 40
ACb-.	1-2	0.08			
			x 38	= 3.0	
				− 3.0	= 35
ACc-.	2-3+	0.08			
			x 12	= 1.0	
				− 1.0	= 11

CLASS	ACYI	MORT	x NUAC	= NBMO	NSAC	x NYPF	= NYPC	MFSR	NMAR	NFER
ACaa.	0-1	0.27								
			x 44	= 11.9						
				− 11.9	= 32.1	x 0.06	= 1.93	1.1:1.0	1.00	0.93
ACbb.	1-2	0.09								
			x 34	= 3.1						
				− 3.1	= 30.9	x 0.70	= 21.6	1.1:1.0	11.2	10.4
ACcc.	2-3+	0.05								
			x 22	= 1.1						
				− 1.1	= 20.9	x 1.3	= 27.2	1.1:1.0	14.1	13.1

The definitions are:

ACYI = age class by year intervals,
MORT = mortality rate,
NUAC = number in the age class,
NBMO = number of mortalities,
NSAC = number surviving in each age class,
NYPF = number of young per female,
MFSR = male to female sex ratio,
NMAR = number of males recruited into the population, and
NFER = number of females recruited into the population.

If survival rates have been determined, the format on the next page is used.

CLASS	ACYI	SURT	x NUAC	= NSAC
ACa-.	0-1	0.80	x 50	= 40.0
ACb-.	1-2	0.92	x 38	= 35.0
ACc-.	2-3+	0.92	x 12	= 11.0

CLASS	ACYI	SURT	x NUAC	= NSAC	x NYPF	= NYPC	MFSR	NMAR	NFER
ACaa.	0-1	0.73	x 44	= 32.1	x 0.06	= 1.93	1.1:1.0	1.00	0.93
ACbb.	1-2	0.91	x 34	= 30.9	x 0.70	= 21.6	1.1:1.0	11.2	10.4
ACcc.	2-3+	0.95	x 22	= 20.9	x 1.30	= 27.2	1.1:1.0	14.1	13.1

The definitions are:

- ACYI = age class by year intervals,
- SURT = suvival rate,
- NUAC = number in the age class,
- NSAC = number surviving in each age class,
- NYPF = number of young per female,
- MFSR = male to female sex ratio,
- NMAR = number of males recruited into the population, and
- NFER = number of females recruited into the population.

WEIGHT-RELATED ARITHMETIC SUMMATIONS

Weight-related summations are completed in the same way as the age-related ones, except that the population is divided into weight classes rather than age classes. There are few data on the relationships between natality, mortality and weight, but derivation of such rates may prove to be biologically useful. The format below shows the sequence of calculations, and WORKSHEETS that follow provide space for completed analyses based on weight. Knowing the use of weight-related inputs may alert field biologists to the need for more attention to weight and its relationship to natality and mortality.

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
JFUSA	50--3	206	207	biga	yield tables for biga hrds	kelker,gh	1952

The formats illustrated are duplicated as WORKSHEETS at the end of this UNIT. The use of such WORKSHEETS is more for illustration of an accounting procedure than for large scale predictions of populations, since such WORKSHEETS require the tabulation of data as inputs, followed by outputs that are again tabulated as inputs for the next cycle. The use of such organized WORKSHEETS helps one to become acquainted with the recruitment of animals from one age class to the next. When several large and real populations are being evaluated, electronic computing equipment should be programmed to do all of the summations, of course, functioning as electronic "worksheets."

REFERENCES, UNIT 4.1

ARITHMETIC SUMMATIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	11--2	177	183	od--	computing rate of increase	kelker,g	1947
NAWTA	34---	372	387	od--	ceel, optimum yield, popul	gross,je	1969
OETAT	130--	1	72	od--	computer simul deer, calif	anderson,fm; con/	1974

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

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

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

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

CHAPTER 19, WORKSHEET 4.1a

Arithmetic predictions based on number of mortalities

The sets of blanks below and on the next page may be used to determine arithemetic predictions based on number of mortalities for a population with nine age classes.

SPECIES: ______________ TIME PERIOD: ______________

LOCATION: ______________ REFERENCE: ______________

CLASS	ACYI	NUAC		NBMO		NSAC
ACa-.	0-1	____	-	____	=	____
ACb-.	1-2	____	-	____	=	____
ACc-.	2-3	____	-	____	=	____
ACd-.	3-4	____	-	____	=	____
ACe-.	4-5	____	-	____	=	____
ACf-.	5-6	____	-	____	=	____
ACg-.	6-7	____	-	____	=	____
ACh-.	7-8	____	-	____	=	____
ACi-.	8-9+	____	-	____	=	____

CLASS	ACYI	NUAC	NBMO	NSAC	NYPF	NYPC	MFSR	NMAR	NFER
ACaa.	0-1								
ACbb.	1-2								
ACcc.	2-3+								
ACdd.	3-4								
ACee.	4-5								
ACff.	5-6								
ACgg.	6-7								
AChh.	7-8								
ACii.	8-9+								

CHAPTER 19, WORKSHEET 4.1b

Arithmetic predictions based on mortality rate

The sets of blanks below and on the next page may be used to determine arithemetic predictions based on mortality rate for a population with nine age classes.

SPECIES: ____________________ TIME PERIOD: ____________________

LOCATION: ____________________ REFERENCE: ____________________

CLASS	ACYI	MTRT	x NUAC	= NBMO		NSAC
ACa-.	0-1	____	x ____	= ____	- ____	= ____
ACb-.	1-2	____	x ____	= ____	- ____	= ____
ACc-.	2-3	____	x ____	= ____	- ____	= ____
ACd-.	3-4	____	x ____	= ____	- ____	= ____
ACe-.	4-5	____	x ____	= ____	- ____	= ____
ACf-.	5-6	____	x ____	= ____	- ____	= ____
ACg-.	6-7	____	x ____	= ____	- ____	= ____
ACh-.	7-8	____	x ____	= ____	- ____	= ____
ACi-.	8-9+	____	x ____	= ____	- ____	= ____

CLASS	ACYI	MTRT	x	NUAC	=	NBMO		NSAC	x	NYPF	=	NYPC	MFSR	NMAR	NFER
ACaa.	0-1		-		=		=		x		=				
ACbb.	1-2		-		=		=		x		=				
ACcc.	2-3		-		=		=		x		=				
ACdd.	3-4		-		=		=		x		=				
ACee.	4-5		-		=		=		x		=				
ACff.	5-6		-		=		=		x		=				
ACgg.	6-7		-		=		=		x		=				
AChh.	7-8		-		=		=		x		=				
ACii.	8-9+		-		=		=		x		=				

CHAPTER 19, WORKSHEET 4.1c

Arithmetic predictions based on survival rate

The sets of blanks below and on the next page may be used to determine arithemetic predictions based on survival rate for a population with nine age classes.

SPECIES: ____________ TIME PERIOD: ____________

LOCATION: ____________ REFERENCE: ____________

CLASS	ACYI	SURT	x	NUAC	=	NSAC
ACa-.	0-1	___	x	___	=	___
ACb-.	1-2	___	x	___	=	___
ACc-.	2-3	___	x	___	=	___
ACd-.	3-4	___	x	___	=	___
ACe-.	4-5	___	x	___	=	___
ACf-.	5-6	___	x	___	=	___
ACg-.	6-7	___	x	___	=	___
ACh-.	7-8	___	x	___	=	___
ACi-.	8-9+	___	x	___	=	___

CLASS	ACYI	SURT	x	NUAC	=	NSAC	x	NYPF	=	NYPC	MFSR	NMAR	NFER
ACaa.	0-1		-		=		x		=				
ACbb.	1-2		-		=		x		=				
ACcc.	2-3		-		=		x		=				
ACdd.	3-4		-		=		x		=				
ACee.	4-5		-		=		x		=				
ACff.	5-6		-		=		x		=				
ACgg.	6-7		-		=		x		=				
AChh.	7-8		-		=		x		=				
ACii.	8-9+		-		=		x		=				

UNIT 4.2: EXPONENTIAL PREDICTIONS

It is generally known that population growth has an "exponential" form. This generality is often visualized as having some kind of an increasing effect through several reproductive cycles. An interesting feature of this generality is that, when natality and mortality rates remain constant, population changes are perfectly exponential; the fit is perfect (R^2 = 1.00).

The formula for an exponential relationship between a dependent variable Y and an independent variable X is:

$$Y = a\ e^{bX}$$

In the population context, X = the time period ahead one wants to predict the number, Y, present. The intercept, a, is the initial number present and the slope of the line, b, (+ or −), expresses population changes. The use of this formula is best illustrated with an example.

Suppose a population consists of one male and one female, and the female has one young. If there is no mortality, the population is three after one reproductive cycle. Substituting these numbers into the formula:

$$Y = 2\ e^{(0.40547)\ (1)} = 3$$

where the value of b, 0.40547, is in the table discussed below.

Predictions may be made for as many years as the reproductive and mortality rates apply, i.e. have not changed. If X = 5 in the sample above, then Y = 15.19. There are variations in these rates due to fluctuations in environmental conditions, the effects of different population levels, changes in range conditions, etc. so one must use caution when predicting several years ahead.

Particular combinations of natality and mortality rates in populations with a 1:1 sex ratio result in specific b values. Thus a table of b values for instant reference and quick prediction of future populations may be derived. Such a table, much abbreviated, looks like this:

ABBREVIATED TABLE OF b VALUES TO BE USED WHEN THE SEX RATIO IS 1:1

Mortality rates	Reproductive rates 0.0	0.5	1.0	1.5	2.0
0.0	0	+0.22374	+0.40547	+0.55962	+0.69315
0.4	−0.51083	−0.28769	−0.10536	+0.04879	+0.18232
0.8	−1.60944	−1.38630	−1.20397	−1.04982	−0.91629

The use of this table is simple. Determine the reproductive rate and locate that column. Determine the mortality rate and locate that row. Move down the reproductive rate column until the mortality rate row is intercepted. Read the b value, and substitute it in the formula. Then ask how many years ahead you wish to predict N (YAPN) and the number of animals present in the initial population (NAIP = a), and substitute them in the formula. The answer, Y, or predicted N (PRDN) may be quickly obtained on any calculator with an exponential function key.

The formula, rewritten to include the four-letter symbols given above, is:

$$\text{PRDN} = \text{NAIP}\ e^{(b)(\text{YAPN})}$$

The following illustration verifies the use of the formula. Suppose 10 animals--5 males and 5 females--are being considered, and that the females have one young each. The males (5) plus the females (5) plus their young (5) results in 15 animals if there is no mortality. NAIP is 10, b = 0.40547, and YAPN is 1.0. The equation and the solution are:

$$\text{PRDN} = (10)\ e^{(0.40547)(1)} = 15$$

The following illustration uses more animals and predicts for more years. Suppose the reproductive rate is 1.0 and the mortality rate is 0.40. The b value on the table is -0.10536. Suppose the prediction is for three years ahead (YAPN = 3), and the number of animals in the initial population (NAIP) is 100. The equation and the solution are:

$$\text{PRDN} = 100\ e^{(-0.10536)(3)} = 73$$

It must be emphasized that the abbreviated table of b values on Page 51 is derived for a 1:1 sex ratio. If the sex ratio is 1:1, if the stated number of animals in the initial population (NAIP = 100) is correct, and if the reproductive and mortality rates are correct for the 3-year period, the tabulated b value applies and the predicted number, 73, must be correct. If the reproductive and mortality rates change, a new b value must be used. The factors affecting the correctness of population predictions are biological rather than mathematical.

Sex ratios, reproductive rates, mortality rates, and the initial number in a population, all biological characteristics of a population, are difficult and expensive to determine, yet they are absolutely essential components in this relationship. Suppose that a reasonable estimate of the population or even an index to the population size, is known rather than a definite value for a, or NAIP. PRDN in relation to NAIP will be proportional, no matter what value of NAIP was used. To illustrate, suppose NAIP is 44 rather than 100 in the previous example. The new PRDN is:

$$\text{PRDN} = (44)\ e^{(-0.10536)(3)} = 32$$

The ratios 73/100 and 32/44 both equal 0.73. The predicted population is 73% of the original in each case after 3 years with these natality and mortality rates.

The table of b values has a feature that may be used to determine the desired b value for any combination of natality and mortality rates. The algebraic sum of the reproductive rate b (bRPR) at zero mortality and the mortality rate b (bMTR) at zero reproductive rate is the b for the two combined. Thus:

$$PRDN = NAIP\ e^{(bMTR\ +\ bRPR)(YAPN)}$$

This may be illustrated by adding the bRPR for a reproductive rate of 1.0 (+0.40547) and the bMTR for a mortality rate of 0.40 (-0.51083), resulting in a b value for the population (bPOP) of [0.40547 + (-0.51083) = -0.10536].

The algebraic addition of bMTR + bRPR suggests that the population b (bPOP) is easily determined from the two parameters. The bMTR and bRPR values on the lists below may be used for direct inputs when the sex ratio is 1:1.

TABLE OF b VALUES FOR ALGEBRAIC ADDITION OF MORTALITY AND REPRODUCTIVE RATES

MTRT	bMTR	RPRT	bRPR
0.00	0.00000	0.00	0.00000
0.04	-0.04082	0.10	0.04879
0.08	-0.08338	0.20	0.09531
0.12	-0.12783	0.30	0.13976
0.16	-0.17435	0.40	0.18232
0.20	-0.22314	0.50	0.22374
0.24	-0.27444	0.60	0.26236
0.28	-0.32850	0.70	0.30010
0.32	-0.38566	0.80	0.33647
0.36	-0.44629	0.90	0.37156
0.40	-0.51083	1.00	0.40547
0.44	-0.57982	1.10	0.43825
0.48	-0.65393	1.20	0.47000
0.52	-0.73397	1.30	0.50078
0.56	-0.82098	1.40	0.53063
0.60	-0.91629	1.50	0.55962
0.64	-1.02165	1.60	0.58779
0.68	-1.13943	1.70	0.61519
0.72	-1.27297	1.80	0.64185
0.76	-1.42712	1.90	0.66782
0.80	-1.60944	2.00	0.69315
0.84	-1.83258	2.10	0.71784
0.88	-2.12026	2.20	0.74194
0.92	-2.52573	2.30	0.76547
0.96	-3.21888	2.40	0.78846
1.00	infinite	2.50	0.81093

The use of the table of bMTR and bRPR values for determining bPOP will require interpolation when mortality and reproductive rates do not coincide exactly with those listed. A linear interpretation is illustrated by the following examples.

Suppose the mortality rate is 0.33. When MTRT = 0.32, bMTR = -0.38566, and when MTRT = 0.36, bMTR = -.44629. The difference between these two values is 0.06063 for the 0.04 change in MTRT. The actual mortality rate of 0.33 is one-fourth of the distance from 0.32 to 0.36. Thus 0.06063/4 = 0.01516, so the interpolated bMRT for 0.33 = (-0.38566) + (-0.01516) = -0.40082. Be sure to use the negative sign properly.

Suppose the reproductive rate is 1.47. When RPRT = 1.40, bRPR = 0.53063, and when RPRT = 1.50, bRPR = 0.55962. The difference in b values is 0.02899. Dividing by 10, multiplying by 7, and adding to the bRPR for RPRT = 1.40, the interpolated bRPR = [(0.02899)/(10)] x 7 = 0.02029; 0.53063 + 0.02029 = 0.55092. Thus:

$$\text{bPOP} = (-0.40082) + (0.55092) = 0.15010$$

An example using the above interpolations follows. If a population consists of 10 males and 10 females, then the number expected after one annual cycle with the mortality and reproductive rates given is:

$$\begin{array}{rl} 10 - 3.30 = \;\; 6.70 & \text{males} \\ 10 - 3.30 = \;\; 6.70 & \text{females; } 6.70 \times 1.47 = 9.85 \text{ young} \\ + \underline{\;9.85\;} & \text{young} \\ 23.25 & \text{total} \end{array}$$

Using the exponential equation:

$$\text{PRDN} = 20\ e^{(0.15010)\ (1)} = 23.24 \text{ total.}$$

Remember, PRDN may be calculated for as many years ahead as the mortality and natality rates apply.

If reasonable estimates of the population are available before and after a specified number of years and either the reproductive or mortality rate (but not both) is known, then the equation may be rearranged to determine the unknown rate. Suppose the reproductive rate for a population is known and the mortality rate is unknown. The rearranged formula is:

$$[(\ln\ (\text{PRDN/NAIP})]/\text{YAPN} = \text{bPOP}$$

Since bPOP = bMTR + bRPR, the equation to solve for bMTR is:

$$\text{bMTR} = \text{bRPR} - \text{bPOP}$$

Solving for unknowns can be further extended to evaluate the contributions of different causes of mortality to the overall mortality rate by subtracting known contributions from the total mortality. Suppose that total mortality was estimated to be 0.4 and known mortality due to hunting was known to be 0.15. Then mortality due to other causes has to be 0.40 less 0.15, which is 0.25. Careful use of some definite mathematical relationships can increase our understanding of some difficult-to-obtain biological relationships.

The disadvantage of this table is its dependence on a 1:1 sex ratio. This problem is complicated by the fact that sex ratios of the adult population are often different from the sex ratio at birth. The exponential prediction does make it easy to predict potential populations within the limitations described, however, and that may be useful when reasonable approximations over long time spans are needed.

REFERENCES, UNIT 4.2

EXPONENTIAL PREDICTIONS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	34---	372	387	od--	ceel, optim yield, populat	gross,je	1969
OETAT	130--	1	72	od--	computer simul deer, calif	anderson,fm; con/	1974

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BPURD	3----	27	30	alal	rata, ecological modeling	harbo,s; haber,g/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECMOD	1---1	303	315	rata	comp simul, bg car dynamic	walters,cj; hilb/	1975

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
BISNA	19--6	524	528		pop model, test pop, tools	silliman,rp	1969
ECOLA	56--4	855	867	many	rates, prey and predat pop	tanner,jt	1975

CHAPTER 19, WORKSHEET 4.2a

Exponential population predictions

The basic procedures for predicting exponential changes in populations having 1:1 sex ratios have been described in UNIT 4.2. The formula on Page 53 is convenient to use along with the TABLE OF b VALUES FOR ALGEBRAIC ADDITION OF MORTALITY AND REPRODUCTIVE RATES, also on Page 53. As a review, write the formula in the space below.

Write the symbol definitions below:

PRDN =

NAIP =

bMTR =

bRPR =

bPOP =

YAPN =

Demonstrate the use of the formula by selecting 100 as NAIP, 0.36 as MTRT, 1.40 as RPRT, and 1 as YAPN. From the b table, bMTR = ________, and bRPR = ________. The equation is:

PRDN = = ________

Repeat the calculation using the calculated PRDN as the new NAIP. The equation is:

PRDN = = ________

Repeat the calculation using the second calculated PRDN as the second new NAIP. The equation is:

PRDN = = ________

Now do a 3-year prediction in one calculation. Begin with the original NAIP (100), and substitute 3 for YAPN. The equation is:

PRDN = = ________

The exercise above provides practice in making the calculation, and it verifies the similarity of the answers when three one-year cycles and one three-year cycle are used.

Now you are ready to set up your own problems. Complete data tabulations and calculation of PRDN in the space below.

NAIP = ________

MTRT = ________

bMTR = ________

RPRT = ________ PRDN = = ________

bRPR = ________

bPOP = ________

YAPN = ________

* * * * * *

NAIP = ________

MTRT = ________

bMTR = ________

RPRT = ________ PRDN = = ________

bRPR = ________

bPOP = ________

YAPN = ________

* * * * * *

NAIP = ________

MTRT = ________

bMTR = ________

RPRT = ________ PRDN = = ________

bRPR = ________

bPOP = ________

YAPN = ________

TOPIC 5. EVALUATIONS OF FACTORS AFFECTING NET POPULATION GROWTH

A large number of factors have the potential for affecting net population productivity, or the growth potential of a population over time. The effects of any one of these factors do not usually occur singly; poor nutrition may result not only in death from starvation but also increased susceptibility to hunting, winter mortality, predation, and other factors. These associative effects are difficult to assess and represent mathematically.

The several UNITS in this TOPIC provide opportunities to develop WORKSHEETS with evaluations for local conditions. Try to build feed-back relationships into the evaluations, linking winter mortality to nutritional stress as well as weather and snow accumulation effects, for example. The formats for POPULATION PREDICTIONS in TOPIC 4 will be used repeatedly; calculations in these UNITS are repetitious of basic calculations, with rates modified by the factors being evaluated.

UNIT 5.1: NUTRITION

Nutrition is a fundamental relationship between animal and range. The nutrient base determines growth rates, reproductive rates, birth weights of the young, antler sizes and weights, fat reserves, endurance, and other characteristics that are dependent on energy transactions.

One of the most important factors affecing the nutrition of wild animals is that of overpopulation, resulting in deteriorating range productivity, reduced body weights, reduced reproductive rates and higher winter mortality.

A series of analyses may be made for white-tailed deer that start with 0.0 fawn reproduction and proportional yearling and adult rates, using the equations given in UNIT 3.2. Put in terms of FARR, the equations are:

$$\text{YERR} = 1.06\ (\text{FARR}) + 1.28$$

$$\text{ADRR} = 0.38\ (\text{FARR}) + 1.78$$

Then, increase fawn reproduction to 0.2 and the yearling and adult rates proportionately. The rates are tabulated below. Repetitions of this calculation for FARR = 0.0, 0.2, and 0.4 cover the range of effects of poor nutrition, when no fawns breed, to very good nutrition, when 40% of them breed. WORKSHEETS provide opportunities for these and other evaluations.

FARR	YERR	ADRR
0.0	0.63	1.49
0.2	1.15	1.70
0.4	1.67	1.91

REFERENCES, UNIT 5.1

NUTRITION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	31--3	697	743	odvi	range vegetation, texas	buechner,hk	1944
JOMAA	32--3	267	280	odvi	notes on fecundity, maine	palmer,rs	1951
JWMAA	11--4	317	323	odvi	die-offs, edwrds plat, tex	taylor,wp; hahn,h	1947
JWMAA	12--1	78	86	odvi	product, yield, george res	o'roke,ec; hamers	1948
JWMAA	15--1	73	80	odvi	product, mortali, coralled	severinghaus,cw	1951
JWMAA	21--2	245	247	odvi	marsh deer die-off, louisi	glasgow,ll; ensmi	1957
JWMAA	29--1	74	79	odvi	reprod study on penned wtd	verme,lj	1965
JWMAA	29--4	706	716	odvi	a die-off in w-t deer, tex	marburger,rg; tho	1965
JWMAA	32--1	130	141	odvi	rang use, food, cons, prod	allen,eo	1968
JWMAA	33--4	881	887	odvi	reproduction, plane nutrit	verme,lj	1969
NAWTA	15---	170	190	odvi	variatn fertil, rnge conds	cheatum,el; sever	1950
NFGJA	11--1	13	27	odvi	product, growth, adirondac	severinghaus,cw;/	1964
PCGFA	8----	83	85	odvi	deer vs livest, gulf coast	goodrum,pd; reid,	1954
PCGFA	13---	62	69	odvi	mast abund, weight, reprod	harlow,rf; tyson,	1959
WVAFA	6---1	2	4	odvi	forg prod deter deer numb?	towry,r	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	38--2	211	224	odhe	food hab, prod, cond, cali	lassen,rw; ferre/	1952
CAFGA	39	177	186	odhe	reprod, 3 chapar cov types	taber,rd	1953
CAFGA	40--3	215	234	odhe	de fora relat lassen-washo	dasmann,w; blaisd	1954
CAFGA	44--3	253	259	odhe	producti, calif deer herds	bischoff,ai	1958
JWMAA	19--1	115	136	odhe	fertility, utah mule deer	robinette,wl; ga/	1955
JWMAA	19--4	503	503	odhe	rocky mountain, high repro	jensen,w; robine/	1955
JWMAA	41--4	785	789	odhe	resp to fire, clea-cu, wyo	davis,pr	1977
NAWTA	9----	156	161	odhe	productivity, central utah	robinette,wl; ols	1944
NAWTA	15---	589	596	odhe	productiv, mule d, colorad	tolman,cd	1950
NAWTA	21---	159	172	odhe	nutr, pop dyn, n coast cal	taber,rd	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	17--2	177	184	ceel	reproduction, yellowstone	kittams,wh	1953
NAWTA	20---	560	567	ceel	increas natal, lowered pop	buechner,hk; swan	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	22--3	261	268	alal	reproductn in a population	edwards,ry; ritce	1958
JWMAA	23--4	381	401	alal	reprod & produc, newfoundl	pimlott,dh	1959

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	36--3	328	329	anam	calif reproduct potentials	chattin,je; lasse	1950
JWMAA	34--3	570	582	anam	forag use, prod, water con	beale,dm; smith,a	1970

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
AMNTA	100--	687	690		nat selec, costs of reprod	williams,gc	1966

CHAPTER 19, WORKSHEET 5.1a

Population changes in a population of 100 deer on poor to good ranges

Differences in net population growth may be evaluated by completing the following tabulations, determining the b values for mortality and natality, and completing the exponential calculations.

Complete the tabulations below and plot the results on the grid on the next page. Note that yearling and adult reproductive rates are proportional to fawn reproductive rates (See the equations on page 57).

A constant mortality rate of 0.20 used, demonstrating the effects of variations in reproductive rates due to range conditions.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	____	x	____	=	____
ACb-. & ACbb.	1-2	36	____	x	____	=	____
ACc-. & ACcc.	2-3+	17	____	x	____	=	____
	SUMS =	[100]= TNAP			[1.00]		[____] = WMTP

* * * * *

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	47	0.00	x	____	=	____
ACb-. & ACbb.	1-2	36	0.63	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.49	x	____	=	____
	SUMS =	[100]= TNAP			[1.00]		[____] = WRTP

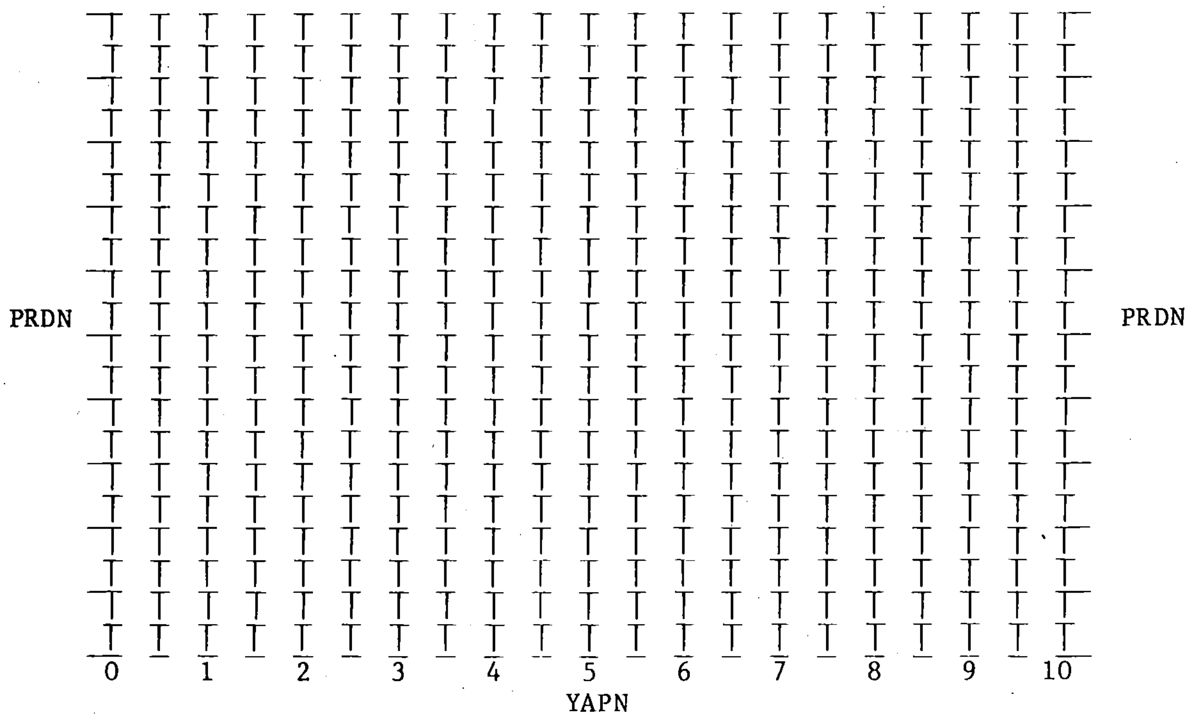
* * * * *

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	47	0.20	x	____	=	____
ACb-. & ACbb.	1-2	36	1.15	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.70	x	____	=	____
	SUMS =	[100]= TNAP			[1.00]		[____] = WRTP

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	47	0.40	x	____	=	____
ACb-. & ACbb.	1-2	36	1.67	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.91	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRTP

* * * * *



UNIT 5.2: HUNTING

Regulated hunting offers many opportunities for regulating net population productivity. Changes in population trends may be directed by selective hunting by sex (or for most species, antlered and anterless animals), and by regulating the total number that can be removed. Generally speaking, most agencies responsible for maintaining stable ruminant populations use both of these two options in their management programs.

Management options are discussed in CHAPTERS 21 and 22. Carrying capacities are discussed in CHAPTER 20. Here in this UNIT 5.2, the effects of hunting, or mortality during a selected time period, may be evaluated.

It is suggested that female reproductive rates be maintained at constant levels while the effects of sex selection options and different rates of removal of antlerless deer are evaluated in the WORKSHEETs that follow. The sequence might be for recruitment rates of 0.20, 0.63, and 1.49 for fawns, yearlings, and adults respectively, be used, with 0, 0.20 . . . 0.80 mortality rates (at 0.20 increments) for males (antlered) only. Then, add female (antlerless) mortality rates due to hunting of 1/4, 1/2, 3/4, and 1/1 of the male (antlered) rates. Such combinations will result in an array of values that will provide a useful visual display when plotted.

Other WORKSHEETS may be derived for species and conditions of your choice. The tabulation of the data is time-consuming. Once weighted mean population rates are determined, the exponential calculation is easily and quickly made.

REFERENCES, UNIT 5.2

HUNTING

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	15--1	27	32	cerv	deer kill, diff systm hunt	westerskov,k	1951

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	2---9	466	476	od--	deer & deer hunting in tex	wright,c	1868
JWMAA	29--2	366	370	od--	primev hunt press, indians	elder,wh	1965

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNSVA	18--4	10	11	odvi	demnd, suppl, party permts	parker,sr	1964
HMECA	4---4	331	349	odvi	garden huntng, amer tropcs	linares,of	1976
JWMAA	5---3	333	336	odvi	trends, kill, bucks, wisco	schunke,wh; bussi	1941
JWMAA	11--4	317	323	odvi	die-offs, edward plat, tex	taylor,wp; hahn,h	1947
JWMAA	16--2	121	131	odvi	hunt stati, ran cond, minn	gunvalson,ve; er/	1952
JWMAA	19--3	346	352	odvi	results of controlld hunts	krefting,lw; eri/	1955
JWMAA	20--3	297	302	odvi	results special hunt, minn	krefting,lw; eric	1956
JWMAA	24--3	342	344	odvi	hunt seas waste, fox trail	schofield,rd	1960
JWMAA	29--1	59	73	odvi	contrlld hunt in enclosure	van etten,rc; sw/	1965
JWMAA	33--4	791	795	odvi	controlld hunt, wildl refg	roseberry,jl; au/	1969
JWMAA	40--3	500	506	odvi	spat dist hntrs; inf forst	thomas,tw; gill,/	1976
MRYCA	32--4	17	17	odvi	harvest increase, maryland	anonymous	1955
NAWTA	4----	449	553	odvi	harvst in natl forst, stud	sanders,rd	1939
NAWTA	13---	459	464	odvi	bow'n'arrw huntng, conserv	haugen,ao	1948
NAWTA	13---	492	508	odvi	harvest of deer, wisconsin	cramer,ht	1948
NAWTA	29---	454	463	odvi	reln hunter access to kill	james,ga; johnso/	1964
NFGJA	10--2	186	193	odvi	eff archry in contrl abund	severinghaus,cw	1963
NOSCA	47--4	250	255	odvi	hunting success, idaho dee	will,gc	1973
NYCOA	10--1	19	23	odvi	deer hunting - then & now	darrow,rw	1955
PCGFA	19---	141	146	odvi	eff opening date, harvest,	murphy,da	1965
PCGFA	27---	114	119	odvi	mgt implic heav hunt press	cook,rl	1974
TNWSD	9----	1	12	odvi	anal kill-curv, female dee	gill,j	1953
TNWSD	33---	19	33	odvi	odhe, unretrvd deer, liter	losch,ta; samuel,	1976
VIWIA	8....	10	13	odvi	knowldg gaind, managd hunt	engle,jw; hanlon,	1952
WLSBA	7---1	10	16	odvi	hunter-inflicted wounding	stormer,fa; kirk/	1979
WSCBA	11--8	6	15	odvi	the 1945 deer kill, wiscon	bersing,os	1946
WSCBA	12--1	5	11	odvi	huntng records 1930-46, wi	buss,io; buss,he	1947
WSCBA	12--9	4	12	odvi	the 1946 deer huntn season	bersing,os	1947
WSCBA	13--4	7	16	odvi	bow & arrow hunting, wisco	bersing,os	1948
WSCBA	13/10	11	12	odvi	1947 deer season, wisconsi	bersing,os	1948
WSCBA	21-12	3	9	odvi	new deal for deer & hunter	keener,jm	1956
WSCBA	23-10	13	17	odvi	less waste in the woods	deboer,sg	1958

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	20--1	79	80	odhe	deer tag returns, in 1933	walner,ol	1934
CAFGA	29--4	180	190	odhe	deer refuge under buck law	cronemiller,fp	1943
CAFGA	38--2	235	238	odhe	reslts special hunt, refug	bryan,hf; long,wi	1952
DRCWD	2....	1	179	odhe	anam, accss priv land, hun	rounds,rc	1975
JOMAA	35--3	457	458	odhe	additional recrds for minn	erickson,ab; bue,	1954
NAWTA	13---	451	457	odhe	crippling losses, utah	costley,rj	1948
XFWLA	295--	1	8	odhe	mortality, gunshot wounds	robinette,wl	1947

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BIOMA	29--4	801	809	ceel	optim age specif harv, pop	beddington,jr; t	1973
JWMAA	24--1	15	21	ceel	on afognak island, alaska	troyer,aw	1960

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AVSPA	57---	1	18	rata	topograph anatomy, hunting	engebretsen,rh	1975

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-----------------	AUTHORW----------	YEAR
				oram			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	12--3	236	240	wldl	meth contr publ hunt, n am	scott,we	1948
JWMAA	40--3	517	522	many	iden hemoglob, law enforce	bunch,td; meadow/	1976
NAWTA	14---	410	423		huntng stats, 1936 vs 1946	ludy,d	1949
NAWTA	22---	544	569	biga	eff hunt, cont pop in n am	longhurst,wm	1957
NPKMA	35---	4	6	wldl	wildl pop control & hunter	cowles,rb	1961
TWASA	53A--	57	65	wldl	aspcts of wldl & hunt, wis	mccabe,ra	1964

CHAPTER 19, WORKSHEET 5.2a

Net population changes in a population of 100 deer
with a mortality rate of 0.00

This WORKSHEET is one of a series demonstrating the effects of mortality rates of 0, 0.20, 0.40, 0.60, and 0.80 on net population change.

The recruitment rates (RCRT) of 0.15, 0.90, and 1.30 are calculated for fawn, yearling, and adult age classes, respectively, and the weighted mean recruitment rate for the population (WRCP) determined. These rates are used in all of the WORKSHEETS in this series.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.00	x	____	=	____
ACb-. & ACbb.	1-2	36	0.00	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.00	x	____	=	____
	SUMS =	[100]=	TNAP		[1.00]		[____] = WMTP
							____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____
	SUMS =	[100]=	TNAP		[1.00]		[____] = WRCP
							____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

$$\text{PRDN} = 100\ e^{(\underline{\qquad\quad})(\text{YAPN})} = \underline{\qquad\qquad}.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.2b

Net population changes in a population of 100 deer
with a mortality rate of 0.20

This WORKSHEET is one of a series demonstrating the effects of mortality rates of 0, 0.20, 0.40, 0.60, and 0.80 on net population change.

The recruitment rates (RCRT) of 0.15, 0.90, and 1.30 are calculated for fawn, yearling, and adult age classes, respectively, and the weighted mean recruitment rate for the population (WRCP) determined. These rates are used in all of the WORKSHEETS in this series.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.20	x	____	=	____
ACb-. & ACbb.	1-2	36	0.20	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.20	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

$$PRDN = 100\, e^{(\_\_\_\_\_\_\_)(YAPN)} = \_\_\_\_\_\_\_\_.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.2c

Net population changes in a population of 100 deer with a mortality rate of 0.40

This WORKSHEET is one of a series demonstrating the effects of mortality rates of 0, 0.20, 0.40, 0.60, and 0.80 on net population change.

The recruitment rates (RCRT) of 0.15, 0.90, and 1.30 are calculated for fawn, yearling, and adult age classes, respectively, and the weighted mean recruitment rate for the population (WRCP) determined. These rates are used in all of the WORKSHEETS in this series.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.40	x	____	=	____
ACb-. & ACbb.	1-2	36	0.40	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.40	x	____	=	____
	SUMS =	[100]	= TNAP		[1.00]		[____] = WMTP
							____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____
	SUMS =	[100]	= TNAP		[1.00]		[____] = WRCP
							____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.2d

Net population changes in a population of 100 deer with a mortality rate of 0.60

This WORKSHEET is one of a series demonstrating the effects of mortality rates of 0, 0.20, 0.40, 0.60, and 0.80 on net population change.

The recruitment rates (RCRT) of 0.15, 0.90, and 1.30 are calculated for fawn, yearling, and adult age classes, respectively, and the weighted mean recruitment rate for the population (WRCP) determined. These rates are used in all of the WORKSHEETS in this series.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.60	x	____	=	____
ACb-. & ACbb.	1-2	36	0.60	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.60	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

PRDN = 100 $e^{(\_\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.2e

Net population changes in a population of 100 deer with a mortality rate of 0.80

This WORKSHEET is one of a series demonstrating the effects of mortality rates of 0, 0.20, 0.40, 0.60, and 0.80 on net population change.

The recruitment rates (RCRT) of 0.15, 0.90, and 1.30 are calculated for fawn, yearling, and adult age classes, respectively, and the weighted mean recruitment rate for the population (WRCP) determined. These rates are used in all of the WORKSHEETS in this series.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.80	x	____	=	____
ACb-. & ACbb.	1-2	36	0.80	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.80	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =

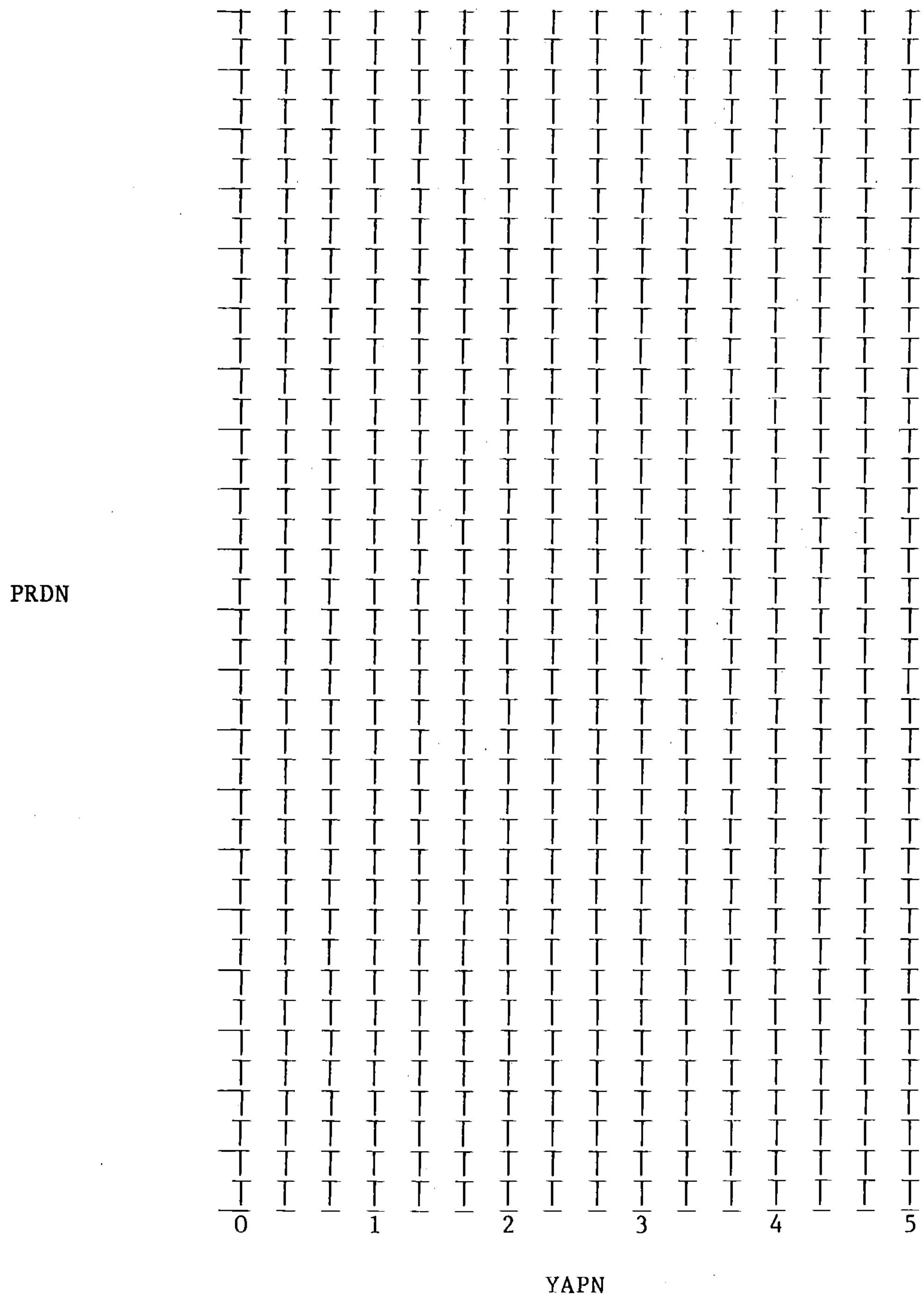
If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

Plot the results of all 5 of these calculations (5.1a-5.1e) on the grid on the next page. Label each curve with the applicable mortality rate.


PRDN
0
1
2
3
4
5
YAPN

UNIT 5.3: WINTER MORTALITY

Winter mortality results when weather and snow conditions place the animals on the range in a negative energy balance for too long a time (see CHAPTER 17). The negative energy balance may be due to hypothermia as a result of cold weather, and to the cost of activity as a result of snow accumulations. Cold weather and deep snow both make conditions even worse for that animal than either alone. Further, continued cold weather perpetuates continued snow accumulations, and the combined effect which results in continued deep accumulations is most detrimental because of the difficulty in obtaining forage.

The amount of fat reserve is a very important factor affecting the amount of winter mortality that may occur. Seasonal weight rhythms discussed in CHAPTER 1 are a natural adaptation to the changing quantities and quality of resources. Peak fall weights occur in response to peak amounts of fat accumulations (CHAPTER 2), and these two rhythms in body weight and body composition are integral parts of survival in the winter.

The effects of winter mortality on net population productivity demonstrate the effects of age specific mortality. In white-tailed deer, fawns are most likely to succumb, as expected. Their lighter weights and the lower fat composition of their bodies simply means they have fewer reserves to live on than older and larger animals. Older animals past their prime are the next likely group to succumb. Thus a WORKSHEET evaluation using reproductive rates of 0.20, 0.63, and 1.49 for fawns, yearlings, and adults and differential mortality rates for these three groups will indicate potential effects of winter mortality on the population. Fawn mortality rates of 0, 0.20, 0.40 . . . 0.80 (at 0.20 intervals) might be accompanied by adult rates that are 1/5 and yearling rates that are 1/10 of the fawn rates. Other combinations may also be tried, of course; WORKSHEET possibilities are indeed many. After evaluating the effects of winter mortality in this UNIT and of nutrition and hunting in the two previous UNITS, the possibilities for combining these effects becomes evident. The results from calculations in the UNITS in this TOPIC 5 should be combined into evaluations for management discussions in CHAPTERS 20, 21, and 22.

REFERENCES, UNIT 5.3

WINTER MORTALITY

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMFOA	51--1	13	15	od--	killing deer by kindness	carhart,ah	1945

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	2---1	1	2	odvi	preventing deer concentrat	cox,wt	1938
JWMAA	6---1	27	30	odvi	deer of allegany state prk	shadle,ar; stullk	1942
JWMAA	11--2	162	177	odvi	surv, over-popul deer rang	leopold,a; sowls/	1947
JWMAA	18--4	482	495	odvi	deer management study: mud	hunt,rw; mangus,l	1954
JWMAA	35--1	47	56	odvi	mort, young fawns, s texas	cook,rs; white,m/	1971
MRYCA	17--1	13	14	odvi	kill of deer in maryland	anonymous	1939
NAWTA	12---	212	223	odvi	weather, wint mort, adiron	severinghaus,cw	1947
NAWTA	15---	170	190	odvi	variatn fertil, rnge conds	cheatum,el; sever	1950
NAWTA	21---	555	566	odvi	larg-scale dead dee survey	whitlock,sc; eber	1956
NFGJA	8---1	61	63	odvi	metho, det kill freq/sq mi	severinghaus,cw	1961
PMACA	46...	277	287	odvi	winter mortality, michigan	blouch,ri	1961
WSCBA	11--7	6	10	odvi	deer as an outdoor problem	swift,e	1946
WSCBA	14--6	1	4	odvi	winter deer range conditns	dahlberg,bl	1949

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	40--3	215	234	odhe	de fora relat lassen-washo	dasmann,w; blaisd	1954
JWMAA	3---4	295	306	odhe	n yellowst wint range stud	grimm,rl	1939
JWMAA	24--1	80	88	odhe	nat mortal, deer, se alask	klein,dr; olson,s	1960

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--2	336	339	alal	marrw fat femr, rel mortal	franzmann,aw; arn	1976

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	37--3	343	352	anam	mort, prongh fawns, w utah	beale,dm; smith,a	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	11-10	624	624	bibi	northrn range of the bison	allen,ja	1877

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	38--4	771	774	ovca	lamb prod surv, mort, colo	woodard,tn; guti/	1974

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
JWMAA	20--2	159	168	many	snow depths & ungul abunda	edwards,ry	1956
XFWLA	283..			biga	big game inventory, u s	anonymous	1943
XFWLA	303..			biga	big game inventory, u s	anonymous	1946
XFWLA	321..			biga	big game inventory, u s	anonymous	1949

OTHER PUBLICATIONS

Proceedings of the Snow and Ice in Relation to Wildlife and Recreation Symposium.

CHAPTER 19, WORKSHEET 5.3a

The effects of winter mortality rates of 0.00 for fawns, 0.00 for yearlings and 0.00 for adults on net population growth of white-tailed deer

The effects of winter mortality rates of 0.00, 0.20, 0.40, 0.60, and 0.80 of fawns and 1/20 and 1/10 of these rates for yearlings and adults respectively may be illustrated by completing the calculations in this series of WORKSHEETS. The recruitment rates are 0.15, 0.90, and 1.30 for fawns, yearlings, and adults, respectively. The weighted mean recruitment rate (WRCP) is then used to determine bRCR.

AGE CLASSES	ACYI	NUAC	MTRT x	FRPA =	MWMA
ACa-. & ACaa.	0-1	47	0.00 x	____ =	____
ACb-. & ACbb.	1-2	36	0.00 x	____ =	____
ACc-. & ACcc.	2-3+	17	0.00 x	____ =	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

* * * * *

AGE CLASSES	ACYI	NUAC	RCRT x	FRPA =	WRCA
ACa-. & ACaa.	0-1	47	0.15 x	____ =	____
ACb-. & ACbb.	1-2	36	0.90 x	____ =	____
ACc-. & ACcc.	2-3+	17	1.30 x	____ =	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.3b

The effects of winter mortality rates of 0.20 for fawns, 0.01 for yearlings and 0.02 for adults on net population growth of white-tailed deer

The effects of winter mortality rates of 0.00, 0.20, 0.40, 0.60, and 0.80 of fawns and 1/20 and 1/10 of these rates for yearlings and adults respectively may be illustrated by completing the calculations in this series of WORKSHEETS. The recruitment rates are 0.15, 0.90, and 1.30 for fawns, yearlings, and adults, respectively. The weighted mean recruitment rate (WRCP) is then used to determine bRCR.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.20	x	____	=	____
ACb-. & ACbb.	1-2	36	0.01	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.01	x	____	=	____
	SUMS =	[100] = TNAP			[1.00]		[____] = WMTP
							____ = bMTR

* * * * *

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____
	SUMS =	[100] = TNAP			[1.00]		[____] = WRCP
							____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

$$\text{PRDN} = 100\, e^{(\_\_\_\_\_\_)(\text{YAPN})} = \_\_\_\_\_\_\_\_.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

The effects of winter mortality rates of 0.04 for fawns, 0.02 for yearlings and 0.04 for adults on net population growth of white-tailed deer

The effects of winter mortality rates of 0.00, 0.20, 0.40, 0.60, and 0.80 of fawns and 1/20 and 1/10 of these rates for yearlings and adults respectively may be illustrated by completing the calculations in this series of WORKSHEETS. The recruitment rates are 0.15, 0.90, and 1.30 for fawns, yearlings, and adults, respectively. The weighted mean recruitment rate (WRCP) is then used to determine bRCR.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.40	x	____	=	____
ACb-. & ACbb.	1-2	36	0.02	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.04	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

* * * * *

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

$$PRDN = 100\ e^{(\_\_\_\_\_\_)(YAPN)} = \_\_\_\_\_\_\_\_.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

The effects of winter mortality rates of 0.60 for fawns, 0.03 for yearlings and 0.06 for adults on net population growth of white-tailed deer

The effects of winter mortality rates of 0.00, 0.20, 0.40, 0.60, and 0.80 of fawns and 1/20 and 1/10 of these rates for yearlings and adults respectively may be illustrated by completing the calculations in this series of WORKSHEETS. The recruitment rates are 0.15, 0.90, and 1.30 for fawns, yearlings, and adults, respectively. The weighted mean recruitment rate (WRCP) is then used to determine bRCR.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.60	x	____	=	____
ACb-. & ACbb.	1-2	36	0.03	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.06	x	____	=	____
	SUMS =	[100]= TNAP			[1.00]		[____] = WMTP
							____ = bMTR

* * * * *

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____
	SUMS =	[100]= TNAP			[1.00]		[____] = WRCP
							____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

$$\text{PRDN} = 100\ e^{(\_\_\_\_\_\_)(\text{YAPN})} = \_\_\_\_\_\_\_\_.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.3e

The effects of winter mortality rates of 0.80 for fawns, 0.04 for yearlings and 0.08 for adults on net population growth of white-tailed deer

The effects of winter mortality rates of 0.00, 0.20, 0.40, 0.60, and 0.80 of fawns and 1/20 and 1/10 of these rates for yearlings and adults respectively may be illustrated by completing the calculations in this series of WORKSHEETS. The recruitment rates are 0.15, 0.90, and 1.30 for fawns, yearlings, and adults, respectively. The weighted mean recruitment rate (WRCP) is then used to determine bRCR.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	47	0.80	x	____	=	____
ACb-. & ACbb.	1-2	36	0.04	x	____	=	____
ACc-. & ACcc.	2-3+	17	0.08	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RCRT	x	FRPA	=	WRCA
ACa-. & ACaa.	0-1	47	0.15	x	____	=	____
ACb-. & ACbb.	1-2	36	0.90	x	____	=	____
ACc-. & ACcc.	2-3+	17	1.30	x	____	=	____

SUMS = [100]= TNAP [1.00] [____] = WRCP
____ = bRCR

bMTR ________ + bRCR ________ = bPOP = ________

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =

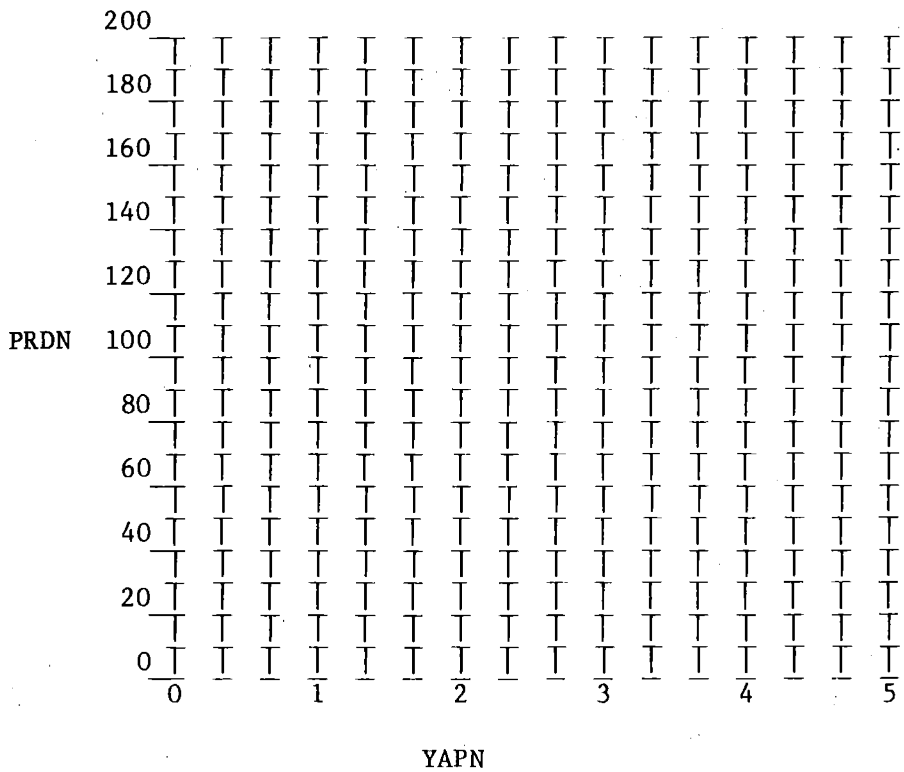
If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

Plot the results of all 5 of these calculations (5.3a-5.3e) on the grid on the next page. Label each curve with the applicable mortality rate.


200
180
160
140
120
PRDN
100
80
60
40
20
0
0
1
2
3
4
5
YAPN

UNIT 5.4: PREDATION

Evaluations of the effects of predation on net population productivity direct ones attention to differential mortality between ages and time of year. Mortality of all species can be very high in the neonates, with wide ranges in mortality rates as a result of weather conditions and predation levels. Predators of wild ruminants appear to be more efficient in killing the very young and the very old than the animals in the ages between these tow extremes. References to many studies of predation by a variety of predators are listed in the SERIALS list, providing many options for evaluating the effects of predation in the WORKSHEETS.

Select predator studies that include dates of age-specific rates throughout the year, resulting in evaluations that indicate changes in populations through the seasons.

REFERENCES, UNIT 5.4

PREDATION

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJDIA	47...	131	137	odvi	patt wolf pack move, kills	frijlink,jh	1977
CAFNA	91--1	28	40	odvi	stat, habi, cougar, manito	nero,rw; wrigley,	1977
CAFNA	92--1	91	94	odvi	seas var food, wolves, ont	theberge,jb; oos/	1978
CJZOA	56--5	1207	1210	odvi	fawn, heart rate,wolf howl	moen,an; dellafe/	1978
JOMAA	26--4	439	440	odvi	wildcat predation on deer	smith,be	1945
JOMAA	29--1	69	70	odvi	bobcats kill deer, pennsyl	matson,jr	1948
JOMAA	43--3	430	431	odvi	bobcat mort, predati on de	petraborg,wh; gun	1962
JOMAA	54--1	291	293	odvi	desc of remains, kill, coy	white,m	1973
JOMAA	56--1	44	63	odvi	wt, grow, surv, wolf, minn	van ballenberghe/	1975
JWMAA	3---2	99	103	odvi	fall, wint foods, bobc, vt	hamilton,wj,jr; /	1939
JWMAA	6---4	328	337	odvi	wint relat, bobcats, maine	marston,ma	1942
JWMAA	9---2	131	145	odvi	habits, foods, bobca, minn	rollings,ct	1945
JWMAA	20--2	199	200	odvi	foods eaten by bobc, maine	westfall,cz	1956
JWMAA	22--1	184	192	odvi	mobility, misso deer, dogs	progulske,dr; ba	1958
JWMAA	35--2	707	716	odvi	respon, deer, hunting dogs	sweeney,jr; mar/	1971
JWMAA	36--2	357	369	odvi	wolf pred, winter, ontario	kolenosky,gb	1972
JWMAA	37--3	253	265	odvi	ecolog, feral dogs, alabam	scott,md; causey	1973
JWMAA	38--4	854	859	odvi	relat, pred remov, product	beasom,sl	1974

odvi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--2	365	368	odvi	energ utiliza, 3 fox diets	litvaitis,ja; ma	1976
JWMAA	40--3	429	441	odvi	deer migration, wolf preda	hoskinson,rl; me	1976
JWMAA	40--4	663	668	odvi	chang, wolf summ foods,ont	voigt,dr; kolen/	1976
JWMAA	41--1	63	69	odvi	neonatal fawn survi, texas	carroll,bk; brown	1977
NAWTA	3----	302	304	odvi	relat, predat, glac nat pk	aiton,jf	1938
NOSCA	45--4	213	218	odvi	pred-prey relatio, coyotes	ogle,tf	1971
PCGFA	25---	69	77	odvi	effe dogs, on radioed deer	corbett,rl; marc/	1972
SCIEA	4314-	320	321	odvi	wolf, buff zone, prey rese	mech,ld	1977
SWNAA	12...	156	162	odvi	behav interact, other mamm	michael,ed	1967
SWNAA	21--4	451	457	odvi	bobcat resp, chan prey abu	beasom,sl; moore,	1977
WLSBA	4---3	128	129	odvi	flush distan, mode of trav	kucera,e	1976
WSCBA	8---8	3	11	odvi	deer irruptions	leopold,a	1943
XFNCA	52---	1	62	odvi	age, sex, cond, wolf kills	mech,ld; frenzel,	1971
XFNCA	148--	1	23	odvi	role wolf, deer decl, minn	mech,ld; karns,pd	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
GRBNA	37--1	101	102	odhe	infl, pred contr, wint her	austin,dd; urnes/	1977
JOMAA	28--1	63	63	odhe	bobcat preys on deer	dill,hh	1947
JOMAA	53--2	393	394	odhe	resp yng deer to pred odor	muller-schwarze,	1972
JWMAA	31--3	496	501	odhe	anam, pred by golden eagle	mcgahan,j	1967
JWMAA	35--2	378	381	odhe	alal, win food, cougar, bc	spalding,dj; leso	1971
JWMAA	41--3	576	578	odhe	ceel, food hab, cougar, or	toweill,de; mesls	1977
JWMAA	43--4	956	958	odhe	coyote predation on fawns	truett,jc	1979
SWNAA	23--1	152	153	odhe	summer foods, coyote, colo	ribic,ca	1978
UTSCB	36...	87	90	odhe	coyotes and deer	nielsen,db	1975
WLMOA	21---	1	39	odhe	ceel, mt lion preda, idaho	hornocker,mg	1970
WLMOA	35---	1	60	odhe	ceel, mt lion soc org, ida	seidensticker,jc/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	46--3	498	498	ceel	calf pursued, coyote, mich	moran,rj; ozoga,j	1965
JOMAA	52--1	199	202	ceel	pred, blac bear on mal elk	barmore,wj; strad	1971
JWMAA	24--1	15	21	ceel	on afognak island, alaska	troyer,aw	1960
JWMAA	36--2	556	561	ceel	grizzly bear-elk, yellowst	cole,gf	1972
WLMOA	21---	1	39	ceel	odhe, mt lion preda, idaho	hornocker,mg	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	97--2	267	279	alal	mort patt, isle royale pop	wolfe,ml	1977
NAWTA	15---	224	234	alal	bear-moose relation, kenai	chatelain,ef	1950
NAWTA	34---	117	131	alal	summary wolf stud, s alask	rausch,ra	1969
NCANA	101-3	457	466	alal	pred, bear, wolverin, swed	haglund,b	1974
NCANA	101-3	467	479	alal	occurenc, wolf food, scats	frenzel,ld	1974
NCANA	101-3	481	492	alal	snow condit, wolf relation	peterson,ro; alle	1974
VILTA	5---6	347	361	alal	wint hab, bear, wolf, swed	haglund,b	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ALLKA	60...	51	54	rata	circle format, etholog mot	anghi,cs	1973
BPURD	1----	209	220	rata	wolf pred, barren-gr, wint	miller,dr	1975
BPURD	1----	474	497	rata	clump behav, preda, caribo	cumming,hg	1975
CAFNA	87--2	183	183	rata	misquotatio of lit on pred	kuyt,e	1973
CWRSB	21---	1	35	rata	food hab, wolves, car rang	kuyt,e	1972
JOMAA	54--2	341	348	rata	dist, densit, wolves, cana	parker,gr	1973
JOMAA	56--4	752	757	rata	diet of wolverines in norw	myhre,r; myrberge	1975
JOMAA	57--3	585		rata	surpl kill reind by wolves	bjarvall,a; nilss	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AUKJA	94--4	789	790	anam	golden eagle predation on	goodwin,ga	1977
CAFNA	84--3	301	304	anam	wint pred by eagles, coyot	bruns,eh	1970
JWMAA	13--3	313	314	anam	predation on antelope	thompson,wk	1949
JWMAA	37--3	343	352	anam	mort pronghorn fawns, utah	beale,dm; smith,a	1973
NAWTA	16---	179	193	anam	pred contr, antel manageme	arrington,n; edwa	1951
NEXRA	245--	1	12	anam	fact restr increase, n mex	howard,vw,jr; en/	1973
SWNAA	18--3	346	348	anam	golden eagle predati, fawn	tigner,jr	1973

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	56--3	206	207	ovca	observ interact, rep preda	weaver,ra; mensc,	1970
JWMAA	38--4	771	774	ovca	lamb prod surv, mort, colo	woodard,tn; guti/	1974

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATICA	23...	197	198	obmo	killing bull, single wolf	gray,dr	1970
JWMAA	35--1	103	108	obmo	pop char, jones sound, nwt	freeman,mmr	1971
MUOXD	20...	87	88	obmo	group attackd, 1 wolf, nwt	miller,fl; gunn,a	1977

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--3	400	407	dosh	sheep kill, behav, coyotes	connolly,ge; tim/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	97---	209	223		predator-prey interactions	rosenzweig,ml; ma	1963
AMZOA	7....	253	265		aspect, pop ecol wolv, ala		1967
AMZOA	7---2	267	278	ungu	wolf pred, ungulate popula	pimlott,dh	1967
BEHAA	35...	259	272		ontog, prey-kil beh, canid	fox,mw	1969
CNDRA	56--1	3	12		food habits, nest gold eag	carnie,sk	1954
ECOLA	56--4	855	867		pred, pry pop, gr rt, stab	tanner,jt	1975
JOMAA	33--4	429	442		trav, rang, food wolv, wis	thompson,dq	1952
JWMAA	23--3	261	273		food hab, coug, utah, neva	robinette,wl; ga/	1959
JWMAA	24--1	1	15	biga	predation on biga, e afric	wright,bs	1960
JWMAA	31--3	492	496		telemetry, study of predat	mech,ld	1967
JWMAA	42--3	528	532		wolf scat conten, prey con	floyd,tj; mech,l/	1978
NAWTA	6----	283	287		coyote-wildlf relationship	horn,ee	1941
NAWTA	39---	230	240		intensi short term removal	beasom,sl	1974
NAWTA	39---	292	300		pred-livesto probl, losses	balser,ds	1974
PASCC	15---	27	32		wolves, coronation island	merriam,hr	1964
PNASA	46--1	143	145		rela repro valu, opti pred	macarthur,rh	1960
QRBIA	21--2	144	177		predation, vertebrate popu	errington,pl	1946
WLSBA	6---1	25	32		1974 coyot harv, 17 w stat	pearson,ew	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	26--2	133	136	caca	predation on roe d, sweden	borg,k	1962

CHAPTER 19, WORKSHEET 5.4a

The effects of different levels of mortality due to predation on net population growth

Select age-related predation and reproductive or recruitment rates from the literature and calculate their effects on net population growth using the formats below and on the next page.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WMTP

____ = bMTR

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WRTP

____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

$$PRDN = 100\ e^{(\_\_\_\_\_\_)(YAPN)} = \_\_\_\_\_\_\_\_.$$

If YAPN = 1, PRDN =

If YAPN = 2, PRDN =

If YAPN = 3, PRDN =

If YAPN = 4, PRDN =

If YAPN = 5, PRDN =

AGE CLASSES	ACYI	NUAC	MTRT x	FRPA =	MWMA
ACa-. & ACaa.	0-1	____	____ x	____ =	____
ACb-. & ACbb.	1-2	____	____ x	____ =	____
ACc-. & ACcc.	2-3+	____	____ x	____ =	____

SUMS = [____]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RPRT x	FRPA =	WRAC
ACa-. & ACaa.	0-1	____	____ x	____ =	____
ACb-. & ACbb.	1-2	____	____ x	____ =	____
ACc-. & ACcc.	2-3+	____	____ x	____ =	____

SUMS = [____]= TNAP [1.00] [____] = WRTP
____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =
If YAPN = 2, PRDN =
If YAPN = 3, PRDN =
If YAPN = 4, PRDN =
If YAPN = 5, PRDN =

* * * * * * * * * * * * * * * * * *

AGE CLASSES	ACYI	NUAC	MTRT x	FRPA =	MWMA
ACa-. & ACaa.	0-1	____	____ x	____ =	____
ACb-. & ACbb.	1-2	____	____ x	____ =	____
ACc-. & ACcc.	2-3+	____	____ x	____ =	____

SUMS = [____]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RPRT x	FRPA =	WRAC
ACa-. & ACaa.	0-1	____	____ x	____ =	____
ACb-. & ACbb.	1-2	____	____ x	____ =	____
ACc-. & ACcc.	2-3+	____	____ x	____ =	____

SUMS = [____]= TNAP [1.00] [____] = WRTP
____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

PRDN = 100 $e^{(\_\_\_\_\_\_)(YAPN)}$ = ________.

If YAPN = 1, PRDN =
If YAPN = 2, PRDN =
If YAPN = 3, PRDN =
If YAPN = 4, PRDN =
If YAPN = 5, PRDN =

CHAPTER 19, WORKSHEET 5.4b

The effects of changes in predation rates on net population growth

Using exponential predictions and the format given in WORKSHEET 5.4a, predict net population in relation to changes from year to year in the predation rate. Use the procedures for successive one-year cycles described in WORKHEET 4.2a, Page 56a. Be sure to incorporate new b values as the rates change.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WRTP
____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

PRDN = 100 e$^{(______)(______)}$ = ________.

* * * * * * * * * * * * * * * * * *

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WMTP
____ = bMTR

AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WRTP
____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

PRDN = 100 e$^{(______)(______)}$ = ________.

AGE CLASSES	ACYI	NUAC	MTRT	x	FRPA	=	MWMA
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WMTP

____ = bMTR

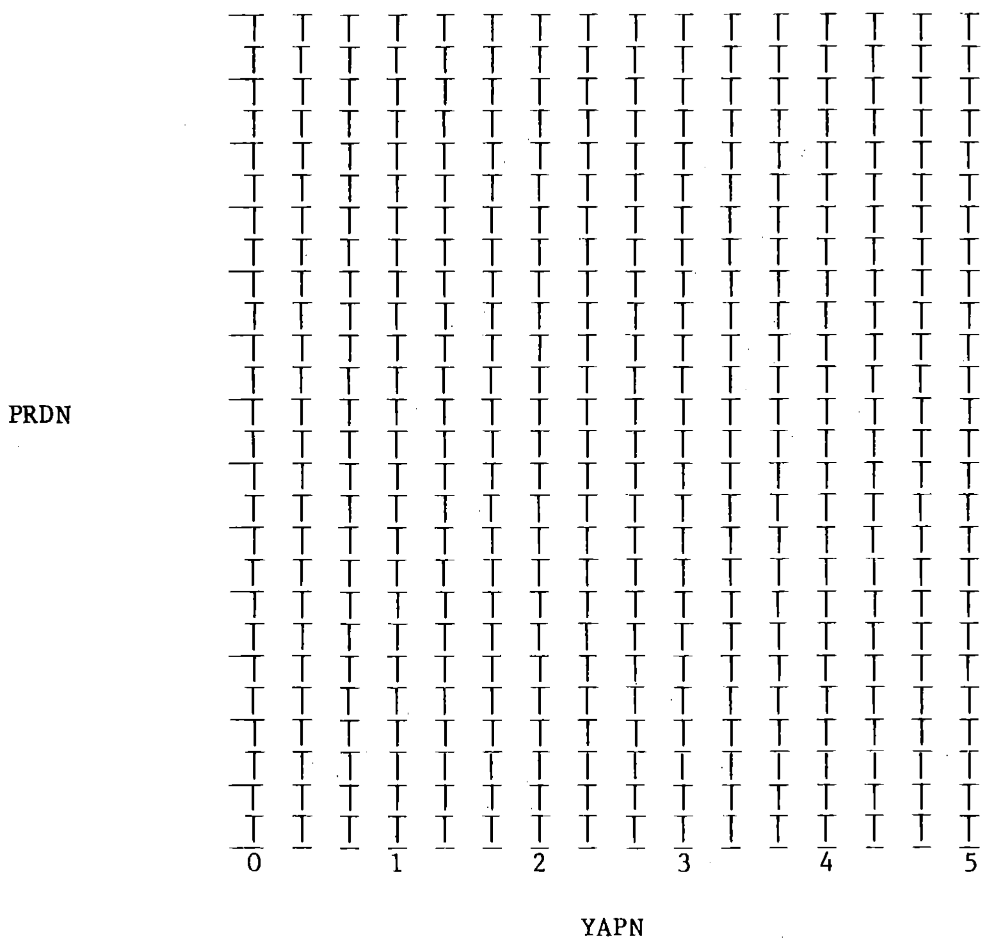
AGE CLASSES	ACYI	NUAC	RPRT	x	FRPA	=	WRAC
ACa-. & ACaa.	0-1	____	____	x	____	=	____
ACb-. & ACbb.	1-2	____	____	x	____	=	____
ACc-. & ACcc.	2-3+	____	____	x	____	=	____

SUMS = [____]= TNAP [1.00] [____] = WRTP

____ = bRPR

bMTR ____ + bRPR ____ = bPOP = ____

PRDN = 100 $e^{(\_\_\_\_\_\_)(\_\_\_\_\_\_)}$ = ________.



UNIT 5.5: HIGHWAY AND RAILWAY MORTALITY

Highway and railway mortality is a part of the population dynamics of wild ruminants living in populated areas. The white-tailed deer, the most wide-spread and adaptable of wild ruminants, is the one species affected the most.

Highway amd railway mortality patterns are dependent not only on traffic patterns but on seasonal movements of the animals. Thus deer mortality increases in the fall during the rut when there is a higher level of activity and more movement, and in the spring during dispersal from winter concentration areas. Land conditions may cause short-term changes in mortality, too.

Evaluations of the effects of highway and railway mortality may be made for the time-periods through the year if such data are available, or for the entire year if necessary. It probably varies less, as a proportion of the population, from year to year than other causes of mortality; it may be a rather density-dependent rate. In fact, some biologists have used highway mortality figures as indicators of population levels.

REFERENCES, UNIT 5.5

HIGHWAY AND RAILWAY MORTALITY

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNSVA	19--2	2	3	odvi	secon deadliest deerslayer	burgin,be	1964
JWMAA	23--2	187	197	odvi	hwy mort, index pop change	jahn,lr	1959
JWMAA	35--2	232	237	odvi	mort, interst hwy, pennsyl	bellis,ed; graves	1971
JWMAA	37--2	212	216	odvi	road kills, pop trend, wis	mccaffery,kr	1973
JWMAA	38--1	16	19	odvi	mortali, interst hwy, mich	reilly,r; green,h	1974
JWMAA	38--4	799	807	odvi	factors, highway mortality	puglisi,mj; lindz	1974
JWMAA	39--3	570	581	odvi	distr, activ, intersta hwy	carbaugh,b; vaug/	1975
JWMAA	40--2	317	325	odvi	deer-car accidents, s mich	allen,re; mccullo	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
XARRA	332--	1	4	odhe	mortal, interstat 80, wyom	goodwin,ga; ward,	1976

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

ceel

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

alal

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

CAFNA 91--3 312 314 rata summer use hi-way crossing johnson,dr; todd, 1977

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

UNIT 5.6: HARASSMENT

A number of factors in the natural environment may harass wildlife, including wild ruminants. The most common one over the years in populated areas has been dogs. They chase and harass deer effectively when snow conditions put the deer at a disadvantage.

A more recent sort of harassment is that of snowmobiles. These machines are capable of traversing a variety of snow conditions at high rates of speeds. Further, they have an unlimited supply of kinetic energy, never tiring as long as their gas tanks hold full for operation. Thus deer and other wild ruminants may be harassed to levels not experienced previously, depending on the attitude and behavior of the machine operator.

It is important to recognize that higher than natural levels of excitement are contrary to long-term energy conservation adaptations which wild ruminants possess (Moen 1976). My suggestion is that we be very conservative about the use of these machines in areas inhabited by deer or other ruminants, letting them live as naturally as possible. This opinion is further strengthened by the results (not yet published) of extensive measurements of heart-rate responses of white-tailed deer to snowmoblies at Cornell's Wildlife Ecology Laboratory. These deer showed no evidence of habituation to the noise as tests proceeded throughout the winter.

Harassment is difficult to convert to reduction in productivity. If harassment results in death, then the conversion is simple. If it simply results in reduced fetal weights, birth weights, etc., the effects are much more subtle.

LITERATURE CITED

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

REFERENCES, UNIT 5.6

HARASSMENT

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energ cons by, in the wint	moen,an	1976
JWMAA	22--2	184	192	odvi	mobility, misso keer, dogs	progulske,dr; ba	1958

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CWPNB	79---	1	23	rata	obsrv respn helicop harass	miller,fl; gunn,a	1977
FUOFA	67...	250	253	rata	magpies attack reind, swed	espmark,y	1972
FUNAA	22...	265	266	rata	raven attacking reindeer	ostbye,e	1969
JEBCA	74...	34	36	rata	insects, alpine region, bc	harling,j; snyde/	1977

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			

UNIT 5.7: CHEMICAL FACTORS

The introduction of chemical factors into the environment in the last 30 years has presented new problems for wildlife biologists to solve and respond to. Pesticides, herbicides, and inorganic fertilizers have been spread over large areas of forested and agricultural lands, and these have entered metabolic pathways of wild ruminants, through the plants they have consumed. Many of these chemicals are passed on to other organisms in the food chain.

Not all of the chemicals have harmful effects. Their ecological effects on wild ruminants may be more subtle than the effects on target species; tiny insects might be killed by an insectide that would only alter metabolism of a large animal for a short time, for example. The effects of repeated exposure, however, might suppress productivity.

FACTORS AFFECTING THE PHYSIOLOGY AND METABOLISM OF WILD RUMINANTS are discussed in CHAPTER 10. There are a good number of references in the SERIALS list that may be useful when evaluating the effects of chemicals on net population productivity.

REFERENCES, UNIT 5.7

CHEMICAL FACTORS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
PCGFA	25---	23	30	odvi	prelim surv, pestic residu	cotton,d; herring	1971
PCGFA	25---	31	45	odvi	pestici residues, s caroli	barrier,mj; reed,	1971

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JWIDA	10--2	166	169	odhe	invest, tansy ragwort pois	dean,re; winward,	1974

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
PEMJA	7---2	97	99	alal	organo chlor residu, idaho	benson,ww; watso/	1973

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
BECTA	19--1	23	31	ovca	chlor hydrocarb resid, fat	turner,jc	1978

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
JWIDA	37--1	1	11	ceni	potas def: facto mass mort	christian,jj	1964

SEE CHAPTER 10 SERIALS LIST ALSO

UNIT 5.8: OTHER AND ALL FACTORS

There are a number of other factors that have the potential for altering net population productivity, in addition to the seven factors already listed. These other factors are best described as "accidents," or occasional causes of changes. Drowning, choking, lightning . . . these are not the basic everyday factors than must be overcome by wild ruminants. Their occurrences have been reported in the literature, and references are listed in the SERIALS at the end of this UNIT.

All factors affecting net population growth should be considered through the annual cycle, with each year divided into as many functional time periods as you can justify with the data base available. Total annual mortalilty is the sum of the mortalities during each time period.

The five time periods introduced at the beginning of this CHAPTER are:

```
      PSPP              PSUP               PFAP         PHUP PWNP
        ↓                 ↓                  ↓             ↓    ↓
 WNTR   |      SPRN       |       SUMR       |    FALL     |HUNT|   WNTR
1 →                              182 →                               365
```

Reorganizing this in tabular form, the following lists of causes of mortality and production rates are helpful reminders of factors to consider.

		CLASS	Mortalities		CLASS	CORT	BIRT	WERT
PHUP	____	____	Hunting	____	____	____	____	____
		____		____				
		____		____				
PWNP	____	____	Crippling loss	____	____	____	____	____
		____		____				
		____		____				
PSPP	____	____	Poaching	____	____	____	____	____
		____		____				
		____		____				
PSUP	____	____	Predation	____	____	____	____	____
		____		____				
		____		____				
PFAP	____	____	Winter losses	____	____	____	____	____
		____		____				
		____		____				
		____	Road kills	____				
		____		____				
		____		____				
		____	Other causes	____				
		____		____				
		____		____				

Using weighted-mean tabular formats as illustrated in previous WORKSHEETS, master WORKSHEETS may be constructded for as many classes, causes of mortality, and production rates as you wish. The final values of bPOP enable you to calculate predicted populations very quickly.

REFERENCES, UNIT 5.8

OTHER AND ALL FACTORS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	48--4	655	656	odvi	hypothermia, water-chill d	moen,an	1968
JOMAA	49--1	148	148	odvi	possibl hered defect, mich	verme,lj	1968
JWMAA	9---1	76	78	odvi	weathr and the kill, maine	fobes,cb	1945
MOCOA	20--9	1	3	odvi	cause of death- accidental	murphy,da	1959
NYCOA	29...	31		odvi	wintring deer vs snowmobil	severinghaus,cw;/	1975
WDABB	3---4	184	184	odvi	accidental choke, w-t deer	fisher,fp	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	83--1	303	304	odhe	accidents, parturient deer	miller,fl	1970
JOMAA	37--2	143	164	odhe	behav with ref to pop ecol	dasmann,rf; taber	1956
JOMAA	46--4	676	676	odhe	mule d killed by lightning	reynolds,hg	1965
JWMAA	16--1	113	114	odhe	bearded grains cause death	winter,kb; honess	1952
JWMAA	40--1	140	144	odhe	odvi, drought infl numbers	anthony,rg	1976
NEXAA	567--	1	32	odhe	ft stanton hrd, ecol, n mx	wood,je; bickle,/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	50--3	640	641	ceel	inciden, mass elk drowning	martinka,cj	1969
NAWTA	20---	560	567	ceel	increas natal, lower popul	buechner,hk; swan	1955

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNAA	91--2	435	438	alal	init resp wildfre, ne minn	peek,jm	1974
JWIDA	8---1	95	98	alal	fatality from overext rnge	miller,fl; broug/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	18--4	521	526	rata	fire and decline of a herd	edwards,ry	1954
NPOAA	1976-	129	136	rata	pop size, reprod, svalbard	alendal,e; byrkje	1976
ORYXA	7....	240	246	rata	the decline of the caribou	kelsall,jp	1964

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NEXRA	245--	1	12	anam	factrs restr increa, n mex	howard,vw,jr; en/	1973

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JOMAA	35--3	453	454	bibi	buffalo killed by fire	cole,je	1954

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFGA	55--3	237	238	ovca	losses, natural trap tank	mensch,jl	1969

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ANBEA	24--4	756	758	obmo	rutting fight mortali, nwt	wilkinson,pf; sha	1976
IZYBA	5----	58	75	obmo	herd of musk-oxen in capti	oeming,a	1965

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMNTA	104--	1	24		life hist conseq, nat sele	gadgil,m; bossert	1970
BEHSA	15--1	101	115		natur select, defined popu	istock,ca	1970
ECOLA	51...	823	828		detect, regula in anim pop	st amant,jls	1970
ECOLA	52--3	453	468		density-depend natur selec	roughgarden,j	1971
JWMAA	20--2	159	168	many	snow depths & ungul abunda	edwards,ry	1956
JWMAA	34--4	681	690		nat selec, param pop growt	hairston,ng; tin/	1970
NAWTA	3----	296	301	biga	fact control pop, rocky mt	couglas,lh	1938

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS----------------	AUTHORS-----------	YEAR
CPSCA	1---2	79	95	ceni	factors, mass mort, sika d	christian,jj; fl/	1960

CLOSING COMMENTS

CHAPTER 19; POPULATION RATES AND PREDICTIONS has dealt with natality and mortality rates and how to use them when predicting population changes. Discussions have been diverted toward the practical year-to-year use of sex, age, and weight data as a basis for decision-making, rather than long-range population theory. If the WORKSHEETS in this CHAPTER 19 have been completed, then the basic calculations in CHAPTER 20 will be very easy to make.

Aaron N. Moen
June 25, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER NINETEEN

ACEY = Age class by end of year
ACMP = Age class at the midpoint
ACYI = Age class by yearly intervals
ADRR = Adult reproductive rate
AGCL = Age class

BIRT = Birth Rate
BIWK = Birth weight in kg

CLWK = Calculated maximum live weight
CORT = Conception rate

FALL = The weight recovery period following weaning of the young and up to the hunt
FARR = Fawn reproductive rate
FEPF = Fetuses per female
FFPA = Fraction of the female population in the age class
FFPW = Fraction of the female population in this weight class
FMPA = Fraction of the male population in each age class
FMPW = Fraction of the male population in this weight class
FRPA = Fraction of the population in each age class
FWMA = Weighted mortality rate of each age class
FWMP = Weighted mean mortality rate of the population
FWMW = Weighted mean mortality rate for each weight class

HUNT = The period in the fall when the hunting season is open

MAWK = Maximum weight in kilograms
MFSR = Male to female sex ratio
MTRT = Mortality rate
MWMA = Weighted mean mortality rate for each age class
MWMP = Weighted mean mortality rate of the male population
MWMW = Weighted mean mortality rate for each weight class

NAIP = Number of animals present in the initial population
NBMO = Number of mortalities
NFAC = Number of females in the age class
NFER = Number of females recruited into the population
NFWC = Number of females in each weight class
NFYR = Number of female young recruited into the population
NMAR = Number of males recruited into the population
NMWC = Number of males in each weight class
NMYR = Number of male young recruited into the population
NSAC = Number of surviving in each age class
NTMR = Natal mortality rate
NTSR = Natal survival rate
NUAC = Number in the age class
NYPF = Number of young per female

PFAP = Prefall population
PHVP = Prehunt population
PRDN = Predicted N
PSPP = Prespring population
PSUP = Presummer population
PWNP = Prewinter population

RCRT = Recruitment rate
RPRT = Reproductive rate

SPNG = The time from the end of winter to parturition
SUMR = The time preiod from parturition through weaning of the young
SUMS = Sums
SURT = Survival rate

TNAP = Total number of animals in the population
TNFP = Total number of females in the population
TNMP = Total number of males in the population

WBRA = Weighted mean birth rate for each age class
WBRP = Weighted mean birth rate of the population
WCMP = Weight class at the midpoint
WCRA = Weighted mean conception rate for each age class
WCRP = Weighted mean conception rate of the population
WCRW = Weighted mean conception rate for each weight class
WERT = Weaning rate
WMTP = Weighted mean mortality rate of the total population
WNTR = The period following the hunt when winter conditions are expected
WRAC = Weighted mean reproductive rate of the age class
WRCA = Weighted mean recruitment rate of the age class
WRCP = Weighted mean recruitment rate of the total population
WRTP = Weighted mean reproductive rate of the total population
WTCL = Weight class
WWRA = Weighted mean weaning rate for each age class
WWRP = Weighted mean weaning rate of the population

YABD = Yearling antler beam diameter in mm
YAPN = Years ahead one wishes to predict N
YDWK = Yearling dressed weight in kg
YERR = Yearling reproductive rate
YLWK = Yearling calculated live weight in kg

AJANA American Journal of Anatomy
ALLKA Allattani Kozlemenyek (Hungary)
AMFOA American Forests
AMNAA American Midland Naturalist
AMNTA American Naturalist
AMZOA American Zoologist
ANBEA Animal Behaviour (England)
ANREA Anatomical Record
ATICA Arctic (Canada)
ATRLA Acta Theriologica (Poland)
AUKJA Auk
AVSPA Acta Veteinaria Scandinavica Supplementum (Denmark)

BEHAA Behaviour (Netherlands)
BEHSA Behavioral Science
BIOMA Biometrics
BIREB Biology of Reproduction
BISNA Bioscience
BJDIA Bijdragen tot de Dierkunde
BPURD Biological Papers of the University of Alaska Special Report

CAFGA California Fish and Game
CAFNA Canadian Field Naturalist
CJZOA Canadian Journal of Zoology
CNDRA Condor
CNSVA Conservationist
COVEA Cornell Veterinarian
CPSCA Chesapeake Science
CWPNB Canadian Wildlife Service Progress Notes
CWRSB Canadian Wildlife Service Report and Management Bulletin Series

DRCWD Colorado Division of Wildlife Division Report

ECMOD Ecological Modeling
ECOLA Ecology
EKIAA Ekologiya

FUNAA Fauna (Oslo)
FUOFA Fauna och Flora

GRBNA Great Basin Naturalist

HMECA Human Ecology

ISJSA Iowa State Journal of Science
IZYBA International Zoo Year Book

JAECA Journal of Animal Ecology
JAVMA Journal of the American Veterinary Medical Association
JBLPA Jelen
JEBCA Journal of Entomological Society of British Columbia
JFUSA Journal of Forestry
JOMAA Journal of Mammalogy
JRPFA Journal of Reproduction and Fertility
JTBIA Journal of Theoretical Biology
JWIDA Journal of Wildlife Diseases
JWMAA Journal of Wildlife Management

MDCRA Michigan Department of Conservation Game Division Report
MOCOA Missouri Conservationist
MRLTA Murrelet, The
MRYCA Maryland Conservationist
MUOXD Musk-ox

NAWTA North American Wildlife and Natural Resources Conference, Transactions of the, NCANA Naturaliste Canadien, Le
NCANA Naturaliste Canadien, Le
NEXAA New Mexico Agricultural Experiment Station Bulletin
NEXRA New Mexico Agricultural Experiment Station Research Report
NFGJA New York Fish and Game Journal
NOSCA Northwest Science
NPKMA National Parks Magazine
NPOAA Norsk Polarinstituut Arbok
NYCOA New York State Conservationist

OETAT Oregon Agricultural Experiment Station Technical Bulletin
OJSCA Ohio Journal of Science
ORYXA Oryx

PASCC Proceedings of the Alaskan Scientific Conference
PCGFA Proceedings of the Southeastern Association of Game and Fish Commissioners
PEMJA Pesticide Monitoring Journal
PIAIA Proceedings of the Iowa Academy of Science
PMACA Papers of the Michigan Academy of Sciences, Arts and Letters
PNASA Proceedings of the National Academy of Sciences of the United States

QJFAA Quarterly Journal of the Florida Academy of Science
QRBIA Quarterly Review of Biology

SCIEA Science

SWNAA Southwestern Naturalist

TISAA Transactions of the Illinois State Academy of Science
TLPBA Theoretical Population Biology
TNWSD Transactions of the Northeast Section, The Wildlife Society
TWASA Transactions Wisconsin Academy of Sciences, Arts, and Letters

UTSCB	Utah Science
VILTA	Viltrevy
VIWIA	Virginia Wildlife
WDABB	Bulletin of the Wildlife Disease Association
WLMOA	Wildlife Monographs
WLSBA	Wildlife Society Bulletin
WSCBA	Wisconsin Conservation Bulletin
WVAFA	West Virginia Agriculture and Forestry
XARRA	U S Forest Service Research Note RM
XFNCA	U S Forest Service Research Paper NC
XFWLA	U S D I Fish and Wildlife Service, Wildlife Leaflet
ZEJAA	Zeitschrift fuer Jagdwissenschaft

LIST OF PUBLISHERS - CHAPTER NINETEEN

acpr	Academic Press	New York	nyny
amel	American Elsevier Publ. Co., Inc.	New York	nyny
dove	Dover Pub. Co.	New York	nyny
fost	Forest and Stream Publishing Co.	New York	nyny
isup	Iowa State University Press	Ames, IO	amia
jwis	John Wiley and Sons, Inc.	New York, NY	nyny
meth	Methuen & Co., Ltd.	London	loen
olbo	Oliver and Boyd	Edinburgh, Scotland	edsc
oost	Oosterbeek	The Netherlends	neth
prup	Princeton Univ. Press	Princeton, NJ	prnj
saco	Saunders Publishing Co.	Philadelphia, PA	phpa
ualb	University of Alberta Press	Edmonton, Alberta	edal
uchp	Univ. of Chicago Press	Chicago, IL	chil
utnp	Univ. Tennesse Press	Knoxville, TN	kntn
whfr	W. H. Freeman Co.	San Francisco, CA	sfca
wiso	Wildlife Society, The	Washington, D.C.	wadc
wmmo	Wm. Morrow and Co.	New York	nyny

LIST OF WORKSHEETS - CHAPTER NINETEEN

JULIAN DAY: MONTH AND DAY EQUIVALENTS*

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

CHAPTER TWENTY

CALCULATIONS OF CARRYING CAPACITY

by

Aaron N. Moen

Professor of Wildlife Ecology

Department of Natural Resources

College of Agriculture and Life Sciences

Cornell University

Ithaca, N.Y. 14853

and

Certified Wildlife Biologist

(The Wildlife Society)

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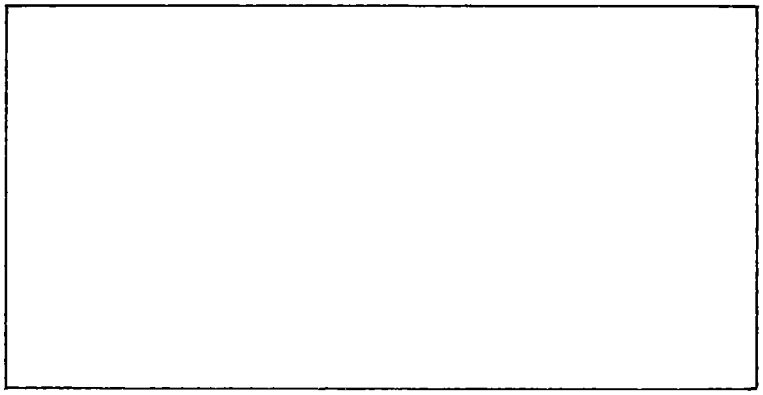
CONTENTS OF CHAPTER TWENTY

CALCULATIONS OF CARRYING CAPACITY

CHAPTER 20. CALCULATIONS OF CARRYING CAPACITY



How many rectangles will fit in the rectangle above? There is, at this point, only one correct answer to that question. An infinite number will fit. If they are small, many will fit. If they are large, few or only a fraction of one will fit. How do we know that to be true? Each rectangle takes up some space--it uses up some of the space resource--and if each one uses a lot of this resource, there is little left for others. If each rectangle uses just a little of the space resource, there is a lot of space left for others.

Suppose that one side of the rectangle above is 10 cm and the other side is 5 cm. The area of the rectangle is easily determined to be 50 square centimeters. How many smaller rectangles, each with an area of 1.0 SQCM (SQCM = square centimeter), will fit? Fifty. How many rectangles, each with an area of 5 SQCM, will fit? Ten. The answer seems so logical that it sort of "falls in place." You actually did a calculation, however, dividing 50 by 5 to get 10. You used a very high-speed computer--your mind--to compute the equation 50/5 = 10.

The rectangle and question above illustrate the biological concept of carrying capacity. How many deer will an area of land support? How many elk? Moose? Bison? Pronghorn? Caribou? These biological questions, not as simple as the plane geometry one about the rectangle, cannot be answered unless both the resources available on the range and the resources required by the animal are known. Animal and range are inexorably linked together.

Animals cannot be very small or very large like a rectangle can, so there are not an infinite number of answers to the question, however. Further, many biological resources are involved in the concept of carrying capacity; space (see PART II) is one, food (see PART IV) is another. Metabolic requirements are discussed in PART III, and modifiers of these relationships are discussed in PART V.

The basic relationship for calculating carrying capacity may be expressed with the word formula:

Resources available/resources required = Number supported

Food is a fundamental resource to be considered when calculating carrying capacity. The formula for determining the number of animals supported by the food energy resource is:

Number supported =
Metabolizable range energy/metabolizable energy required per individual

Note that metabolizable energy is used in the above formula. This is the ultimate level of interaction between animal and range, the biochemical plane at which the interaction occurs.

A white-tailed deer may require an average of 2500 kcal of energy per day during the winter. If the range supplies 40 kg of forage per hectare, the equation for determining the number supported is:

$$(40)(4500)(0.50)(0.82)/2500 = 73800/2500 = 29.5$$

if the gross energy per kg of forage is 4500 kcal, the digestible energy coefficient 0.50, and the metabolizable energy coefficent is 0.82. The answer, 29.5, is based on all of the energy being consumed. If only half should be consumed, then

$$(73800)(0.50)/2500 = 14.8,$$

and if only three-fourths of that is available, then

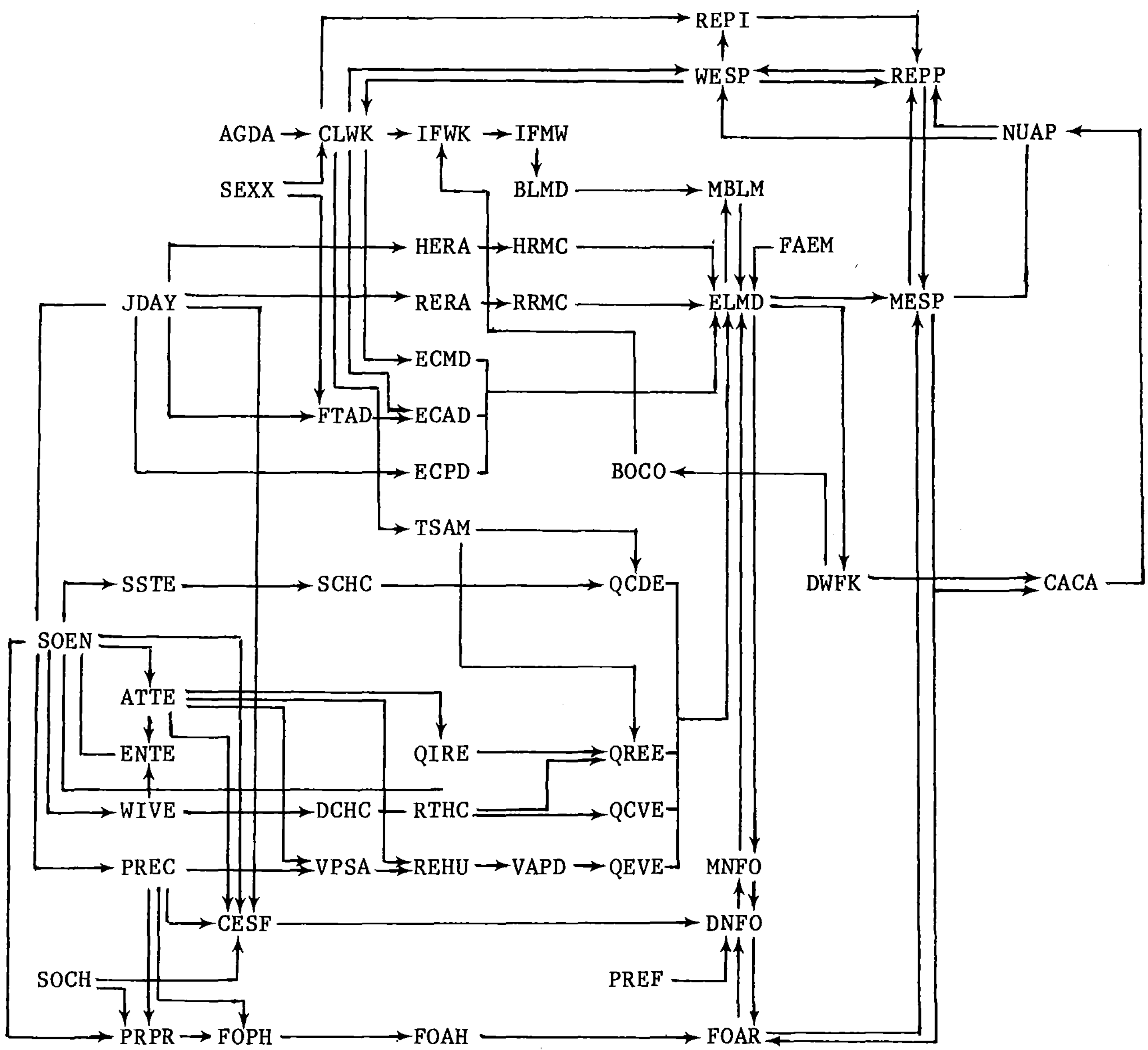
$$(73800)(0.50)(0.75)/2500 = 11.1.$$

Eleven deer-days are supported by 40 kg of forage, given these constraints.

Requirements change through time, and so do range resources. Thus one cannot make a single calculation for a given area and say that the answer is <u>the</u> carrying capacity for that area. Rather, carrying capacity changes with seasons as both the resources available and resources required change.

Modifiers of the resources available and resources required are illustrated on the flow chart on page 3. They should be familiar to those of you who have completed all of the WORKSHEETS in the first 19 CHAPTERS. The mathematical evaluations have been based on biological and physical functions, presented for analyses with scientific calculators so thoughts are converted to numerical statements that can be linked together and the relationships evaluated.

BIOLOGICAL RELATIONSHIPS CONSIDERED IN THE CALCULATION OF CARRYING CAPACITY



DEFINITIONS OF SYMBOLS IN THE FLOW CHART

AGDA = Age in days
ATTE = Atmospheric temperature

BLMD = Base-line metabolism per day
BOCO = Body composition

CACA = Carrying capacity
CESF = Cell structure of forage
CLWK = Calculated live weight in kg

DCHC = Dynamic conductivity of the hair coat
DNFO = Digestible nutrients in the forage
DWFK = Dry weight forage in kg

ECAD = Energy cost of activity per day
ECMD = Energy cost of maintenance per day
ECPD = Energy cost of production per day
ELMD = Ecological metabolism per day
ENTE = Environmental temperature

FAEM = Factors affecting ecological metabolism
FOAH = Forage available per hectare
FOAR = Forage available on the range
FOPH = Forage production per hectare
FTAD = Fraction of time in activity per day

HERA = Heart rate
HRMC = Heart rate to metabolism conversion

IFMW = Ingesta-free metabolic weight
IFWK = Ingesta-free weight in kg

JDAY = Julian day

MBLM = Multiple of base-line metabolism
MESP = Metabolic structure of the population
MNFO = Metabolizable nutrients in the forage

NUAP = Number of animals in the population

PREC = Precipitation
PREF = Preference of the consumer for forage species
PRPR = Primary production

QCDE = Quantity of conductive energy exchange
QCVE = Quantity of convective energy exchange
QEVE = Quantity of evaporative energy exchange
QIRE = Quantity of infrared energy exchange
QREE = Quantity of radiant energy exchange

REHU = Relative humidity
REPI = Reproductive potential of the individual
REPP = Reproductive potential of the population
RERA = Respiration rate
RRMC = Respiration rate to metabolism conversion
RTHC = Radiant temperature of the hair coat

SCHC = Static conductivity of the hair coat
SEXX = Sex of the animal
SOCH = Soil characteristics
SOEN = Solar energy
SSTE = Substrate temperature

TSAM = Total surface area in square meters

VAPD = Vapor pressure deficit
VPSA = Vapor pressure of saturated air

WESP = Weight structure of the population
WIVE = Wind velocity

Not all of the parameters included in the flow chart on page 3 are used in every calculation of carrying capacity. Those listed, and more that are not listed, are modifiers of carrying capacity, affecting either animals' requirements or range supplies.

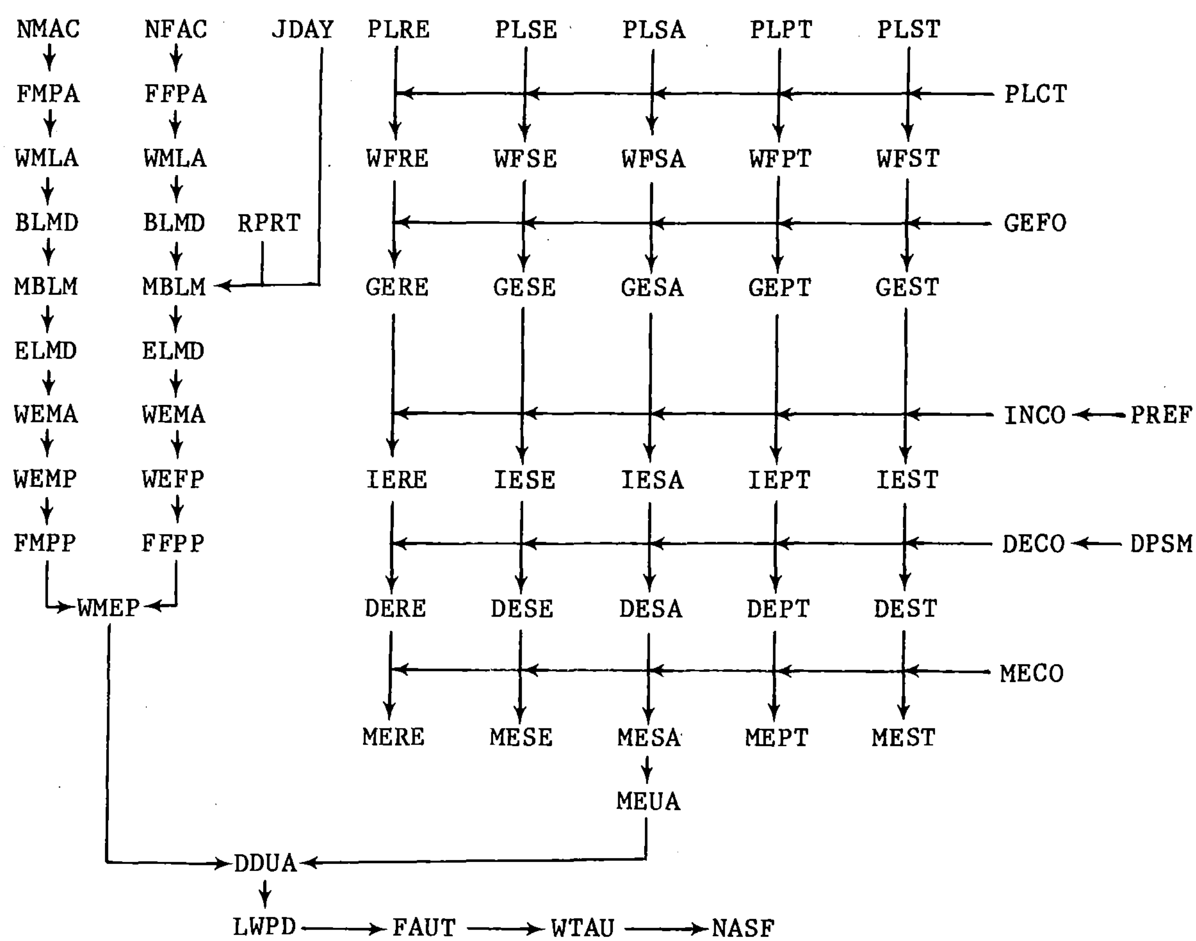
The calculations of carrying capacity in this CHAPTER 20 will emphasize the forage resources (TOPIC 1), with some considerations of space resources in TOPIC 2.

TOPIC 1. FORAGE RESOURCES

Forage resources are an appropriate base for the calculation of carrying capacities for wild ruminant range, because of the potential impact these animals can have on these resources. Calculations of carrying capacity in relation to forage resources are made in relation to particular nutrients in the forages consumed. Hence it is necessary to identify the nutrient being used as a base. Calculations of the amounts of forage consumed were described for an energy base in CHAPTER 12, TOPIC 3; for a protein base TOPIC 4, and for a mineral base in TOPIC 5 of CHAPTER 12.

The first of these, energy, has been evaluated quite thoroughly and calculations may be readily made for available data. The second, protein, has been evaluated to a considerable extent, and first-approximation calculations may be made. The third, minerals, are not well understood in the ecological context as requirements have not be determined and mineral compositions of different forages are not well known.

A flow sheet for the calculation of carrying capacity of white-tailed deer based on the forage production in different stages of forest succession in New York State is shown below. The meanings of all of the symbols have been defined and discussed, so the calculations may now be linked together within the concept of carrying capacity.



DEFINITIONS OF SYMBOLS USED

BLMD = Base-line metabolism per day - CHAPTER 7

DDUA = Deer days of forage per unit area - CHAPTER 20, TOPIC 2
DECO = Digestible energy coefficient - CHAPTER 11
DEPT = Digestible energy in pole timber area - CHAPTER 11
DERE = Digestible energy in regeneration area - CHAPTER 11
DESA = Digestible energy in sapling area - CHAPTER 11
DESE = Digestible energy in seedling area - CHAPTER 11
DEST = Digestible energy in saw timber area - CHAPTER 11
DPSM = Number of deer per square mile - CHAPTER 18, TOPIC 1

ELMD = Ecological metabolism per day - CHAPTER 7

FAUT = Fraction of the area used per unit time - CHAPTER 3, UNIT 3.2
FFPA = Fraction of the female population in each age class - CHAPTER 18, UNIT 2.1
FFPP = Fraction of the total population in the female population - CHAPTER 18, UNIT 2.1
FMPA = Fraction of the male population in each age class - CHAPTER 18, UNIT 2.1
FMPP = Fraction of the total population in the male population - CHAPTER 18, UNIT 2.1

GEFO = Gross energy in forage - CHAPTER 11
GEPT = Gross energy in pole timber area - CHAPTER 11
GERE = Gross energy in regeneration area - CHAPTER 11
GESA = Gross energy in sapling area - CHAPTER 11
GESE = Gross energy in seedling area - CHAPTER 11
GEST = Gross energy in saw timber area - CHAPTER 11

IEPT = Ingestible energy in pole timber area
IERE = Ingestible energy in regeneration area
IESA = Ingestible energy in sapling area
IESE = Ingestible energy in seedling area
IEST = Ingestible energy in saw timber area
INCO = Ingestibility coefficient

JDAY = Julian day of the year

LWPD = Length of the winter period in days

MBLM = Multiple of base-line metabolism - CHAPTER 7
MECO = Metabolizable energy coefficient - CHAPTER 11
MEPT = Metabolizable energy in pole timber area - CHAPTER 11
MERE = Metabolizable energy in regeneration area - CHAPTER 11
MESA = Metabolizable energy in sapling area - CHAPTER 11
MESE = Metabolizable energy in seedling area - CHAPTER 11
MEST = Metabolizable energy in saw timber area - CHAPTER 11
MEUA = Metabolizable energy per unit area - CHAPTER 11

NASF = Number of animals supported by the forage - CHAPTER 20, TOPIC 1
NFAC = Number of females in each age class - CHAPTER 18, UNIT 2.1
NMAC = Number of males in each age class - CHAPTER 18, UNIT 2.1

PLCT = Percent of land in each cover type - CHAPTER 13, UNIT 1.4
PLPT = Percent of land in pole timber stage - CHAPTER 13, UNIT 1.4
PLRE = Percent of land in regeneration stage - CHAPTER 13, UNIT 1.4
PLSA = Percent of land in sapling stage - CHAPTER 13, UNIT 1.4
PLSE = Percent of land in seedling stage - CHAPTER 13, UNIT 1.4
PLST = Percent of land in saw timber - CHAPTER 13, UNIT 1.4
PREF = Deer preference for forage species - CHAPTER 12, UNIT 1.2

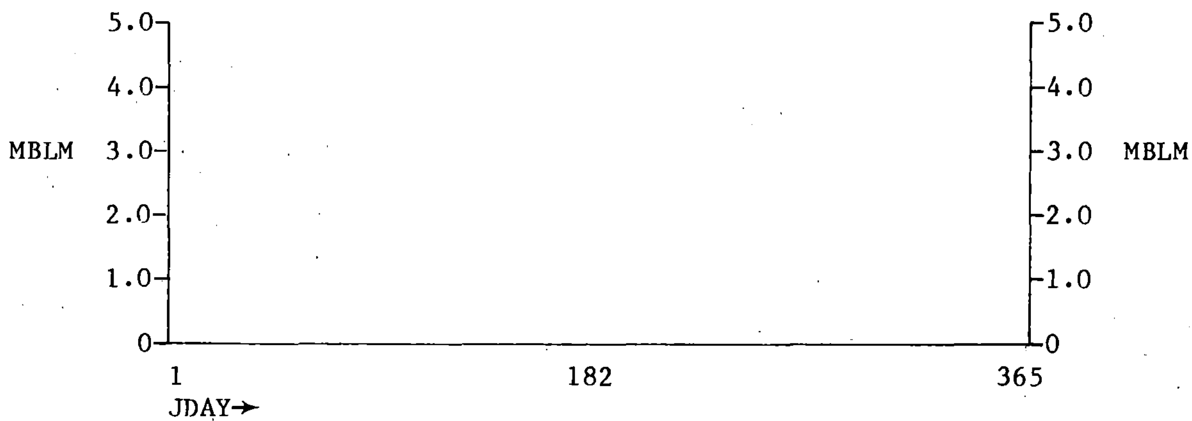
RPRT = Reproductive rate - CHAPTER 19, UNIT 1.1

WEFP = Weighted-mean ecological metabolism of the female population - CHAPTER 18, UNIT 2.5
WEMA = Weighted-mean ecological metabolism of the age class - CHAPTER 18, UNIT 2.5
WEMP = Weighted-mean ecological metabolism of the male population - CHAPTER 18, UNIT 2.5
WFPT = Weighted-mean forage production in pole timber area - CHAPTER 13, UNIT 1.4
WFRE = Weighted-mean forage production in regeneration area - CHAPTER 13, UNIT 1.4
WFSA = Weighted-mean forage production in sapling area - CHAPTER 13, UNIT 1.4
WFSE = Weighted-mean forage production in seedling area - CHAPTER 13, UNIT 1.4
WFST = Weighted-mean forage production in saw timber area - CHAPTER 13, UNIT 1.4
WMEP = Weighted-mean ecological metabolism of the population - CHAPTER 18, UNIT 2.5
WMLA = Weighted-mean live weight of the age class - CHAPTER 18, UNIT 2.2
WTAU = Weighted-mean time and area used - CHAPTER 3, UNIT 3.2

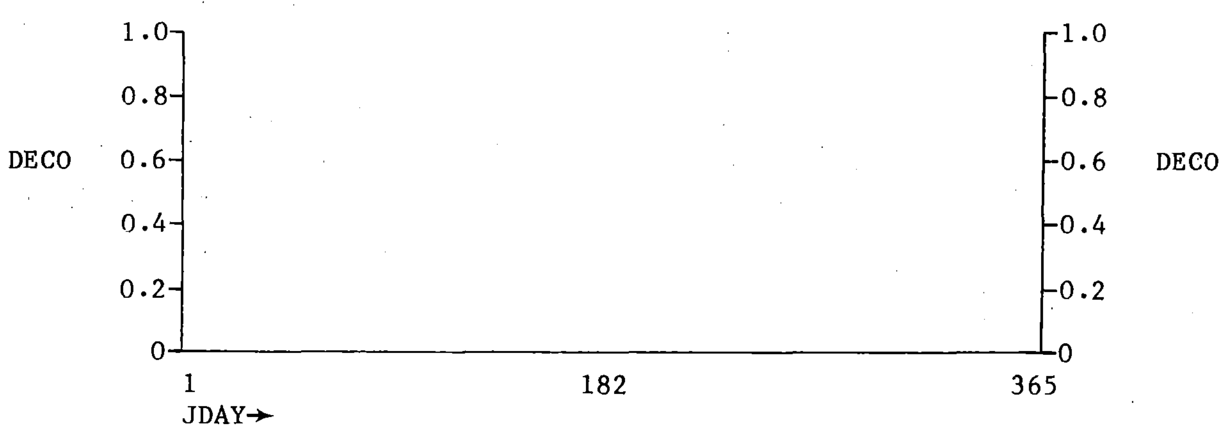
The first five UNITS that follow are based on energy and the sixth on protein. The basic formula for calculating carrying capacity as a relationship between resources required and resources available is the same for all nutrients; only the data are missing for some of the nutrients so they cannot be used as a base for calculating carrying capacity.

UNIT 1.1: CARRYING CAPACITY CHANGES IN RELATION TO ENERGY METABOLISM RHYTHMS

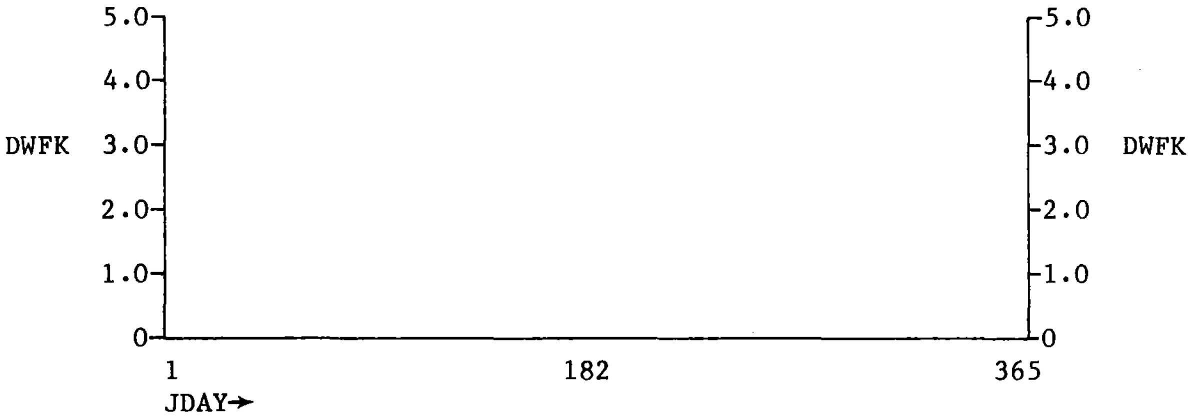
Forage consumption in relation to energy metabolism rhythms was illustrated for the annual cycle that was described for white-tailed deer in my paper in the Journal of Wildlife Management (Moen 1978). The calculations included seasonal changes in energy metabolism, seasonal changes in diet digestibility, and variations in the timing of the length of winter and arrival of spring. Seasonal changes in energy metabolism have also been discussed at length in CHAPTER 7 of this book, emphasizing the use of the multiple of base-line metabolism to represent different levels of cost throughout the year. As a review of the seasonal changes in ecological metabolism, draw the seasonal pattern of variations in the multiple of base-line metabolism (MBLM) in the space below.



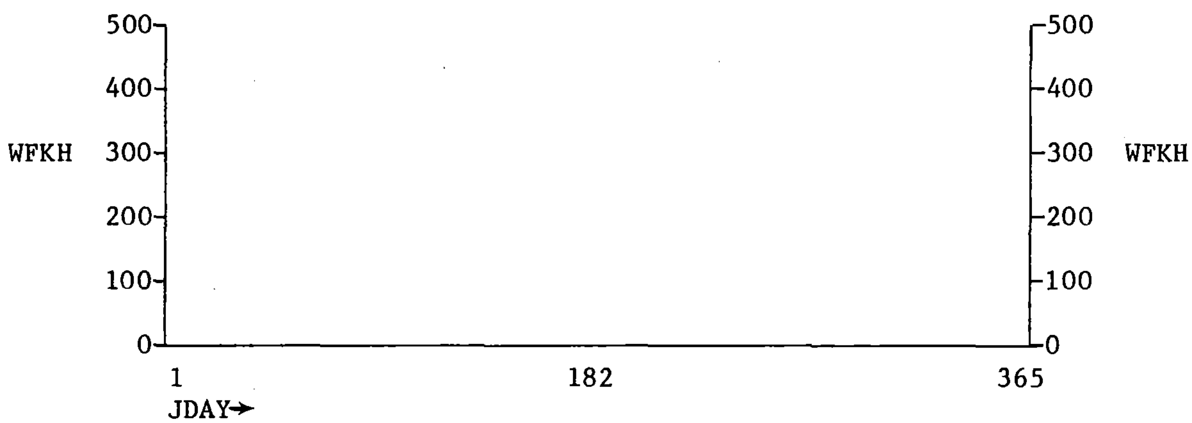
Diet digestibilities change as a result of seasonal patterns of cell development and plant growth. These were discussed in CHAPTER 11. As a review, draw the seasonal pattern of variations in digestible energy coefficient and metabolizable energy coefficients in the space below.



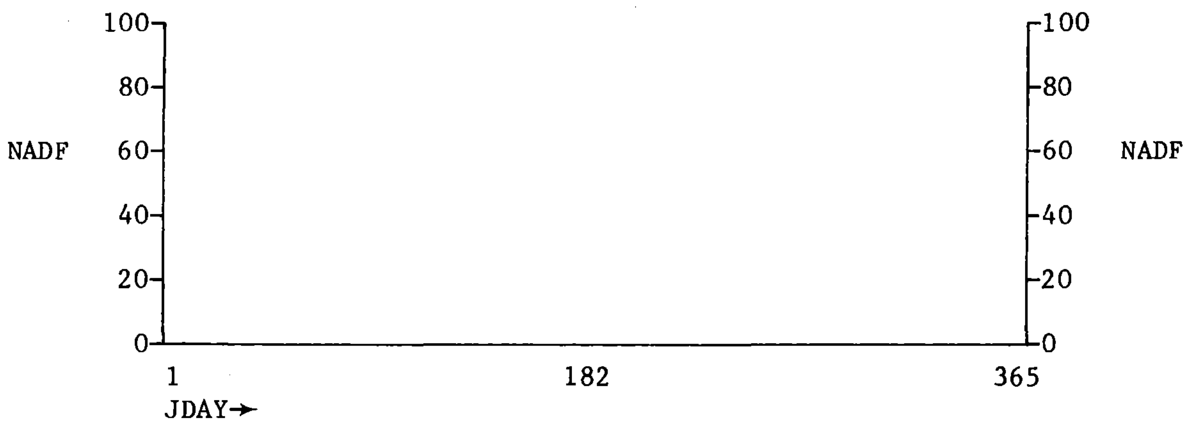
The amount of forage required to meet daily energy needs is calculated by dividing the ecological metabolism per day by the metabolizable energy in the forage. Doing that for your two review illustrations above, plot the pattern of dry weight forage in kg (DWFK) required to meet metabolic needs in the space below. How does your pattern compare to the calculated values published in Moen (1978:734 and 735)? Review the calculations of forage consumption, complete additional calculations as necessary, and then go on to the calculation of carrying capacity.



Calculations of carrying capacity must consider changes in the amount of forage available to wild ruminants throughout the annual cycle. Primary production in different plant communities was discussed in CHAPTER 13. As a review, draw the seasonal patterns of the weight of forage available in kg per hectare (WFKH) in the space below.



A final picture can now be drawn for this sequence. The number of animal days supported by the forage (NADF) plotted over the annual cycle will show that the carrying capacity of the range varies throughout the year. Specifically, the number of animal days supported by the forage will decline in the early part of the calendar year when winter is still present, and then rise sharply when plant growth begins and forage becomes abundant. As plant growth slows, NADF declines slowly. Then, when snow covers up much of the available forage from the previous summer growth leaving only the woody browse available, carrying capacity, expressed as NADF, declines sharply. As winter progresses, it declines further, at a slower rate. Illustrate the pattern below, mentally integrating these changes through the annual cycle.



The shape and values of the curve drawn above varies in relation to the specific values for ELMD, DECO, and WFKH through time. WORKSHEETS provide opportunities for you to compile your own data and make your own calculations.

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 1.1

CARRYING CAPACITY CHANGES IN RELATION TO ENERGY METABOLISM RHYTHMS

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	9---4	319	322	odvi	symptoms, deer malnutritio	harris,d	1945
JWMAA	42--4	715	738	odvi	seas, metab, forage intake	moen,an	1978

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

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

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

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

HMECA 7---2 135 149 doca comp energ flow, graz anim ellis,je; jennin/ inpr

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
CEXSB	TB109	1	28	many	energ budg rang, ran lives	cook,cw	1970
ECMOA	30--2	187	206	many	energ dyn, food ch, old fi	golley,fb	1960
ESASA	26---	89	125	many	mamm cons mod for grasslan	anway,jc	1978
JWMAA	3---4	295	306	many	yellowst wint rnge studies	grimm,rl	1939

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
AECOD	3---1	45	54	....	energy flow and partioning	coleman,dc; andr/	1976

UNIT 1.2: CARRYING CAPACITY CHANGES IN RELATION TO HORIZONTAL AND VERTICAL DISTRIBUTIONS OF FORAGE

Forage energy is not uniformly distributed in space. Differences between stages in succession and between plant communities occur, and differences in the vertical distribution of forage within plant communities occur. These differences were discussed in CHAPTER 13.

The vertical distribution of forage is an important consideration in the winter when the balance between resources required and resources available is critical. The use of three different white-tailed deer weights will illustrate calculations of carrying capacity in relation to the vertical distribution of forage.

Suppose the data tabulated below are used to calculate ecological metabolism per day (ELMD) (see CHAPTER 7) and the height of forage reached in cm (HFRC) is calculated with the following equation from CHAPTER 1, WORKSHEET 2.2b, Page 36b:

$$HFRC = 145 + 0.792\ LIWK$$

where LIWK = live weight in kg, and may be considered equal to CLWK. Complete the two columns on the right in the table below.

MALES

CLASS	AGCL	JDAY	AGDA	NMAC	CLWK	IFWK	MWKG	MBLM	x	BLMD	=	ELMD	HFRC
ACa-.	____	____	____	____	____	____	____	____	x	____	=	____	____
ACb-.	____	____	____	____	____	____	____	____	x	____	=	____	____
ACc-.	____	____	____	____	____	____	____	____	x	____	=	____	____

SUMS = [____]
TNMP

FEMALES

CLASS	AGCL	JDAY	AGDA	NFAC	CLWK	IFWK	MWKG	RPRT	MBLM	x	BLMD	=	ELMD	HFRC
ACaa.	____	____	____	____	____	____	____	____	____	x	____	=	____	____
ACbb.	____	____	____	____	____	____	____	____	____	x	____	=	____	____
ACcc.	____	____	____	____	____	____	____	____	____	x	____	=	____	____

SUMS = [____]
TNFP

The weight of forage in kg per hectare in the 70-year-old mixed hardwood stand discussed in CHAPTER 13, WORKSHEET 1.3b, Page 24b. The equation, with rounded numbers, is given below.

$$WFKH = 2.3 + 0.04\ HFRC$$

For males, WFKH = _____ when CLWK = 45,

_____ when CLWK = 70, and

_____ when CLWK = 85.

For females, WFKH = _____ when CLWK = 42,

_____ when CLWK = 56, and

_____ when CLWK = 62.

Dry weight forage consumption in kg is determined by (See CHAPTER 12):

$$DWFK = ELMD/[(GEFO)(DECO)(MECO)]$$

and the number of animal days supportd by the forage is determined by:

$$NADF = WFKH/DWFK$$

Complete the following table.

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	____	____	____	/	____	=	____
ACaa.	____	____	____	/	____	=	____
ACb-.	____	____	____	/	____	=	____
ACbb.	____	____	____	/	____	=	____
ACc-.	____	____	____	/	____	=	____
ACcc.	____	____	____	/	____	=	____

Note how NADF varies due to differences in the amounts of forage within reach of the animals, and in relation to differences in ELMD. The larger, higher-reaching animals are not very considerate, of course, eating forage at the lower heights as well, depriving the smallest animals of some of the only forage they can reach.

The example above illustrates how the effects of different vertical distributions on carrying capacity may be calculated. WORKSHEETS provide opportunities for you to complete calculations for species and areas of your choice.

REFERENCES, UNIT 1.2

CARRYING CAPACITY CHANGES IN RELATION TO HORIZONTAL AND VERTICAL DISTRIBUTIONS OF FORAGE

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAPEA	14-2	433	444	odvi	veget habitat classificatn	stocker,m; gilber	1977
PCGFA	14---	98	103	odvi	deter rnge carry capac, ga	moore,wh; ripley/	1960

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				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
CLCHA	18--7	605	612		est norm range & cum propo	harris,ek; demets	1972

CODEN	VO-NU	BEPA	ENPA	FRGE*	KEY WORDS-----------------	AUTHORS----------	YEAR
JFUSA	65-11	807	813	frge	forest cover and logging	young,ja; hedric/	1967
JRMGA	25--6	446	449	frge	yld, 2 for zon, n b, nov s	telfer,es	1972
PSAFA	1962-	165	167	frge	timb ovrstry detrm od fora	schuster,jl; hall	1962
RWLBA	9---1	1	146	frge	edge eff, lesser veg, adir	barick,fb	1950
XFPNA	112--	1	12	frge	seas forag use, elk & deer	edgerton,pj; smit	1971
XFWWA	43...	1	48	frge	rata st matthw islan range	klein,dr	1959
ZHIVA	11...	62	68	frge	rata fodder supply, zhivot	ustinov,vi; pokro	1954

*FRGE = forage type

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
CNSVA	27--6	37	37	brws	propos to imprv od habitat	severinghaus,cw	1973
JWMAA	5---1	90	94	brws	mgt sugges for wh-cedr typ	aldous,se	1941
JWMAA	23--3	273	278	brws	odvi win rng veg stud, wis	habeck,jr	1959
JWMAA	35--3	533	537	brws	wldlf food, hrdwd, reg cut	crawford,hs,jr; /	1971
JWMAA	40--2	326	329	brws	odvi brwse inventor, louis	pearson,ha; stern	1976
MXSBA	294--	1	43	brws	isl roy forst, wldlf, fire	hansen,hl; kreft/	1973
NAWTA	18---	581	596	brws	od yard carry cap, browsng	davenport,la; sw/	1953
NFGJA	14--2	193	198	brws	witchhob, site exp, brwsng	bailey,ja	1967
PCGFA	9----	134	156	brws	brow cens, 100 % clip meth	harlow,rf	1955
VILTA	9---3	45	192	brws	wiru, win habita, land use	ahlen,i	1975
WLSBA	6---4	259	260	brws	age, densi, fert, oak prod	wolgast,lj	1978
XFNSA	140--	1	4	brws	odvi browse resourc, arkan	segelquist,ca; p/	1972
XFSEA	2----	1	20	brws	od browse resourc, n georg	ripley,th; mcclur	1963

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	32--1	185	186	twig	brows yield, forst opening	halls,lk; alcaniz	1968

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	27--3	195	204	hrbg	graz val natv veg, so pine	campbell,rs	1946
ECOLA	35--1	59	62	hrbg	for prod, longlf pne, alab	gaines,em; campb/	1954
JECOA	45--2	593	599	hrbg	stand crop nat veg, subarc	pearsall,wh; newb	1957
JFUSA	63--4	282	283	hrbg	tree - herbage relations	hall,lk; schuster	1965
JRMGA	5---2	76	80	hrbg	herb, ungu, wint-rang util	buechner,hk	1952
JRMGA	26--6	423	426	hrbg	s pine overstory infl herb	wolters,gl	1973
PSAFA	1957-	156	158	hrbg	undrstory veg, stand chars	pase,cp; hurd,rm	1957

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	50--5	802	804	leav	foliage profile, vert meas	macarthur,rh; hor	1969

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS------------------	AUTHORS----------	YEAR
JFUSA	48--2	118	126	gras	chng pond pne bnchgras rng	arnold,jf	1950

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS------------------	AUTHORS----------	YEAR
ASZBA	16--2	155	161	lich	prod arboreal lichns, rata	scotter,gw	1961

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS------------------	AUTHORS----------	YEAR
ECMOA	35...	259	284		ecolog, deer range, alaska	klein,dr	1965
JFUSA	46--6	416	425		util summ range plnts, uta	cook,cj; cook,cw/	1948
JWMAA	32--2	330	337		odvi food ylds, 4 for typs	segelquist,ca; gr	1968
JWMAA	42--4	799	810		ceel diet, actv, ldgpl pne	collins,wb; urne/	1978
WMBAA	18---	1	111		effs wldfre rata wint rnge	scotter,gw	1964

FRGE = forage type

frge = mixed or unspecified forage types
brws = browse
twig = twigs
hrbg = herbage or herbaceous vegetation
leav = leaves
gras = grasses
lich = lichens

CHAPTER 20, WORKSHEET 1.2a

Calculating carrying capacity for male white-tailed deer in relation to the vertical distribution of forage

The amount of forage (WFKH) varies with height above the ground, and can be calculated using the equation on Page 17 of this UNIT. Formats are given below and on the next page for tabulating five sets of calculations of carrying capacity for male white-tailed deer based on the vertical distribution of forage. Refer back to Page 18 for a review of the calculations of dry-weight forage in kg (DWFK) required to meet the cost of ecological metabolism per day.

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	____	____	____	/	____	=	____
ACb-.	____	____	____	/	____	=	____
ACc-.	____	____	____	/	____	=	____
ACd-.	____	____	____	/	____	=	____
ACe-.	____	____	____	/	____	=	____
ACf-.	____	____	____	/	____	=	____
ACg-.	____	____	____	/	____	=	____
ACh-.	____	____	____	/	____	=	____
ACi-.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	____	____	____	/	____	=	____
ACb-.	____	____	____	/	____	=	____
ACc-.	____	____	____	/	____	=	____
ACd-.	____	____	____	/	____	=	____
ACe-.	____	____	____	/	____	=	____
ACf-.	____	____	____	/	____	=	____
ACg-.	____	____	____	/	____	=	____
ACh-.	____	____	____	/	____	=	____
ACi-.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH / DWFK	=	NADF
ACa-.	____	____	____ / ____	=	____
ACb-.	____	____	____ / ____	=	____
ACc-.	____	____	____ / ____	=	____
ACd-.	____	____	____ / ____	=	____
ACe-.	____	____	____ / ____	=	____
ACf-.	____	____	____ / ____	=	____
ACg-.	____	____	____ / ____	=	____
ACh-.	____	____	____ / ____	=	____
ACi-.	____	____	____ / ____	=	____

CLASS	CLWK	HFRC	WFKH / DWFK	=	NADF
ACa-.	____	____	____ / ____	=	____
ACb-.	____	____	____ / ____	=	____
ACc-.	____	____	____ / ____	=	____
ACd-.	____	____	____ / ____	=	____
ACe-.	____	____	____ / ____	=	____
ACf-.	____	____	____ / ____	=	____
ACg-.	____	____	____ / ____	=	____
ACh-.	____	____	____ / ____	=	____
ACi-.	____	____	____ / ____	=	____

CLASS	CLWK	HFRC	WFKH / DWFK	=	NADF
ACa-.	____	____	____ / ____	=	____
ACb-.	____	____	____ / ____	=	____
ACc-.	____	____	____ / ____	=	____
ACd-.	____	____	____ / ____	=	____
ACe-.	____	____	____ / ____	=	____
ACf-.	____	____	____ / ____	=	____
ACg-.	____	____	____ / ____	=	____
ACh-.	____	____	____ / ____	=	____
ACi-.	____	____	____ / ____	=	____

CHAPTER 20, WORKSHEET 1.2b

Calculating carrying capacity for female white-tailed deer in relation to the vertical distribution of forage

The amount of forage (WFKH) varies with height above the ground, and can be calculated using the equation on Page 17 of this UNIT. Formats are given below and on the next page for tabulating five sets of calculations of carrying capacity for female white-tailed deer based on the vertical distribution of forage. Refer back to Page 18 for a review of the calculations of dry-weight forage in kg (DWFK) required to meet the cost of ecological metabolism per day.

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	____	____	____	/	____	=	____
ACbb.	____	____	____	/	____	=	____
ACcc.	____	____	____	/	____	=	____
ACdd.	____	____	____	/	____	=	____
ACee.	____	____	____	/	____	=	____
ACff.	____	____	____	/	____	=	____
ACgg.	____	____	____	/	____	=	____
AChh.	____	____	____	/	____	=	____
ACii.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	____	____	____	/	____	=	____
ACbb.	____	____	____	/	____	=	____
ACcc.	____	____	____	/	____	=	____
ACdd.	____	____	____	/	____	=	____
ACee.	____	____	____	/	____	=	____
ACff.	____	____	____	/	____	=	____
ACgg.	____	____	____	/	____	=	____
AChh.	____	____	____	/	____	=	____
ACii.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	_____	_____	_____	/	_____	=	_____
ACbb.	_____	_____	_____	/	_____	=	_____
ACcc.	_____	_____	_____	/	_____	=	_____
ACdd.	_____	_____	_____	/	_____	=	_____
ACee.	_____	_____	_____	/	_____	=	_____
ACff.	_____	_____	_____	/	_____	=	_____
ACgg.	_____	_____	_____	/	_____	=	_____
AChh.	_____	_____	_____	/	_____	=	_____
ACii.	_____	_____	_____	/	_____	=	_____

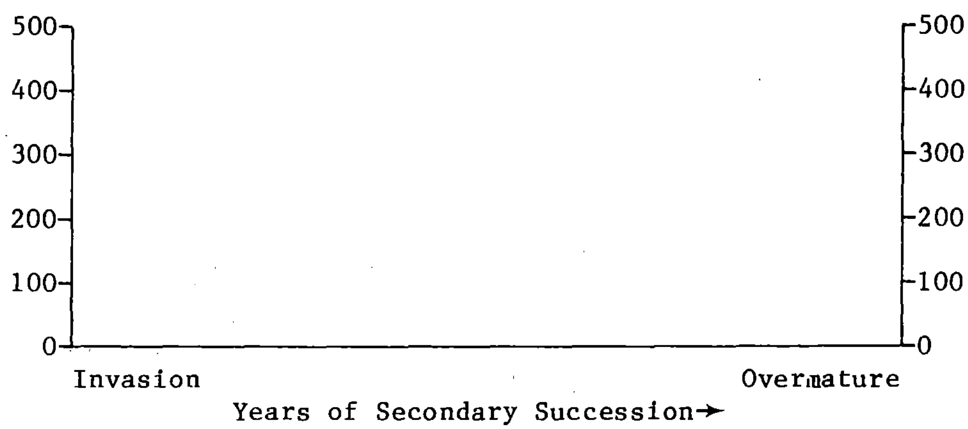
CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	_____	_____	_____	/	_____	=	_____
ACbb.	_____	_____	_____	/	_____	=	_____
ACcc.	_____	_____	_____	/	_____	=	_____
ACdd.	_____	_____	_____	/	_____	=	_____
ACee.	_____	_____	_____	/	_____	=	_____
ACff.	_____	_____	_____	/	_____	=	_____
ACgg.	_____	_____	_____	/	_____	=	_____
AChh.	_____	_____	_____	/	_____	=	_____
ACii.	_____	_____	_____	/	_____	=	_____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	_____	_____	_____	/	_____	=	_____
ACbb.	_____	_____	_____	/	_____	=	_____
ACcc.	_____	_____	_____	/	_____	=	_____
ACdd.	_____	_____	_____	/	_____	=	_____
ACee.	_____	_____	_____	/	_____	=	_____
ACff.	_____	_____	_____	/	_____	=	_____
ACgg.	_____	_____	_____	/	_____	=	_____
AChh.	_____	_____	_____	/	_____	=	_____
ACii.	_____	_____	_____	/	_____	=	_____

UNIT 1.3: CARRYING CAPACITY CHANGES IN RELATION TO STAGES IN SUCCESSION

Forage production is, in part, a function of canopy characteristics. Canopy characteristics in forested areas change from no overhead canopy to a very dense overhead canopy as secondary succession proceeds from the early invasion stage to the mature forest. As the forest becomes overmature, the canopy opens up again and forage production increases in response to added light penetration.

As a review, draw the pattern of forage production expected over a period of secondary succession from the invasion stage to the overmature stage.



Compare your pattern above with that discussed in CHAPTER 13, UNIT 1.4.

Now select suitable average values for the weight and ecological metabolism of a population (MBLM = 2.5 is a suitable annual average to use for determining ELMD to demonstrate this pattern), and an average digestibility coefficient, and calculate the carrying capacity at one or several year intervals through the forage production pattern drawn above. How does your pattern compare to that of Wallmo and Schoen (1980), or to the results of calculations made in earlier CHAPTERS?

Calculations for populations in given areas may be made on the WORKSHEET at the end of this UNIT. It is my recomendation that management decisions concerning the hunting of wild ruminants should always be accompanied by evaluations of carrying capacity, thereby evaluating not only the potential changes in the animal population but also the potential effects of those changes on forage and range conditions.

LITERATURE CITED

Wallmo, O. C. and J. W. Schoen. 1980. Response of deer to secondary forest succession in Southeast Alaska. Forest Sci. 26(3):448-462.

REFERENCES, UNIT 1.3

CARRYING CAPACITY CHANGES IN RELATION TO STAGES IN SUCCESSION

SERIALS

CODEN	VO-NU	BEPA	ENPA	FRGE*	KEY WORDS-----------------	AUTHORS----------	YEAR
CNSVA	29--1	39	48	frge	return of the deer	severinghaus,cw	1974
FOSCA	26--3	448	462	frge	resp deer sec succ, alaska	wallmo,oc; schoen	1980

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
CNRDA	28--5	249	271	brws	alal, successn, quan, nutr	cowan,im; hoar,w/	1950
JFUSA	48-10	675	678	brws	deer in reln plnt successn	leopold,as	1950
JFUSA	56--6	416	421	brws	od brws prod fr felled tre	stoeckeler,jh; k/	1958
NAWTA	15---	571	578	brws	deer in reln plnt successn	leopold,as	1950

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	41--1	34	49	gras	orgnc produc, old fld succ	odum,ep	1960

CODEN	VO-NU	BEPA	ENPA	FRGE	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	85--3	231	234		chngs carr capac deer rnge	telfer,es	1971
ECMOA	24--4	349	376		ecol successi abandon farm	beckwith,sl	1954
FRCRA	29--3	218	232		survey, conif fores, rocki	cormack,rgh	1953
WMBAA	18---	1	111		effs wldfre rata wint rnge	scotter,gw	1964

FRGE = forage type

frge = mixed or unspecified forage type
brws = browse
gras = grass

*FRGE = forage type

CHAPTER 20, WORKSHEET 1.3a

Carrying capacity changes in relation to stages in succession

The format for calculating carrying capacity in relation to stages in succession is very similar to that for vertical distribution of forage shown in WORKSHEETS 1.2a and 1.2b. The only change is in the source of information on WFKH. In this UNIT, the successional pattern you illustrated on Page 23 is the source of WFKH. Complete calculations of the CLWK →ELMD → DWFK sequence as discussed in CHAPTER 12 and earlier in this CHAPTER, tabulate the results below, and calculate the number of animal days supported by the forage (NADF).

Review the flowsheet on Page 7 when you complete this WORKSHEET. Note that if a time period is designated, then the the number of animals supported by the forage (NASF) may be determined.

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	____	____	____	/	____	=	____
ACb-.	____	____	____	/	____	=	____
ACc-.	____	____	____	/	____	=	____
ACd-.	____	____	____	/	____	=	____
ACe-.	____	____	____	/	____	=	____
ACf-.	____	____	____	/	____	=	____
ACg-.	____	____	____	/	____	=	____
ACh-.	____	____	____	/	____	=	____
ACi-.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	____	____	____	/	____	=	____
ACbb.	____	____	____	/	____	=	____
ACcc.	____	____	____	/	____	=	____
ACdd.	____	____	____	/	____	=	____
ACee.	____	____	____	/	____	=	____
ACff.	____	____	____	/	____	=	____
ACgg.	____	____	____	/	____	=	____
AChh.	____	____	____	/	____	=	____
ACii.	____	____	____	/	____	=	____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	_____	_____	_____	/	_____	=	_____
ACb-.	_____	_____	_____	/	_____	=	_____
ACc-.	_____	_____	_____	/	_____	=	_____
ACd-.	_____	_____	_____	/	_____	=	_____
ACe-.	_____	_____	_____	/	_____	=	_____
ACf-.	_____	_____	_____	/	_____	=	_____
ACg-.	_____	_____	_____	/	_____	=	_____
ACh-.	_____	_____	_____	/	_____	=	_____
ACi-.	_____	_____	_____	/	_____	=	_____

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	_____	_____	_____	/	_____	=	_____
ACbb.	_____	_____	_____	/	_____	=	_____
ACcc.	_____	_____	_____	/	_____	=	_____
ACdd.	_____	_____	_____	/	_____	=	_____
ACee.	_____	_____	_____	/	_____	=	_____
ACff.	_____	_____	_____	/	_____	=	_____
ACgg.	_____	_____	_____	/	_____	=	_____
AChh.	_____	_____	_____	/	_____	=	_____
ACii.	_____	_____	_____	/	_____	=	_____

* * * * *

CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACa-.	_____	_____	_____	/	_____	=	_____
ACb-.	_____	_____	_____	/	_____	=	_____
ACc-.	_____	_____	_____	/	_____	=	_____
ACd-.	_____	_____	_____	/	_____	=	_____
ACe-.	_____	_____	_____	/	_____	=	_____
ACf-.	_____	_____	_____	/	_____	=	_____
ACg-.	_____	_____	_____	/	_____	=	_____
ACh-.	_____	_____	_____	/	_____	=	_____
ACi-.	_____	_____	_____	/	_____	=	_____

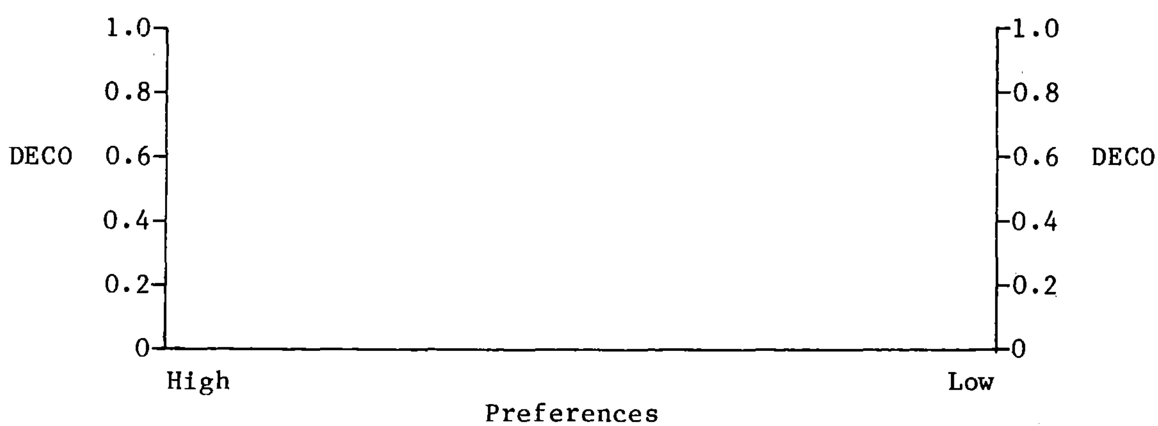
CLASS	CLWK	HFRC	WFKH	/	DWFK	=	NADF
ACaa.	_____	_____	_____	/	_____	=	_____
ACbb.	_____	_____	_____	/	_____	=	_____
ACcc.	_____	_____	_____	/	_____	=	_____
ACdd.	_____	_____	_____	/	_____	=	_____
ACee.	_____	_____	_____	/	_____	=	_____
ACff.	_____	_____	_____	/	_____	=	_____
ACgg.	_____	_____	_____	/	_____	=	_____
AChh.	_____	_____	_____	/	_____	=	_____
ACii.	_____	_____	_____	/	_____	=	_____

UNIT 1.4: CARRYING CAPACITY CHANGES IN RELATION TO BIOLOGICAL FACTORS AFFECTING FORAGE AVAILABILITY AND USE

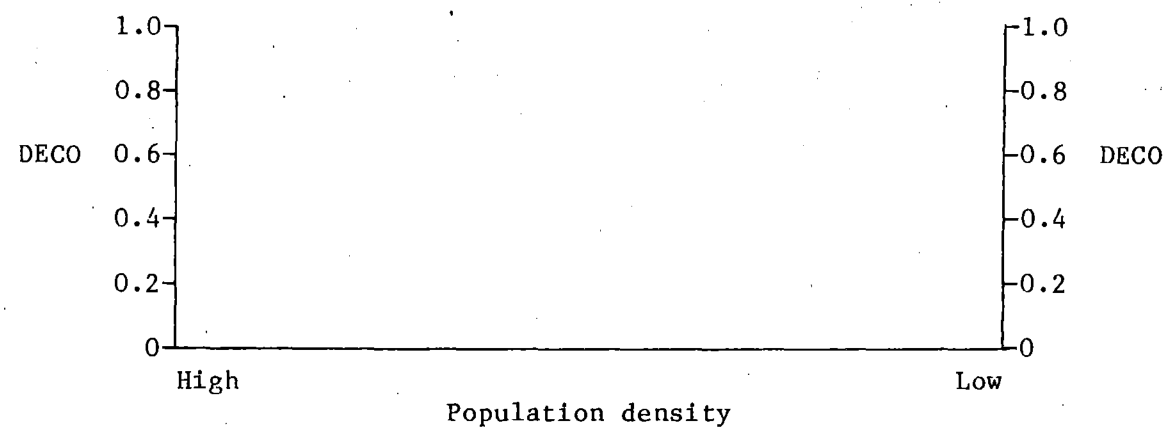
Carrying capacity changes occur in relation to biological factors affecting forage availability, since wild ruminants compete with others of their own species and with other species. The competition for forages eaten by two different species living on the same range means that a common resource that must be divided. Sometimes that common resource is shared by two species of wild ruminants (white-tailed deer and moose, for example), sometimes by a wild and domestic ruminant (mule deer and cattle, for example) and sometimes by a wild or domestic ruminant and a species in a different ORDER, such as rodents.

Competition between species is minimized by differences in food habits and preferences. Thus several species can coexist on ranges that are in good condition with a wide variety of vegetation. As the range condition deteriorates and less forage is produced and fewer forage species are present, competition increases.

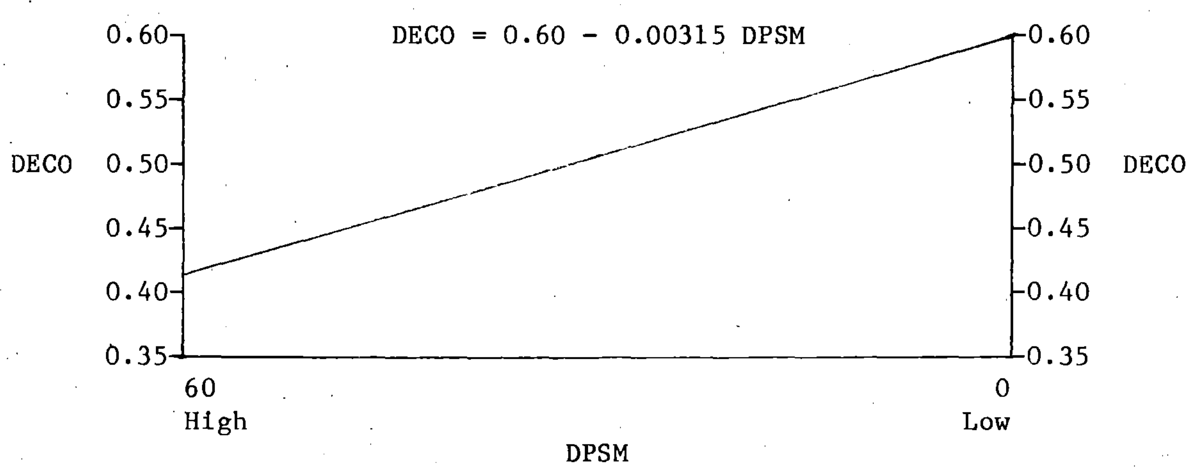
The effects of competition may be illustated with a single species that overpopulates the range. As their numbers increase, the most preferred foods are depleted and only less prefered foods are available for consumption. The relationship between preference and digestibility that was discussed in CHAPTER 12, UNIT 1.2. As a review, draw the relationship between forage preferences and digestibilities below.



If preferences are forced downward as a result of competition due to overpopulation, then the illustration on the previous page may be repeated with a new label on the x-axis.



What is the relationship between population densities and forage preferences left on the range? Discussions at Cornell's Wildlife Ecology Laboratory have resulted in the expression of digestibility coefficients in relation to deer per square mile. The concept has been expressed mathematically, using a linear regression equation to calculate DECO as a function of DPSM. The relationship is illustrated below.



The equation itself has not been calculated from discrete data sets, but rather from the 60 years of experience and reasonable judgement which I and C. W. Severinghaus, retired from the New York State Department of Environmental Conservation, claim to possess. We are convinced the slope of the line is in the right direction. Persons wishing to change the measured value of b should feel perfectly free to do so, in accordance with their reasonable judgement concerning their own local areas. Note that the line must go through the highest reasonable value for DECO (never 1.0) at a population density that has essentially no impact on the availability of any of the forage species on the range.

Derive new expressions for the concept if you wish, incorporating results published in the literature listed at the end of this UNIT and also in CHAPTER 12. Such exercises are not only mentally stimulating, but they are fun as thoughts are converted to words and words to equations.

REFERENCES, UNIT 1.4

CARRYING CAPACITY CHANGES IN RELATION TO BIOLOGICAL FACTORS AFFECTING FORAGE AVAILABILITY AND USE

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CAFNA	85...	231	234	od--	chan in car cap, w nova sc	telfer,es	1971
JRMGA	11--1	18	21	od--	livest, tech study competn	julander,o	1958
JWMAA	11--2	162	177	od--	survey over-pop ranges, us	leopold,a; sowls/	1947
JWMAA	17--2	101	112	od--	sheep competition in utah	smith,jg; julande	1953
NAWTA	9----	144	149	od--	carry capac mich dee yards	davenport,la; sh/	1944
NAWTA	18---	581	596	od--	yard carry capac, browsing	davenport,la; sw/	1953
PCGFA	14...	98	104	od--	deter rel range carry capa	moore,wh; rysley/	1960

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	12--4	750	752	odvi	carryng capac, penn wdlnds	forbes,eb; overho	1931
FOSCA	1....	130	139	odvi	od, doca range relat, utah	julander,o	1955
JRMGA	18--1	1	17	odvi	de, livestock control graz	mcmahan,ca; ramse	1965
JRMGA	30--2	138	142	odvi	pop reac, aerial herbicide	beasom,sl; scifre	1977
JWMAA	10--1	60	63	odvi	summ brow, cut-ov hardw la	cook,db	1946
JWMAA	39--2	321	329	odvi	nutri, south, diff seasons	short,hl	1975
NAWTA	30---	321	335	odvi	feed coact bet hares and d	bookhout,ta	1965
NFGJA	21--1	47	57	odvi	carry capac deer range, ny	jackson,lw	1974
NYCOA	5---3	6	8	odvi	what's happen to deer rang	darrow,rw	1950
NYCOA	10--6	2	4	odvi	too many deer?	cheatum,el	1956

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECMOA	47--3	255	278	odhe	odvi, ecological relations	anthony,rg; smith	1977
NAWTA	4----	560	569	odhe	ceel relationships, oregon	cliff,ep	1939
NAWTA	29---	404	414	odhe	ceel, doca, sum rang, utah	julander,o; jeffe	1964
UASPA	43--2	22	28	odhe	use of mtn rangeland, utah	julander,o	1966
WUICA	21...	1	53	odhe	mod for ecosys, par 7, res	garcia,jc; schre/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	9---1	11	14	ceek	elk, livestock competition	morris,ms	1956
JWMAA	7---3	328	332	ceel	comp, dom livest, summ for	pickford,gd; reid	1943
JWMAA	17--2	162	166	ceel	assoc w/alal on feed groun	mcmillan,jf	1953
JWMAA	30--2	349	363	ceel	range relat, livest, monta	stevens,dr	1966
MAMLA	40--3	355	376	ceel	caca, food selection, carr	goffin,ra; decrom	1976
NAWTA	4----	560	569	ceel	odhe, rel bet, oregon moun	cliff,ep	1939
NCANA	101-1	505	516	ceel	alal, rnge relns, rcky mts	stevens,dr	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	24--1	52	60	alal	snows hare, foo & rng comp	dodds,dg	1960
JWMAA	31--3	418	425	alal	odvi, compr win rng nov sc	telfer,es	1967

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	40--1	151	162	rata	obmo, summ rnge relns, nwt	wilkinson,pf; sh/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	32--5	365	368	anam	livest, foods, dese steppe	johnson,mk	1979
NAWTA	15---	627	644	anam	rang ecol, wichita mt, kan	buechner,hk	1950
UTSCB	29--1	3	6	anam	season forage use, wes uta	beale,da; scotter	1968

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	13--4	417	419	ovca	od food relation, so n mex	halloran,af; kenn	1949

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
JRMGA	25--5	346	352	dosh	biga, guidlines, graz, ran	jensen,ch; smith/	1972

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAECA	29--2	375	384	many	interspec relations, scotl	batcheler,cl	1960
JRMGA	28--1	43	47	many	diet overlap, southern col	hansen,rm; reid,l	1975
JWMAA	3---4	295	306	many	yellowst wint rang studies	grimm,rl	1939
JWMAA	41--1	76	80	many	foods of ungulates, colora	hansen,rm; clark,	1977
NCANA	103..	153	167	many	resour div, comm larg herb	hudson,rj	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AUKJA	81--3	436	436	ungu	birds associating with ung	benson,cw	1964
ECOLA	16--3	531	533		range capacity determinatn	stoddart,la	1935
FAFLB	13---	19	23	game	game on farms	kettlitz,wk	1962
NAWTA	6----	348	353	wldl	remov surplus from refuges	dumont,pa; krumme	1941
NAWTA	10---	251	256	biga	b ga-liv compet, west rang	stoddart,la; rasm	1945
NOSCA	51--2	101	110	wiru	hab util, resour partition	hudson,rj	1977
NWGRA	36--8	12	13	biga	livestock, national forest	haskell,es	1946
VILTA	9---3	45	192	wiru	wint habita, lnd use, scan	ahlen,i	1975

UNIT 1.5: CARRYING CAPACITY CHANGES IN RELATION TO PHYSICAL FACTORS AFFECTING FORAGE AVAILABILITY AND USE

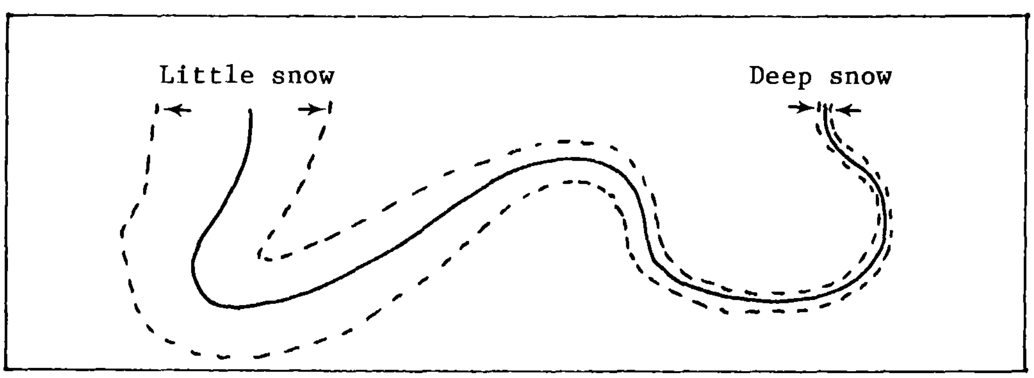
Physical factors such as topography and accumulated snow affect energy expenditures. Energy expenditures for vertical ascent are greater than for movement on horizontal surfaces (see CHAPTER 7, UNIT 4.3). Some wild ruminants live on mountainous topography and others live on rather flat land. Sometimes there are seasonal differences in topographies used. The tendency for deer to seek out the more level bottom-lands in the winter in some areas can be interpreted as an energy conservation response (Moen 1976). How is this change in topography reflected in energy savings, and how important are other factors in this apparent choice?

Questions such as the one above can be evaluated by determining a range of energy costs associated with different movement patterns on variable topographies and relating that pattern to forage consumption patterns. Recalculate ELMD to consider extremes in topography. Evaluate the likelihood of animals living at reasonable rates of ecological metabolism if they must traverse steep hillsides each day.

Recalculate ELMD in relation to increased snow depths too. Moving through snow is very costly (see CHAPTER 17) and there is a limit to the amounts of energy that can be expended for this activity. When does the cost of movement begin to exceed the returns from forage reached?

Even if ELMD is not increased as result of accumulating snow, the amounts of forage available in different stands goes down as snow covers up some of the forage. The amounts of forage covered by snow depends on the vertical distribution of forage and snow depths. Refer to the equation discussed earlier in UNIT 1.2, which was taken from CHAPTER 13, UNIT 1.3, and subtract the amounts of forage covered by 10, 20, 30. . . 100 cm of snow from the total amount of forage available to the height reached.

All of the factors mentioned above have been discussed in previous CHAPTERS. One very important physical factor to be illustrated next is the range areas used in different seasons. Wild ruminant ranges are often much smaller in the winter than during the rest of the year. The smaller area used by the population is reduced even further by snow accumulations that cause or at least encourage animals to stay on trails. These reductions are illustrated below.



The width of the activity corridor on either side of the trails is dependent on snow depths. As snow depths increase, the width of the activity corridor decreases. The overall area of winter range may be only a fraction of the summer range, and only a fraction of the range resources may be accessible.

The area of the winter range and the resources available to the animals over the area of the winter range is one of the most dynamic and variable factors in the calculation of carrying capacity. It varies relatively more than the sums associated with forage estimates, more than digestibility coefficients, even if they are estimated, and more than even careful estimates of the total population.

The area used and forage resources available to a population over time may be calculated with a weighted-mean procedure. Multiply the fraction of the days of a time period--winter, for example--by the area of the range that is accessible. The answer is the weighted time-area fraction, which is multiplied by the weight of the forage available to get the weighted-mean forage weight. The sample calculation below illustrates the procedure.

For a 220-day winter period:

Number of days	Fraction of the range
70	1.00
42	0.10
75	0.03
33	0.10
220	

The calculations, where NDFR = number of days on fractions of the range, LWPD = length of the winter period in days, FRTP = fraction of the time period, FRRA = fraction of the range, WFOK = weight of forage in kg, and WMFK = weighted-mean weight of forage in kg on the range, are:

NDFR/LWPD		= FRTP	x FRRA	x WFOK		
70/220	=	0.32	x 1.00	= ____	= ____	
42/220	=	0.19	x 0.10	= ____	= ____	
75/220	=	0.34	x 0.03	= ____	= ____	
33/220	=	0.15	x 0.10	= ____	= ____	
SUMS	=	1.00			____	= WMFK

Multiply the SUM by the weight of forage in kg to determine the forage within the area used over time. The result may be divided by the weighted-mean forage consumption per animal per day to get the carrying capacity in relation to area used over time.

Considerable attention should be given to the distribution, density, and areas used by ruminant populations throughout the year. Then, carrying capacity calculations may be made for the actual ranges and resource bases used.

REFERENCES, UNIT 1.5

CARRYING CAPACITY CHANGES IN RELATION TO
PHYSICAL FACTORS AFFECTING FORAGE AVAILABILITY AND USE

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
NAWTA	1----	410	415	od--	forest-car cap, food probs	clepper,he	1936

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ECOLA	57--1	192	198	odvi	energy conservatio, winter	moen,an	1976
JWMAA	39--3	563	569	odvi	effect snowmobiles on deer	dorrance,mj; sav/	1975
NFGJA	16--2	129	135	odvi	est area, deer habitat, ny	severinghaus,cw;/	1969
XATBA	840--	1	60	odvi	meth, herd cond, avail for	park,bc; day,bb	1943

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJNA	56--3	531	542	odhe	foo hab fll, win, spri, bc	willms,w; mclean/	1976
NAWTA	29---	404	414	odhe	ceel, doca, sum rang, utah	julander,o; jeffe	1964
NEXAA	567--	1	32	odhe	ft stanton hrd, ecol, n mx	wood,je; bickle,/	1970
UASPA	43--2	22	28	odhe	use of mtn rangeland, utah	julander,o	1966

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CBCPA	61---	43	48	ceel	oxy util dur locom by calv	cohen,y; robbins/	1977
NAWTA	29---	438	444	ceel	od, pinyon-jun wood, n mex	reynolds,hg	1964

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	56--2	215	223	rata	energy expend, walk, tundr	white,rg; yousef,	1978
OIKSA	25--3	379	387	rata	relatv abund food in wintr	bergerud,at	1974

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

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

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

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

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

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

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AMSCA	62--2	172	181	many	endangered spec: mod, pred	miller,rs; botkin	1974
JFUSA	45-10	749	754		dist.fr watr, grazng capac	valentine,ka	1947
NAWTA	10---	251	256	biga	b ga-liv compet, west rang	stoddart,la; rasm	1945
OIKSA	33...	182	189	....	imp landsc hetero, breedin	hansson,l	1979
VILTA	9---3	45	192	wiru	wint habita, lnd use, scan	ahlen,i	1975

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
ATRLA	22--1	3	24	caca	energy metabolism, roe dee	weiner,j	1977

CHAPTER 20, WORKSHEET 1.5a

Area-time calculations of forage available

The format on Page 32 may be used to calculate the weighted-mean forage available, depending on conditions which affect the amount of area used over time. Complete calculations of weighted-mean forage available, using data for locations of your choice. It would be interesting to evaluate the effect of changes in use over time of areas in different stages of successon.

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

Location: ____________________

NDFR/LWPD = FRTP x FRRA x WFOK

____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____
____/____ = ____ x ____ = ____ = ____

SUMS = 1.00 ____ = WMFK

UNIT 1.6: CARRYING CAPACITY CHANGES IN RELATION TO FORAGE CONSUMPTION BASED ON PROTEIN REQUIREMENTS

Carrying capacity calculations based on protein requirements are made with exactly the same format as the energy calculations, except that the total protein requirement replaces ELMD, and the metabolizable protein in the forage replaces the metabolizable energy in the forage. Thus the formula for calculating dry-weight forage in kg (DWFK) required to meet daily protein needs is:

DWFK = Protein required per day/metabolizable protein in the forage

The basic calculation was discussed in CHAPTER 12, UNIT 4.4. Estimations of protein requirements may be made from material in CHAPTER 8 and protein in the forage may be estimated from literature listed in CHAPTER 11. Calculations of forage consumption are discussed in CHAPTER 12.

Once these calculations have been completed, the analysis of carrying capacity is completed by dividing the forage resources available by the forage resources required to determine the number of animal-days supported by the forage (NADF).

REFERENCES, UNIT 1.6

CARRYING CAPACITY CHANGES IN RELATION TO FORAGE CONSUMPTION BASED ON PROTEIN REQUIREMENTS

SERIALS

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

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TOPIC 2. SPACE RESOURCES

Space resources are not only obviously necessary, but are also easily calculated within the concept of carrying capacity as a dynamic balance between resources required and resources available. The conceptual illustration at the beginning of this CHAPTER 20 dealt with space, and similar calculations may be made in the UNITS that follow, using biological data.

UNIT 2.1: CARRYING CAPACITY CHANGES IN RELATION TO BEHAVIORAL CONSTRAINTS

Individual animals have, by virtue of their existence, a home range. Some animals have a territory, or defended area that is respected by other members of the species. In addition, individuals have a social space characteristic of their standing in the population. These basic space characteristics were discussed in CHAPTERS 3, 4, and 5.

Using literature listed in CHAPTERS 3, 4, and 5, deterine the space needs of wild ruminants and calculate the number that can fit into different spatial habitat configurations. Note that these space requirements change during the year, so calculations should be repeated for whatever seasonal or JDAY intervals are appropriate.

A WORKSHEET illustrates the basic idea for calculating carrying capacity in relation to space requirements.

REFERENCES, UNIT 2.1

CARRYING CAPACITY CHANGES IN RELATION TO BEHAVIORAL CONSTRAINTS

SERIALS

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

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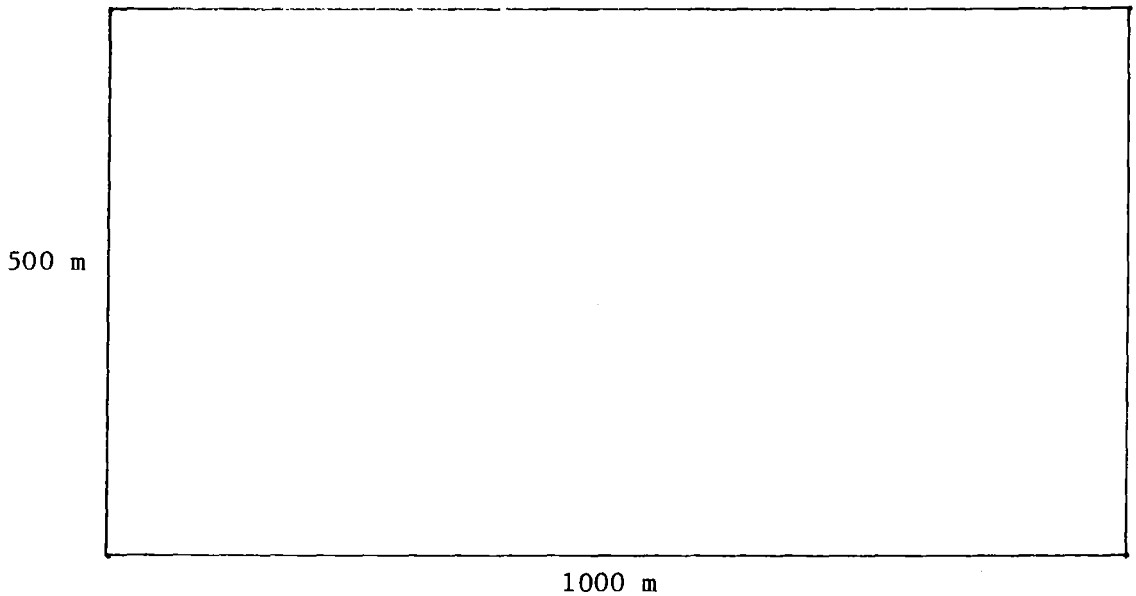
CHAPTER 20, WORKSHEET 2.1a

Calculations of carrying capacity based on space resources

The use of space may be shared, or it may be exclusive. Suppose the space required for the territory of an animal is 20 hectares per animal. How many animal territories will fit in the space below? (_______)



Suppose each animal allows a 50% shared use. How many territories will fit in the space above then? (_______)

Deer are not territorial in the winter, tending rather to concentrate in selected areas. Suppose the forage density was 40 kg per ha on the space above. How many deer-days will the area support if each deer consumed 2 kg of forage per day and 50% of the forage was allowed to be consumed? (______)

Deer often concentrate on only a fraction of their total summer range in the winter. How many deer-days will the area support if 50% of it is used? (_______) 40%? (_______) 30%? (_______) 20%? (________) 10%? (_______)

Space and forage densities become critical factors for deer in winter concentration areas.

UNIT 2.2: CARRYING CAPACITY CHANGES IN RELATION TO OTHER BIOLOGICAL CONSTRAINTS

Carrying capacity may be affected by other biological constraints, such as predation, diseases, and abnormalities. Such effects are not likely to be important, however, in a population on good range. If forage resources are ample and the population density is low enough to prevent social interactions detrimental to productivity, background levels of predation, disease, and abnormalities are tolerated well.

The effects of other biological constraints are best evaluated when making population predictions in CHAPTER 19. If populations are not in precarious energy, protein, or space balances with the resources on their ranges, these factors are not likely going to limit the population.

Exceptions may occur. Diseases may affect the population potential of some species, bighorn sheep for example, when the population is low in a particular area. If the transmission of the disease is density independent, a large proportion of the small number of animals may die. Insights into some of these possibilities may be gained from the references listed in CHAPTER 10.

There are many variations that can be thought of in the calculations of carrying capacity within the basic concept of resources required in relation to resources supplied. Consider the examples that have been given to be the beginning rather than the end.

REFERENCES, UNIT 2.2

CARRYING CAPACITY CHANGES IN RELATION TO OTHER BIOLOGICAL CONSTRAINTS

SERIALS

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

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CLOSING COMMENTS

The calculations of carrying capacity in this CHAPTER 20 illustrate a potentially large array of different combinations that could be analyzed. Consider the illustrations given to be examples of the kinds of calculations and considerations that could be made, and derive new ones that pertain to your local situations. Many of the calculations in the first 20 CHAPTERS will be used over and over again as management decisions are not just thought about but tested. Using the best and most complete knowledge available, convert ideas to words and words to equations. Then, assemble the equations into simulations that help you understand the results of different interactions. If this is done, then the first twenty CHAPTERS in The Biology and Management of Wild Ruminants will form a basis for the last five CHAPTERS on management.

Aaron N. Moen
May 6, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER TWENTY

ACa- = Age class - males
ACaa = Age class - females
AGCL = Age class
AGDA = Age in days
ATTE = Atmospheric temperature

BLMD = Base-line metabolism per day
BOCO = Body composition

CACA = Carrying capacity
CESF = Cell structure of forage
CLWK = Calculated live weight in kg

DCHC = Dynamic conductivity of the hair coat
DDUA = Deer days of forage per unit area
DECO = Digestible energy coefficient
DEPT = Digestible energy in pole timber area
DERE = Digestible energy in regeneration area
DESA = Digestible energy in sapling area
DESE = Digestible energy in seedling area
DEST = Digestible energy in saw timber area
DPSM = Number of deer per square mile
DWFK = Dry weight forage in kg

ECAD = Energy cost of activity per day
ECMD = Energy cost of maintenance per day
ECPD = Energy cost of production per day
ELMD = Ecological metabolism per day
ENTE = Environmental temperature

FAUT = Fraction of the area used per unit time
FFPA = Fraction of the female population in each age class
FFPA = Fraction of the total population in the female population
FMPA = Fraction of the male population in each age class
FMPP = Fraction of the total population in the male population
FRRA = Fraction of the range
FRTP = Fraction of the time period
FTAD = Fraction of time in activity per day

GEFO = Gross energy in forage
GEPT = Gross energy in pole timber area
GERE = Gross energy in regeneration area
GESA = Gross energy in sapling area
GESE = Gross energy in seedling area
GEST = Gross energy in saw timber area

HERA = Heart rate
HFRC = Height of forage reached
HGTC = Height in cm
HRMC = Heart rate to metabolism conversion

IEPT = Ingestible energy in pole timber area
IERE = Ingestible energy in regeneration area
IESA = Ingestible energy in sapling area
IESE = Ingestible energy in seedling area
IEST = Ingestible energy in saw timber area
IFMW = Ingesta-free metabolic weight
IFWK = Ingesta-free weight in kg
INCO = Ingestibility coefficient

JDAY = Julian day

LIWK = Live weight in kilograms
LWPD = Length of the winter period in days

MBLM = Multiple of base-line metabolism
MECO = Metabolizable energy coefficient
MEPT = Metabolizable energy in pole timber area
MERE = Metabolizable energy in regeneration area
MESA = Metabolizable energy in sapling area
MESE = Metabolizable energy in seedling area
MESP = Metabolic structure of the population
MEST = Metabolizable energy in saw timber area
MEUA = Metabolizable energy per unit area
MWKG = Metabolic weight in kilograms

NADF = Number of animal days supported by the forage
NASF = Number of animals supported by the forage
NDFR = Number of days on fraction of the range
NFAC = Number of females in each age class
NMAC = Number of males in each age class
NUAP = Number of animals in the population

PLCT = Percent of land in each cover type
PLPT = Percent of land in pole timber stage
PLRE = Percent of land in regeneration stage
PLSA = Percent of land in sapling stage
PLSE = Percent of land in seedling stage
PLST = Percent of land in saw timber
PREC = Precipitation
PREF = Preference of the consumer for forage species

QCDE = Quantity of conductive energy exchange
QCVE = Quantity of convective energy exchange
QDER = Quantity of digestible energy on the range
QEVE = Quantity of evaporative energy exchange
QGER = Quantity of gross energy on the range
QIRE = Quantity of infrared energy exchange
QMER = Quantity of metabolizable energy on the range
QREE = Quantity of radiant energy exchange

REHU = Relative humidity
REPI = Reproductive potential of the individual
REPP = Reproductive potential of the population
RERA = Respiration rate
RPRT = Reproductive rate
RRMC = Respiration rate to metabolism conversion
RTHC = Radiant temperature of the hair coat

SCHC = Static conductivity of the hair coat
SEXX = Sex of the animal
SOCH = Soil characteristics
SOEN = Solar energy
SQCM = Square centimeter
SSTE = Substrate temperature

TSAM = Total surface area in square meters

VAPD = Vapor pressure deficit
VPSA = Vapor pressure of saturated air

WEMA = Weighted-mean ecological metabolism of the age class
WEFP = Weighted-mean ecological metabolism of the female population
WEMP = Weighted-mean ecological metabolism of the male population
WESP = Weight structure of the population
WFKH = Weight of forage available in kg per hectare
WFOK = Weight of forage in kg
WFPT = Weighted-mean forage production in pole timber area
WFRE = Weighted-mean forage production in regeneration area
WFSA = Weighted-mean forage production in sapling area
WFSE = Weighted-mean forage production in seedling area
WFST = Weighted-mean forage production in saw timber area
WIVE = Wind velocity
WMEP = Weighted-mean ecological metabolism of the population
WMFK = Weighted-mean weight of forage in kg
WMLA = Weighted-mean live weight of the age class
WTAU = Weighed-mean time and area used

AECOD Agro-Ecosystems
AMSCA American Scientist
ASZBA Archivum Societatis Zoologicae - Botanicae Fennicae Vanamo'
ATRLA Acta Theriologica (Poland)
AUKJA Auk

CAFNA Canadian Field Naturalist
CBCPA Comparative Biochemistry and Physiology
CEXSB Colorado State University Experiment Station Bulletin
CJZOA Canadian Journal of Zoology
CLCHA Clinical Chemistry
CNJNA Canadian Journal of Animal Science
CNRDA Canadian Journal of Research, Section D, Zoological Sciences
CNSVA Conservationist

ECMOA Ecological Monographs
ECOLA Ecology
ESASA Ecological Studies, Analysis and Synthesis

FAFLB Fauna and Flora (Transvaal)
FOSCA Forest Science
FRCRA Forestry Chronicle

HMECA Human Ecology

JAECA Journal of Animal Ecology
JAPEA Journal of Applied Ecology
JECOA Journal of Ecology
JFUSA Journal of Forestry
JOMAA Journal of Mammalogy
JRMGA Journal of Range Management
JWMAA Journal of Wildlife Management

MAMLA Mammalia
MXSBA Minnesota Agricultural Experiment Station, Station Bulletin

NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NCANA Naturaliste Canadien, Le
NCANA Naturaliste Canadien, Le
NEXAA New Mexico Agricultural Experiment Station Bulletin
NFGJA New York Fish and Game Journal
NOSCA Northwest Science
NWGRA National Wool Grower
NYCOA New York State Conservationist

OIKSA	Oikos (Denmark)
PCGFA	Proceedings of the Southeastern Association of Game and Fish Commissioners
PSAFA	Proceedings of the Society of American Foresters
RWLBA	Roosevelt Wild Life Bulletin
UASPA	Proceedings of the Utah Academy of Sciences, Arts and Letters
UTSCB	Utah Science
VILTA	Viltrevy
WLSBA	Wildlife Society Bulletin
WMBAA	Wildlife Management Bulletin (Ottowa) Series 1 (Canada)
WUICA	University of Washington Institute of Forest Products contribution
XATBA	U S D A Technical Bulletin
XFNSA	U S Forest Service Research Note SO
XFPNA	U S Forest Service Research Paper PNW
XFSEA	U S Forest Service Resource Bulletin SE
XFWWA	U S Fish and Wildlife Service Special Scientific Report - Wildlife
ZHIVA	Zhivotnovodstvo

LIST OF WORKSHEETS - CHAPTER 20

JULIAN DAY: MONTH AND DAY EQUIVALENTS*

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.