Return to R. Moen

THE BIOLOGY AND MANAGEMENT OF WILD RUMINANTS

A Sequence of Learning Experiences in Seven Parts

and Twenty-five Chapters

To Ron! from with love — Dad — 12/19/80

by

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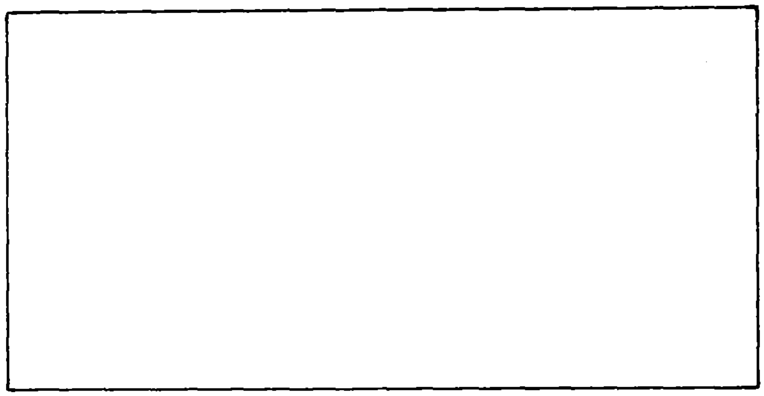
INTRODUCTION



How many squares will fit in this square? There is, at this point, only one correct answer to that question. An infinite number of squares will fit in this square. They could be small and many will fit, or large and few or only a fraction of a square will fit. How do we know that to be true? Each square 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 other squares. If each square uses just a little of the space resource, then there is a lot of space left for other squares.

Suppose that one side of the rectangle above is 10 cm and the other side is 5 cm. The area of the square is easily determined to be 50 cm. Fifty smaller rectangles, each with an area of 1.0 SQCM (SQCM = square centimeter), will fit in that rectangle. Further, it is easy to determine the number of rectangles, each with an area of 5 SQCM that will fit--10 seems to "fall in place" as the answer.

None of the above conclusions come from instinct, even though it almost seems that way. In fact, each of you was using a very high-speed computer as you were reading about a very basic ecolgogical concept, a magnificant computer that deserves the best of care because it has so much useful work to do. This computer--your mind--is your most valuable resource.

THE CONCEPT OF CARRYING CAPACITY

The example of the square illustrates 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 square, 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. Some answers can be quickly determined with the use of our mental computer, but when the calculations become rather lengthy (and they quickly do!) an electronic computing system, especially a programmable one, is of distinct value.

Rapid calculations are useless and even dangerous unless they represent sound biological relationships. What biological relationships are involved in the concept of carrying capacity? Space is one, food is another. Other relationships will be discussed throughout this book. All of the relationships within the concept of carrying capacity have the same form, and may be expressed in a word formula as:

Resources available/resources required = Number supported

A rectangle 10 cm on one side xand 5 cm on the other provides 50 square cm of space resources. If the included rectangles require 25 cm^2 each, then 10 will fit, determined by dividing 50 (space resource available) by 5 (space resource required). If each rectangle requires 25 cm^2, then 2 will fit. The relationship is obvious.

Food resources may be used to illustrate the concept of carrying capacity too. Food supplies energy and nutrients that are synthesized into body tissue. The formula for determining the number supported on the basis of energy resources is:

Range energy/available energy required per individual = Number supported

Suppose that individual animals require 500 units of energy each day and the range has 10,000 units available. The equation is:

$$10{,}000/500 = 20$$

Similar relationships can be set up for other nutrients such as protein. The form of the relationships remains the same. Simply substitute the word "protein" for energy in the formula and the appropriate numbers in the equation.

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 is a time-dependent concept, changing with seasons as both the resources available and the resources required change.

The calculations in this book follow the basic sequence illustrated on the flow chart on page viii. Note the use of four-letter symbols to represent parameters on the flow chart. These symbols are usually made up of the first and second letters of the words and units represented and are easily remembered. Those used in the flow chart are defined immediately after the chart. The symbols added as the number of parameters considered and equations increases are defined in the GLOSSARY at the end of this PART.

Metabolic characteristics and relationships are illustrated in the top half of the flow chart. Weight (CLWK) is a central component of these relationships, and considerable attention is devoted to seasonal patterns of weight changes since the relationship between animal weight and metabolism is a very fundamental ecological consideration. Weight varies--it increases as animals grow older and it changes during the annual cycle--so both age in days (AGDA) and Julian day of the year (JDAY) are important parameters for predicting weights. Derivation of weight equations is one of the first considerations in this sequence of learning experiences. Ecological metabolism (ELMD) is a very important output from this sequence of calculations.

Thermal characteristics and relationships are illustrated in the bottom half of the flow chart, except for the last line. Solar energy (SOEN) is the driving force behind meteorological parameters. These influence thermal boundary region characteristics at the animal-atmosphere interface, which may influence ecological metabolism. Weather factors also influence forage production on the range, and SOEN is necessary for photosynthesis.

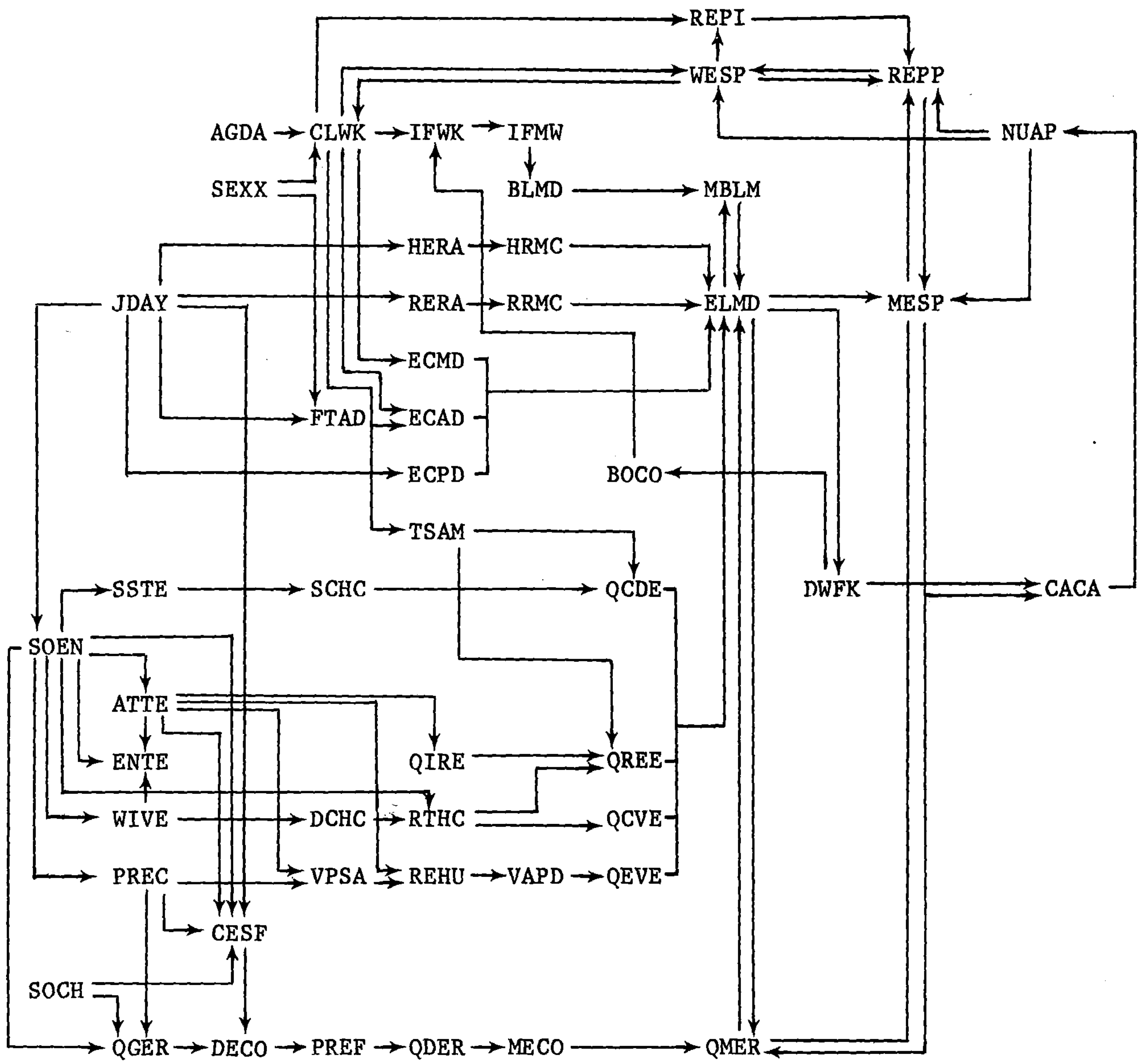
Forage energy, from gross to metabolizable, is illustrated on the last line of the flow chart. The important output from this sequence of calculations, quantity of metabolizable energy on the range (QMER), is of importance to the ecological metabolism of individuals (ELMD), and to the metabolic structure of the population (MESP). Population simulations are used in PART VI as a basis for testing the effects of different weight and metabolic population structures on the amounts of forage consumed.

Ecological relationships have a large number of dimensions. Many of these dimensions must be estimated or derived as first approximations because definitive, long-term experimental results are not available for most species of free-ranging animals. The use of variability estimates and error analyses can be made quickly with programmed computing systems that complete repetitious steps, and the results provide valuable insights into the importance of different parameters in ecological relationships.

All of these analyses form a framework for the evaluation of carrying capacity. The evaluations are mathematical, based on biological and physical functions. Every serious wildlife biologst ought to own a scientific calculator, and each equation given in this text should be verified. The more storage and programming capabilities the calculator has, the more useful it will be since many calculations are repeated several times. The equations are explained fully, shorter equations are compiled into longer ones, and WORKSHEETS provide opportunities for their use.

Completion of each of the WORKSHEETS for the species of interest will result in better understanding of relationships between ecological variables. Some relationships have not been evaluated fully for all species due to a lack of data. Readers may also derive new ways to analyze relationships that are different from those presented here. This is encouraged as long as the new analyses are completed within the framework of natural laws, focusing on cause and effect rather than simple correlations.

BIOLOGICAL RELATIONSHIPS TO CONSIDER



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
DECO = Digestible energy coefficient
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
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
MECO = Metabolizable energy coefficient
MESP = Metabolic structure of the population
NUAP = Number of animals in the population

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
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

TAXONOMIC ORGANIZATION OF WILD RUMINANTS

Wild ruminants are members of the class MAMMALIA; they all have hair and nurse their young. They are all members of the order ARTIODACTYLA; they have hooves that are divided in two. Deer, elk, and moose are members of the family CERVIDAE, or deer family. The pronghorn is the only member of the family ANTILOCAPRIDAE. Bison, goats, muskox, and sheep are members of the family BOVIDAE.

Scientific names used in this book are those used in BIG GAME OF NORTH AMERICA, edited by J.C. Schmidt and D. L. Gilbert (1979: Stackpole Books, Harrisburg, PA 17105, 494 pp.), and may be different from the scientific names given in the original literature. The taxonomic organization and abbreviations of North American wild ruminants used in this book are listed below, followed by brief descriptions of the families and genera.

TAXONOMIC ORGANIZATION OF NORTH AMERICAN WILD RUMINANTS

CLASS: MAMMALIA

ORDER: ARTIODACTYLA	Abbreviation
FAMILY: CERVIDAE	cerv
GENUS: _Odocoileus_ (deer)	od--
SPECIES: _O. virginianus_ (white-tailed deer)	odvi
O. hemionus (mule deer)	odhe
GENUS: _Cervus_ (Wapiti, elk)	ce--
SPECIES: _C. elaphus_	ceel
GENUS: _Alces_ (moose)	
SPECIES: _A. alces_	alal
GENUS: _Rangifer_ (caribou)	
SPECIES: _R. tarandus_	rata
FAMILY: ANTILOCAPRIDAE	
GENUS: _Antilocapra_	
SPECIES: _A. americana_	anam
FAMILY: BOVIDAE	bovi
GENUS: _Bison_ (bison)	bi--
SPECIES: _B. bison_	bibi
GENUS: _Ovis_ (sheep)	ov--
SPECIES: _O. canadensis_ (bighorn sheep)	ovca
O. dalli (Dall sheep)	ovda
GENUS: _Ovibos_	
SPECIES: _O. moschatus_ (muskox)	obmo
GENUS: _Oreamnos_	
SPECIES: _O. americanus_ (mountain goat)	oram
O. dalli (Dall sheep)	ovda
GENUS: _Ovibos_	
SPECIES: _O. moschatus_ (muskox)	obmo
GENUS: _Oreamnos_	
SPECIES: _O. americanus_ (mountain goat)	oram

The family Cervidae, or deer family, includes deer, elk, moose, and caribou. Males in all genera have antlers of solid bone, and female caribou are also antlered. The antlers of white-tailed deer, mule deer and elk are cylindrical in shape, tapering to points. Caribou have slightly palmated antlers, with a brow tine that extends forward over the face. Moose have very palmated antlers. The antlers are large, and shed annually.

White-tailed deer are the most widely distributed members of this family, being present throughout the United States and most of the wooded and agricultural regions of Canada. Mule deer are found in the western part of the United States and Canada. The genetic history of deer, especially whitetails, is somewhat mixed up now because of numerous trap and transfer operations that occurred after they were extirpated from much of their original range during the early years of human settlement.

Wapiti, known more often as elk in North America, originally occupied the central part of North America from coast-to-coast. This wide geographic distribution included eastern deciduous forests, the southern edge of the northern coniferous forest, prairie in the central part of the United States and south-central Canada, and both slopes of the mountainous regions in the west. The wide distribution over different plant communities and climates indicates that the genus Cervus is quite adaptable. Moose are much less adaptable, being found in the north central and northeast states, in the western states, and in the adjoining parts of Canada. They inhabit wooded areas with lakes and streams as they are well adapted for feeding in water.

The family Antilocapridae contains only one living representative, the pronghorn, genus Antilocapra and species A. americana. Pronghorns are rather small ruminants, with a slender, graceful body. A large patch of long, white erectile hairs on the rump, and black and white markings on the face and neck give this buff-colored animal a distinctive appearance. Pronghorns live almost exclusively on the open plains, and are usually found in small bands. They run very fast, using a combination of visual accuity and fleetness to escape from predators. Living on the open plains presents few obstacles to be jumped; fences are barriers foreign to their existence.

The family BOVIDAE includes the domestic cattle and three genera of wild ruminants, including the bison, wild sheep, and wild goats. All have horns which continue to grow each year. The bovids are capable of living in rather harsh environments. Bison live on the plains and foothills and in northern Canada, and sheep and goats in the more rugged and mountainous regions of the west.

Reference to some European species of wild ruminants are included also as there are excellent articles on their basic biology that provide background information of value when analyzing other species. The taxonomic organization and abbreviations of European wild ruminants used in this book are given next.

TAXONOMIC ORGANIZATION OF EUROPEAN WILD RUMINANTS

CLASS: MAMMALIA

ORDER: ARTIODACTYLA	Abbreviation
FAMILY: CERVIDAE	cerv
GENUS: *Capreolus* (roe deer)	ca--
SPECIES: *C. capreolus*	caca
GENUS: *Dama* (fallow deer)	da--
SPECIES: *D. dama*	dada
GENUS: *Odocoileus* (deer)	od--
SPECIES: *O. virginianus* (white-tailed deer)	odvi
GENUS: *Cervus* (Wapiti, elk)	ce--
SPECIES: *C. elaphus* (red deer)	ceel
GENUS: *Alces* (moose)	
SPECIES: *A. alces*	alal
GENUS: *Rangifer* (caribou)	
SPECIES: *R. tarandus*	rata
FAMILY: BOVIDAE	
GENUS: *Bison* (bison)	
SPECIES: *B. bonasus*	bibo
GENUS: *Capra* (ibex, wild goat)	cp--
SPECIES: *C. aegagrus* (Persian ibex)	cpae
C. siberica (Siberian ibex)	cpsi

Abbreviations for a few other species and groups of species may appear in the reference lists. These are listed below.

Axis axis (axis deer)	axax
Elaphurus davidianus (Pere David's deer)	elda
Cervus nippon (Sika deer)	ceni
Hydropotes inermis (Chinese water deer)	hyin
Muntiacus muntjac (Indian muntjac)	mumu
Moschus moschiferus (musk deer)	momo
Ovis nivicola (snow sheep)	ovni
Ovis musimon (moufflon)	ovmu
Ovis linnaeus (Iranian sheep)	ovli
Rupicapra rupicapra (chamois)	ruru

big game	biga
domestic sheep	dosh
domestic cattle	doca
domestic goat	dogo
mammals	mamm
three or more species of wild ruminants	many
ruminants	rumi
ungulates	ungu
vertebrates	vert
wildlife	wldl

ORGANIZATION OF REFERENCE LISTS

Extensive reference lists, based on computer-assisted searches back to 1970 and manual searches of literature published prior to 1970, are included in each of the PARTS. The lists are organized in a functional way for use in the library rather than in the conventional alpabetized-by-author way, with the information necessary for locating the references in libraries given in abbreviated, one-line form. The reference books listed after each PART, CHAPTER, and TOPIC contain background information for the material covered, and may contain specific information for several of the UNITS and WORKSHEETS.

The headings for the lists of BOOKS are:

type publ city page anim kewo auth/edit year

The type of book could have either an author (auth) or an editor (edit). Publishers (publ) and city of publication are given with four-letter mnemonic symbols defined in the GLOSSARY. The page column give the number of pages in the book; anim refers to the species discussed in the book (given as a four-letter abbreviation of genus and species), and kewo lists key words from the title. The authors' names and year of publication are given in the last two columns. Thus all of the essential information for finding each book in the library is given on just one line.

Serial publications that pertain to each division are listed with a slightly different format. (Serials are identified by a five-character, generally mnemonic code called CODEN, published in 1977 BIOSIS, LIST OF SERIALS (BioSciences Information Service, 2100 Arch Street, Philadelphia, PA 19103).

The headings for the lists of SERIALS are:

CODEN vo-nu bepa enpa anim kewo auth year

The volume and issue numbers (vo-nu) are given after the CODEN entry, followed by beginning page (bepa), ending page (enpa), species discussed (anim), key words from the title (kewo), author (auth), and year.

Specific authors and dates of publication can be located quickly by scanning the two right-hand columns. If the author's name fits in the 17 characters, some character spaces are left blank. If there are two authors and all of the first author's name and part of the second author's name fits in the 16 character spaces, the second author's name is truncated at the right margin of the author column. If there are more than two authors and the names of additional authors do not appear in the author column, there is a slash (/) at the right margin of the column.

References cited in the text material and in the WORKSHEETS are given under LITERATURE CITED in the traditional format (author, date, title of article, journal, volume, issue number, and page numbers.

A third category, OTHER PUBLICATIONS, may be included at the beginning of PARTS or in the CHAPTERS. This category contains references to publications that are not authored or edited books or serials listed by BioSciences Information Service. Examples are "Transactions of the Northeastern Deer Study Group Meetings" and "Biannual Pronghorn Antelope Workshop, Proceedings." Both of these contain many articles on deer and pronghorns, respectively, but are not included in the one-line abbreviated form. Such publications are listed by titles, which should make it possible to locate the publications in libraries.

HOW TO USE THIS SYSTEM

The one-line format used to list references makes it possible to list several thousand references in a minimum amount of space. The logic of the one-line entries in the reference lists is based on the order of decision-making when finding literature. First, the references are grouped according to biological functions and relationships discussed in this book. Second, species of interest are selected. Third, journals containing references to be read are located in the library. Fourth, the publications are located in the journals. The use of this reference list format in the library will confirm the logic of this arrangement. Call numbers and stack levels should be added in the margins so references may be quickly located in a particular library.

CODEN entries are identified by the full title of the serial publication and its country, territory, or commonwealth of origin in the APPENDIX. CODEN entries in the serial lists are alphabetized. This results in some of the full titles being out of alphabetical order. Since the user of this book will usually work from CODEN to consult the list of full titles in the APPENDIX, this disorder will result in nothing more than occasional inconvenience. Most of the full titles will be near alphabetized, so the CODEN for a specific serial can be quickly found by scanning the appropriate part of the list.

Serials, including journals and report literature, constitute the major portion of the literature on wild ruminants. Scientists are urged to publish their findings in recognized journals so the results of their work are readily available.

A FINAL INTRODUCTORY REMARK

The concept of carrying capacity, taxonomic organization of wild ruminants, and the organization of literature references have been introduced. You are encouraged to begin reading the CHAPTERS, solving the equations, and completing the WORKSHEETS in the order in which the material is presented. The flow sheet given in this INTRODUCTION is a guide to the sequence of and linkages between some very basic biological functions. The PARTS, CHAPTERS, TOPICS, and UNITS are logically arranged to insure an understanding of the basic biological relationships that are the foundation of population ecology and management. These relationships are best understood when you, the reader, become actively involved in their analyses and applications.

Your ideas and suggestions are welcome, and will be considered as revisions are made and new books on other species considered. It is my intent to provide the most useful and comprehensive educational publications possible for the students in the 1980's who will be professional biologists in the next century.

Aaron N. Moen
December 1, 1980