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)

Published by

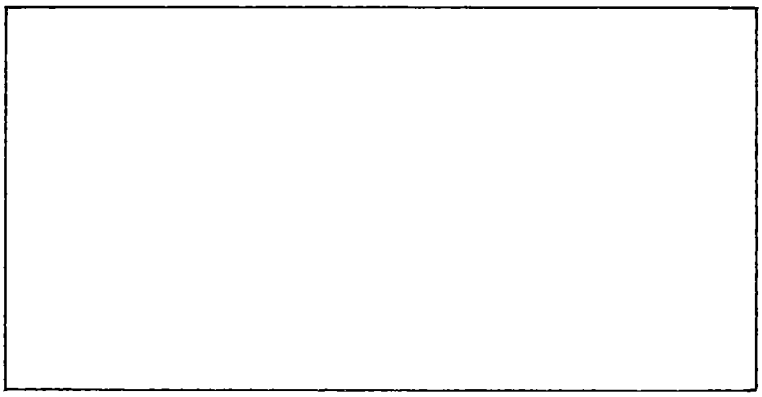
CornerBrook Press
Box 106
Lansing, N.Y. 14882

Library of Congress Catalog Number 80-70984

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

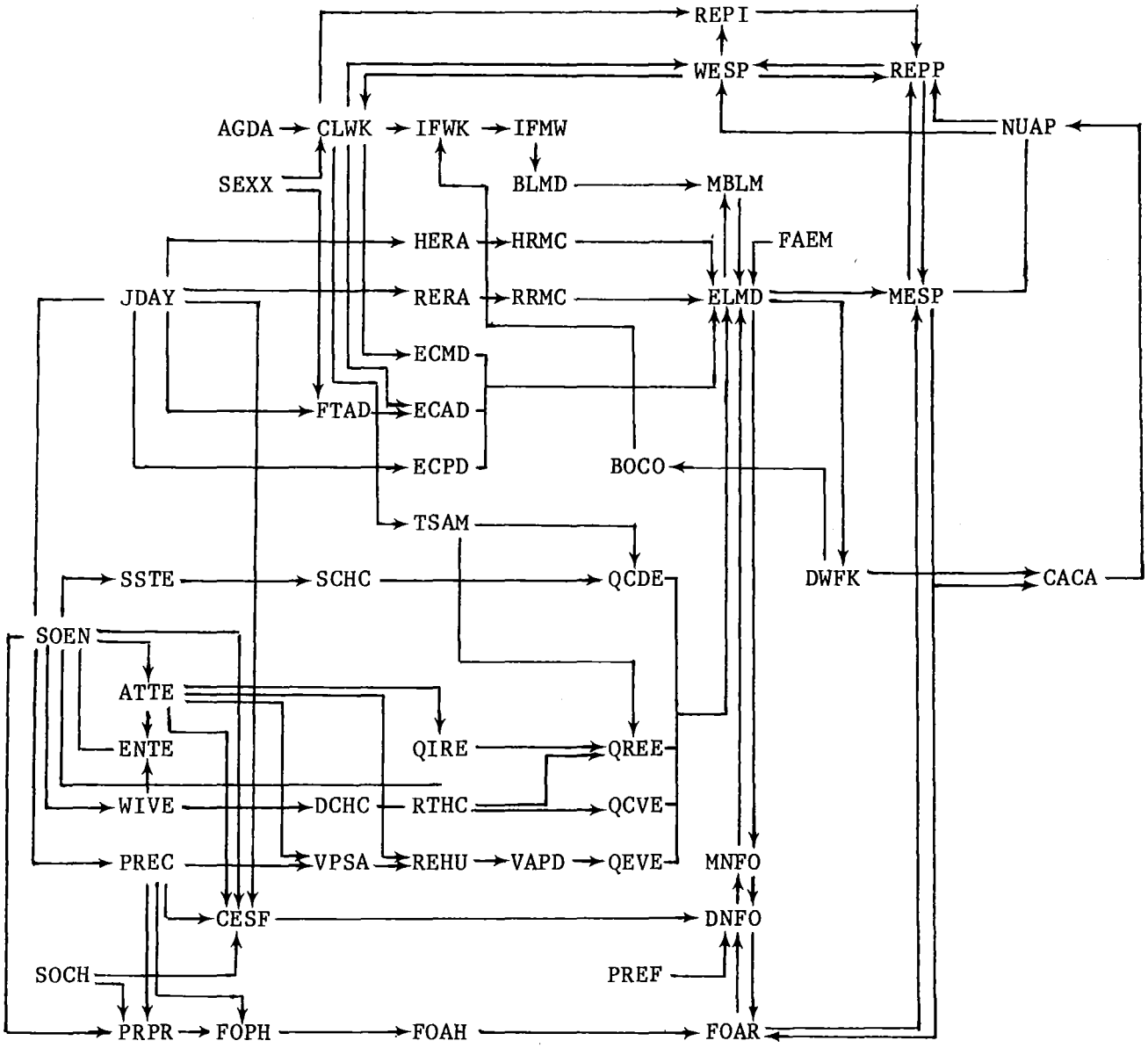
$$(73800)(0.50)(0.75)/2500 = 11.1.$$

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 the 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.