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A Simulation Model of Dietary Competition in the Great Smoky Mountains National Park

John Steven Cherry
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by John Steven Cherry entitled "A Simulation Model of Dietary Competition in the Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

Boyd L. Dearden, Major Professor

We have read this thesis and recommend its acceptance:

Michael R. Pelton, Edward E. C. Clebsch

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor
Graduate Studies and Research

A SIMULATION MODEL OF DIETARY COMPETITION IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

John Steven Cherry

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ABSTRACT

Interactive feeding among a group of vertebrates in the Great Smoky Mountains National Park was simulated. Consumer density, biomass production, consumer consumption rates, and seasonal food habits of adults of each species were calculated using field or literature values.

The consumers included the European wild hog, black bear, raccoon, wild turkey, white-tailed deer, three sciurid species, and several rodents. The sciurids and rodents were considered as two respective canonical groups making a total of seven consumer groups. Literature values of requisite parameters from various studies, primarily in the Southeast, were utilized. These values were allowed to vary randomly.

Simulations were run for five years at one-half month intervals with a four year comparison period. Mast and fungi were the most limited foods with various fruits also being rare. Grasses, various browse species, roots, blueberry, and animal foods were the most abundant. The European wild hog did not compete with the other consumers even when their population size was doubled. The sciurids were the major competitors. The black bear was the consumer best able to cope with the vicissitudes of life in the Park; however, all consumers gave evidence of being able to usually find enough to eat by relying on alternative foods.

Suggestions for future research in the Park and improvements in the model are discussed.

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CHAPTER I

INTRODUCTION AND DESCRIPTION OF STUDY AREA

I. INTRODUCTION

Ecology has been defined as the study of the structure and function of nature (Odum 1971). To understand the structure and function of nature involves an understanding of the interactions among and between the biotic and abiotic components comprising natural systems. Those involved in planning for the wise usage of natural resources have acknowledged the importance of the ecological approach and have been responsible for many studies on ecosystem structure and function. But they have not fully grasped the importance of understanding the interactions among the components of ecosystems.

Interspecific competition for food resources is an area of natural resource management in which the interactions among components in ecosystems have not been properly considered. Odum (1971) defined competition as, "any interaction between two or more species which adversely affects their growth and survival." Dietary competition among a group of consumers results when a common food resource is not available in sufficient quantity to satisfy the dietary requirements of these consumers. Determining the extent of competition for food among a set of consumers thus requires knowledge of their seasonal food habits (studies of structure), of the productivity of the communities where they live (studies of function), and of the interactions among and between the producers and consumers. Past attempts to quantify dietary competition have relied upon determining how similar the seasonal diets of potential competitors were and the condition of the vegetative community where these consumers fed (Pickford and Reid 1943, Smith and Julander 1953, and Constan 1972). Various similarity indices have been used to quantify the amount of dietary overlap among consumers (Hansen et al. 1973 and Hansen and Reid 1975). These studies of structure and function may indicate that competition is occurring, but they do not elucidate the interactions among components of the systems. If sound management plans for the use of natural resources are to be developed more than just the awareness that competition is occurring will be needed. Also required will be the answers to such questions as, "Which consumers are being affected the least and which the most by competition?," and, "Which foods are the focal points of competition?"

Since natural systems are so complex, it is difficult to study and understand the interactive feeding of several different species of consumers. The systems analysis approach to ecological systems and the digital computer offer a way to investigate these complex interactions (Watt 1968).

Walters and Bunnell (1971) developed a computer model designed to facilitate management decisions in regard to land use and big game populations. Their model simulated interactions involving plant production, plant succession, wildlife habitat, food selection, and population dynamics of big game herds. Harris and Francis (1972) modeled interactive feeding among herbivores in an African grasslands community. The model allowed for control of birth rates, death rates, production rates, and competitive shifts in the diet by simulating changes in food quality and quantity. Gilbert (1973) developed a model which utilized seasonal food habits, consumption rates, densities, and plant productivity to simulate interactive feeding among a group of consumers in a Colorado grasslands community.

A simulation model was developed to determine the flow of plant and animal biomass through and the dietary interaction of selected vertebrates in the Great Smoky Mountains National Park (GSMNP or Park). Currently, little is known of the interactions among animal species in the Park. This problem has become increasingly important in recent years due to concern expressed about the impact of the exotic European wild hog (*Sus scrofa*) on native species.

Gilbert's (1973) model was used in this study and modified to simulate dietary competition in the Park. Biomass flows are defined in much the same way as the original version of the model (i.e. by using seasonal food habits, consumption rates, population densities, and productivity). The major changes involved adding a random number generator and deleting various wastage flows. The model is data dependent for the Park; thus, the values for the intensity of biomass flows can be adjusted to simulate not only average conditions but conditions of stress (i.e. food shortages, high population densities, etc.).

II. DESCRIPTION OF STUDY AREA

The GSMNP is a 2048 km^2 area located along the Tennessee-North Carolina border. It includes parts of Haywood and Swain counties in North Carolina and parts of Cocke, Sevier, and Blount counties in Tennessee. U.S. Highway 441 bisects the Park in a northwest-southeast direction and the Appalachian Trail bisects it in a southwest-northeast direction.

The GSMNP is located in the Southern Appalachians and is part of the Unaka Mountain Range section of the Blue Ridge province. Elevations range from 271 m where Abrams Creek flows into Chilhowee Lake to 2025 m atop Clingman's Dome. Narrow ridges, steep-sloped V-shaped valleys, and numerous streams typify the area.

Shanks (1954a) described the climate of the Park as quite variable but characterized generally by cool wet conditions (Table 1). The low-lands are warmer and drier than the upper elevations. There is an average drop in temperature of 1.23°C for every 305 m increase in elevation. The peaks average about 6°C cooler than the valleys.

Precipitation ranges from 127 cm/year at Park Headquarters (elevation 445 m) to approximately 229 cm/year atop the higher peaks. In general, precipitation increases rapidly with altitude, being 50 percent greater around 1500 m elevation than in the valleys 1000 m below.

Shanks (1954b) lumped the complex vegetative patterns into seven physiognomic types; (i) cove hardwood forests, (ii) closed oak forests, (iii) hemlock forests, (iv) northern hardwood forests, (v) grassy balds, (vi) open oak and pine stands; heath balds, and (vii) spruce-fir forests. These seven types occur in distinct elevational and topographical positions (Fig. 1), and have relatively distinct associations of important species (Table 2). R. H. Whittaker (1956) has presented the most comprehensive analysis of the vegetative patterns in this area.

The study area encompassed a 50,588 ha segment of the Park (Fig. 2). This section constituted approximately one-quarter of the total Park area and lay south of U.S. Highway 441 and west of the state line. This

Table 1. Temperature and precipitation data from Gatlinburg, Tennessee (ele 445 m)

Month	Monthly average temperature °C	Monthly average rainfall cm/year
January	4.0	12.3
February	5.5	12.1
March	8.8	13.5
April	13.8	11.4
May	18.2	11.4
June	22.2	13.2
July	23.1	14.4
August	23.2	13.4
September	20.5	7.6
October	14.4	7.9
November	8.2	8.7
December	4.6	11.3

Source: Records of Great Smoky Mountains National Park (1923-1967).

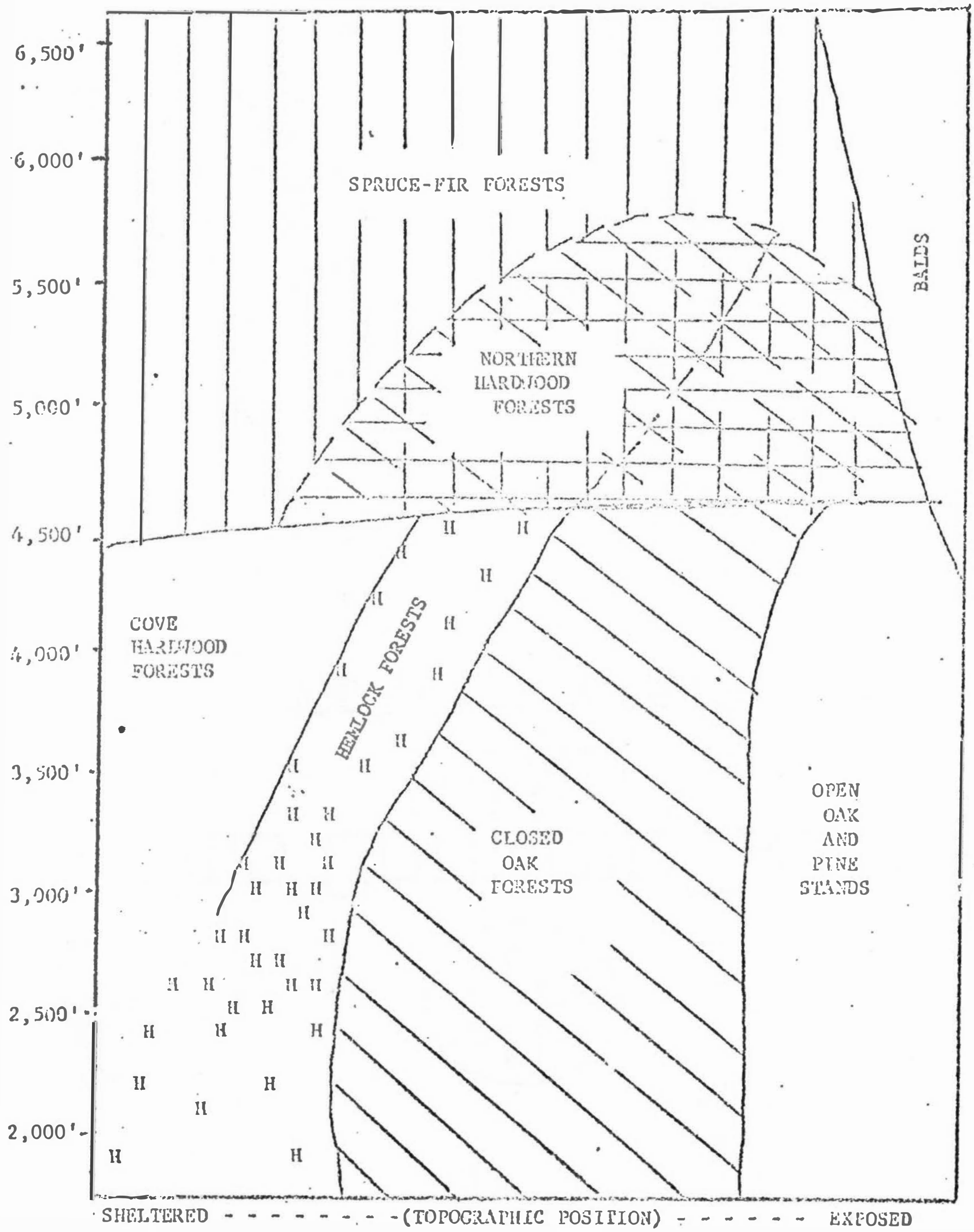

Figure 1. Elevation and topographical positions of vegetation types in the Great Smoky Mountains National Park.

Table 2. Important tree species of the vegetation types in the Great Smoky Mountains National Park.

Vegetation type	Important tree species
Cove Hardwood	Sugar Maple (*Acer saccharum*)
	Yellow Buckeye (*Aesculus octandra*)
	Beech (*Fagus grandifolia*)
	Tulip Poplar (*Liriodendron tulipifera*)
	Eastern Hemlock (*Tsuga canadensis*)
	Silverbell (*Halesia monticola*)
Hemlock	Eastern Hemlock (*Tsuga canadensis*)
	Silverbell (*Halesia monticola*)
	Holly (*Ilex opaca*)
	Fire Cherry (*Prunus pennsylvanica*)
	White Ash (*Fraxinus americana*)
Northern Hardwood	Fraser Fir (*Abies fraseri*)
	Sugar Maple (*Acer saccharum*)
	Service Berry (*Amelanchier laevis*)
	Beech (*Fagus grandifolia*)
	Black Cherry (*Prunus serotina*)
Spruce-Fir	Fraser Fir (*Abies fraseri*)
	Yellow Birch (*Betula allenghenìensis*)
	Red Spruce (*Picea rubens*)
	Mountain Ash (*Sorbus americana*)
Closed Oak	Red Maple (*Acer rubrum*)
	Sweet Birch (*Betula lenta*)
	Hickory (*Carya* spp.)
	Tulip Poplar (*Liriodendron tulipifera*)
	Black Gum (*Nyssa sylvatica*)
	Sourwood (*Oxydendrum arboreum*)
	White Oak (*Quercus alba*)
	Chestnut Oak (*Q. prinus*)
	Northern Red Oak (*Q. rubra*)
	Black Oak (*Q. velutina*)
Open Oak and Pine Stands	Red Maple (*Acer rubrum*)
	Black Gum (*Nyssa sylvatica*)
	Table Mountain Pine (*Pinus pungens*)
	Pitch Pine (*P. rigida*)
	White Pine (*P. strobus*)
	Scarlet Oak (*Quercus coccinea*)
	Chestnut Oak (*Q. prinus*)

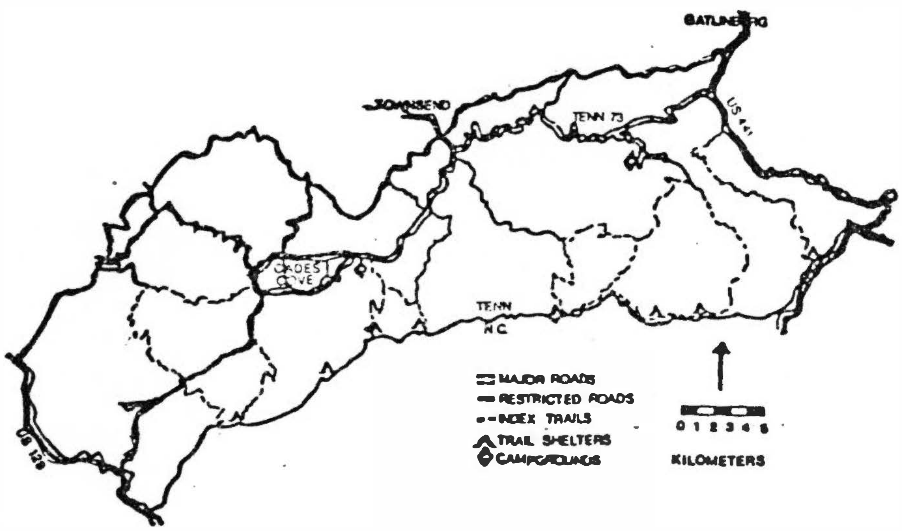

Figure 2. Area in which interactive feeding was simulated in the Great Smoky Mountains National Park.

area is not typical of the rest of the Park, for it includes Cades Cove, a 1012 ha area devoted primarily to pasture. About 1600 head of cattle and a few horses are grazed there annually.

CHAPTER II

DOCUMENTATION

I. COMPONENTS OF THE MODEL

The consumers included the European wild hog, black bear (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallapavo*), gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), northern red squirrel (*Tamiasciurus hudsonicus*), raccoon (*Procyon lotor*), and various small rodents (*Peromyscus* spp., and *Napaeozapus insignis*). The rodents and sciurids were placed into separate canonical classifications to simplify the model. The selection of these species for inclusion in the model was based on the potential for competition of food resources.

Food Habits

The literature provided information on the seasonal food habits of the above consumers (Appendix A). Whenever possible, dietary studies from the Southern Appalachians were utilized. If more than one source was used to determine a seasonal diet, then that diet was computed as a weighted average based on sample size.

Not all the foods utilized by the consumers were considered in the model. Those foods included in the model were chosen in the following manner. The relative percentage each species comprised in the diet of a consumer was computed using the formula

$$RP_j = \sum_{i=1}^{12} PFS_{ij} \Big/ \sum_{j=1}^{n} \sum_{i=1}^{12} TPFS_{ij}$$

where:

RP_j = relative percentage species j comprises in the diet on a yearly basis.

PFS_{ij} = total percentage species j comprises in the diet on a yearly basis.

$TPFS_{ij}$ = total percentage all species comprise in the diet on a yearly basis.

n = number of species in the literature diet.

If RP_j was less than one percent, species j was not included in the model. If RP_j was less than five percent and more than one percent, species j was eliminated provided it did not occur in the diet of more than one consumer (i.e. was not a source of competition), and provided no production data was available for that species. If these conditions were not met, species j was considered important enough to include in the diet. A total of 24 foods partitioned among the seven consumers was chosen in this manner (Appendix B). Appendix B also gives the scientific names of the plant foods.

The modelling required that a combination of foods not make up more than 100 percent of the diet and that the diets be expressed on a monthly basis. The first requirement necessitated using studies which presented their results on a percentage volume, or comparable, basis. Since most investigators of food habits presented their results on a seasonal basis, the percentage a given food item comprised in a consumer's diet in any given month was assumed to be the percentage that item comprised in the diet in the season in which that month occurred. Unless otherwise indicated by the various authors of the studies used, fall was assumed to be September to November, winter was December to February, spring was March to May, and summer was June to August. Thus, if food item A accounted for 50 percent of consumer B's summer diet then food item A was assumed to comprise 50 percent of the June, July, and August monthly diets.

The diets were varied during simulation by including monthly threshold values for each dietary item in the model. The contribution any item made to a consumer's diet fluctuated between zero and this maximum threshold value as food availability changed. The threshold values either came from sources used to compute the diets in Appendix A or from Martin et al. (1951), whichever had the highest values. The European wild hog was the exception to this, and the threshold values for this consumer's diet were taken from Scott (1973) or Henry and Conley (1972), whichever had the highest values.

Information on food habits was not available for all species included in the two canonical groupings. The diet of the canonical sciurid was assumed to be the diet of the gray squirrel based on a study by Dudderar (1967), since no food habits studies on chipmunk and northern red squirrel were found in which results were expressed on a percentage volume basis. Layne (1954) and Graybill (1970) furnished information on northern red squirrel and chipmunk diets respectively indicating their diets were similar to the gray squirrel's diet. It is unrealistic to have the red squirrel and chipmunk diets equal to that of the gray squirrel, but it was assumed justifiable since no attempt was being made to investigate the competitive interactions among these sciurids. The intent was to analyze how these sciurids as a canonical group affected the other species with which they coexisted.

J. O. Whittaker (1963, 1966) reported on the summer food habits of Peromyscus maniculatus and P. leucopus in New York and Indiana, and Martin et al. (1951) presented general information on the diet of P. leucopus. Information on the food habits of small mammals in the Park was presented by Linzey and Linzey (1973). Their results were reported on a percent frequency of occurrence basis which was of no value for the purposes of the model but did provide an idea of what small mammals consume in the Park. Enough information was available from these studies to compute realistic dietary percentages for mast, fungi, and blackberry. Because of the lack of information on rodent food habits, the canonical rodent was considered a "sink" serving to consume various amounts of important foods, but their interactions with the other consumers were not examined.

Densities

Densities were varied randomly between the minimum and maximum values found in the literature (Table 3). The black bear's density was kept stable because it is believed that they presently have a relatively stable population in the Park (Pelton, personal communication). The two squirrels and the chipmunk were varied independently of each other.

Consumption Rates

Consumption rates were calculated in kilograms dry weight per individual consumer per month (Table 4). The squirrels and chipmunks were considered separately, and the chipmunk diet was reduced 85 percent in the winter (Graves 1971). Bacon (personal communication) found the consumption rate of penned bears increased from late March to Fall. They consumed 32.7 kg dry weight per individual per month in March and in

Table 3. Range in densities (no. animals/ha), average densities, and literature sources.

	Densities		
Consumers	Range	Average	Source(s)
Squirrels[a]	0.519 - 13.29	2.15	Barkalow et al. (1970) Uhlig (1957)
Chipmunk	1.03 - 23.91	11.33	Yerger (1953)
Canonical Rodent	0 - 42	9.77	Mohr (1947) Terman (1968)
Wild Turkey	.00286 - .00974	.00623	Mosby (1967)
Raccoon	.012 - .418	.156	Johnson (1970) Steuwer (1943)
White-Tailed Deer	.0198 - .0593	.0395	Pelton (PC)[b]
European Wild Hog	.00217 - .0285	.0144	Tennessee Game and Fish Commission (1972)
Black Bear	.00395[c]		Pelton (PC)

[a]Northern red squirrel was assumed to have the same density as gray squirrel because density figures from Layne (1954) and Kemp and Keith (1970) were comparable.

[b]PC: Personal Communication.

[c]Assumed stable.

Table 4. Monthly consumption rates in kilograms dry weight per individual and their literature sources.

Consumers	Consumption rate	Sources
Squirrels[a]	1.12	Short and Duke (1971)
Chipmunk	0.91	(see text)
Canonical Rodents	0.154	Gilbert (1973)
Wild Turkey	3.41	Goodrum et al. (1971)
Raccoon	6.8	Knoxville Municipal Zoo
White-Tailed Deer	40.8	Goodrum et al. (1971)
Wild Hog	61.3	Conley (PC)[b]
Black Bear	32.7 - 98.1	Bacon (PC)

[a]No information was available on red squirrel. Assume they consume same amount as gray squirrel.

[b]PC: personal communication.

September they consumed 98.1 kg. Assuming this increase was linear a linear interpolation routine was used to find the consumption rates for April through August. The rates of consumption in October and early November were assumed equal to the rate in September, and the consumption rate was set to zero from mid-November to mid-March to account for the dormant period.

The consumption rate for chipmunks was calculated from Verme's (1957) report on the number of acorns consumed per day per chipmunk and Downs' (1944) data on the number of acorns required to make a pound. Their data and data on moisture content from Goodrum et al. (1971) resulted in the chipmunk consumption rate (Table 4).

The amount of food required by the wild turkey was not given in kg dry weight by Goodrum et al. (1971) (Table 4), and it was assumed that the foods which the turkey consumes were 50 percent water on the average.

Consumers were assumed to waste 50 percent as much as they eat. Various studies reviewed in Gilbert (1973) indicated this was not an unrealistic figure. An estimated edible factor was built into the model by assuming that only 75 percent of the food available to the consumers was edible. There were no data to indicate how reasonable this figure might be.

Annual Net Production

Literature sources were available giving annual net production values in kg dry weight per ha for most foods included in the model (Table 5). Where literature sources were lacking reasonable estimates were made. Fungi was the only dietary item of potential competitive importance for

Table 5. Net annual production data for foods utilized by consumers in kg dry weight/ha.

Foods	Net annual production	Source
Honeysuckle	5	Moore and Strode (1966)
Grasses	33	R. H. Whittaker (1963, 1966)
Fungi	10	N/A[a]
Rhododendron	339	R. H. Whittaker (1961, 1962, 1963, and 1966)
Mountain Laurel	339	R. H. Whittaker (1962, 1963, and 1966)
Wintergreen	142	R. H. Whittaker (1963)
Galax	28	R. H. Whittaker (1963, 1966)
Blueberry Browse	142	R. H. Whittaker (1962, 1963, and 1966)
Sheep Sorrel	0.28	R. H. Whittaker (1966)
Mast	62	Conley (PC)[b]
Animal	198	N/A
Garbage	1	N/A
Roots[c]	500	Harris et al. (1973)
Cherry Fruits	0.0056	Graybill (1970)
Dogwood Fruits	0.067	R. H. Whittaker (1966)
Yellow Poplar Fruits	0.0056	R. H. Whittaker (1966)
Red Maple Seeds	0.20	R. H. Whittaker (1966)
Squawroot Fruits	1	N/A
Squawroot Forage	10	N/A
Apple Fruits	0.1	N/A
Juneberry	0.005	R. H. Whittaker (1966)
Mayapple Fruits	0.053	R. H. Whittaker (1966)
Yellow Poplar Browse	0.1	R. H. Whittaker (1966)
Red Maple Browse	5.5	R. H. Whittaker (1966)
Oak Browse	85	R. H. Whittaker (1966)
Wild Grape Fruits	0.006	R. H. Whittaker (1966) and Graybill (1970)
Persimmon	0.009	N/A
Blackberry Fruits	0.42	R. H. Whittaker (1962, 1963, and 1966)
Blueberry Fruits	5.5	R. H. Whittaker (1962, 1963, and 1966)
Huckleberry Fruits	18	R. H. Whittaker (1962, 1963, and 1966)

[a]N/A: Not Applicable. No sources were available and a reasonable guess had to be made.

[b]PC: Personal Communication.

[c]Production of roots greater than 0.5 cm in diameter.

which data was lacking. The value of ten kg dry weight per ha is probably too high but not unreasonable (Clebsch, personal communication). The other foods for which production data was lacking were either not a source of competition (e.g. squawroot) or were known to be present in such small amounts in the Park as to be unimportant in the diet (e.g. garbage).

The values for annual net production were determined in the following manner. The sources (Table 5) were reviewed and production data in kg dry weight per ha were computed. The vegetation types in which these food species were found were listed (Shanks 1954b). The number of ha each vegetation type comprised in the study area was calculated by multiplying the area of the study (50,588 ha) times the percentage each vegetation type accounted for in the entire Park (National Park Service 1969). The production figures in kg dry weight per ha were then multiplied by the number of ha the vegetation types they occurred in comprised in the study area. Finally, they were divided by 50,588 ha to derive the values in Table 5.

Long-term data was available only for mast [for the purposes of this study, mast is defined to be the nuts of oak (Quercus spp.), hickory (Carya spp.), and buckeye (Aesculus octandrus)]. The production of mast on an annual basis in the Southern Appalachians has been researched by many investigators (Downs and McQuilken 1944, Beck and Olson 1968, and Strickland 1972). Oak mast summaries from 1970 - 1974 inclusive for the Tellico Wildlife Management Area (Conley, personal communication) adjacent to and southwest of the Park were chosen for this study. These estimates were derived using a method developed by Whitehead (1969), and they included correction factors due to arboreal feeding and number of unsound acorns. With a 50 percent moisture content (Goodrum et al. 1971) the average mast production over the five year period was calculated.

The production figures were varied annually through use of the random number generator. Browse was varied within 25 percent of the mean, fruits within 50 percent, and mast was allowed to vary between the maximum and minimum values recorded in the study above. The 25 percent and 50 percent values were reasonable estimates of annual variation in production (Clebsch, personal communication).

The food species were grouped together into seasonal orders and fed into the biomass pool at the appropriate time every simulated year. For example, mast was fed in and renewed every September, deciduous browse and grasses were fed in during the spring, and various fruits during the summer. Those species which were present only a few months every year (e.g. summer berries) were zeroed out at the appropriate time. These seasonal orders were realistic (Clebsch, personal communication).

II. MODEL IMPLEMENTATION

The model was implemented on the SIMCOMP 2.1 programming system (Gustafson and Innis 1972). SIMCOMP was chosen because it has the capability of defining 300 flows among 99 state variables, consolidated declaration of parameters permitting communication among subprograms, graphical and tabular output, and it allows the user to define any functions and subroutines needed.

SIMCOMP conceptualizes flows in difference equation form. The general equation describing flows is:

$$x(t + \Delta t) = x(t) + t\ (\Sigma F)$$

where:

$x(t + \Delta t)$ = amount in component x at time $t + \Delta t$
$x(t)$ = amount in component x at time t
ΣF = sum of flows into and out of x
t = time increment

A box and arrow diagram (Figs. 3 and 4) aided in the initial formalization of the model. The symbols used follow Forrester (1971) and Weins and Innis (1974). The solid arrows indicate flows of biomass and the dashed arrows indicate flows of information. The circles function as input variables and the five-sided figures are control variables. The valve shaped symbol represents a rate control. The activity blocks are not Forrester symbols but were necessary to depict the working of the model in as concise a form as possible.

The computer program of the model (Appendix C) was modified from Gilbert (1973). The flowchart in Fig. 5 is a schematic representation of how the program functioned.

A listing of the variables used in the model can be found in Appendix D.

Subroutines

The main part of the program determined density, consumption rate, diet, and threshold values for dietary items of a given consumer. It also served to compute the flows of biomass. Subprograms were used to perform various other tasks such as redistribution of diets (Fig. 5). These subprograms and their functions are described below.

Subroutine (subprogram) START was called prior to simulation. Data was read in and initial conditions were set in START. CYCLE was called

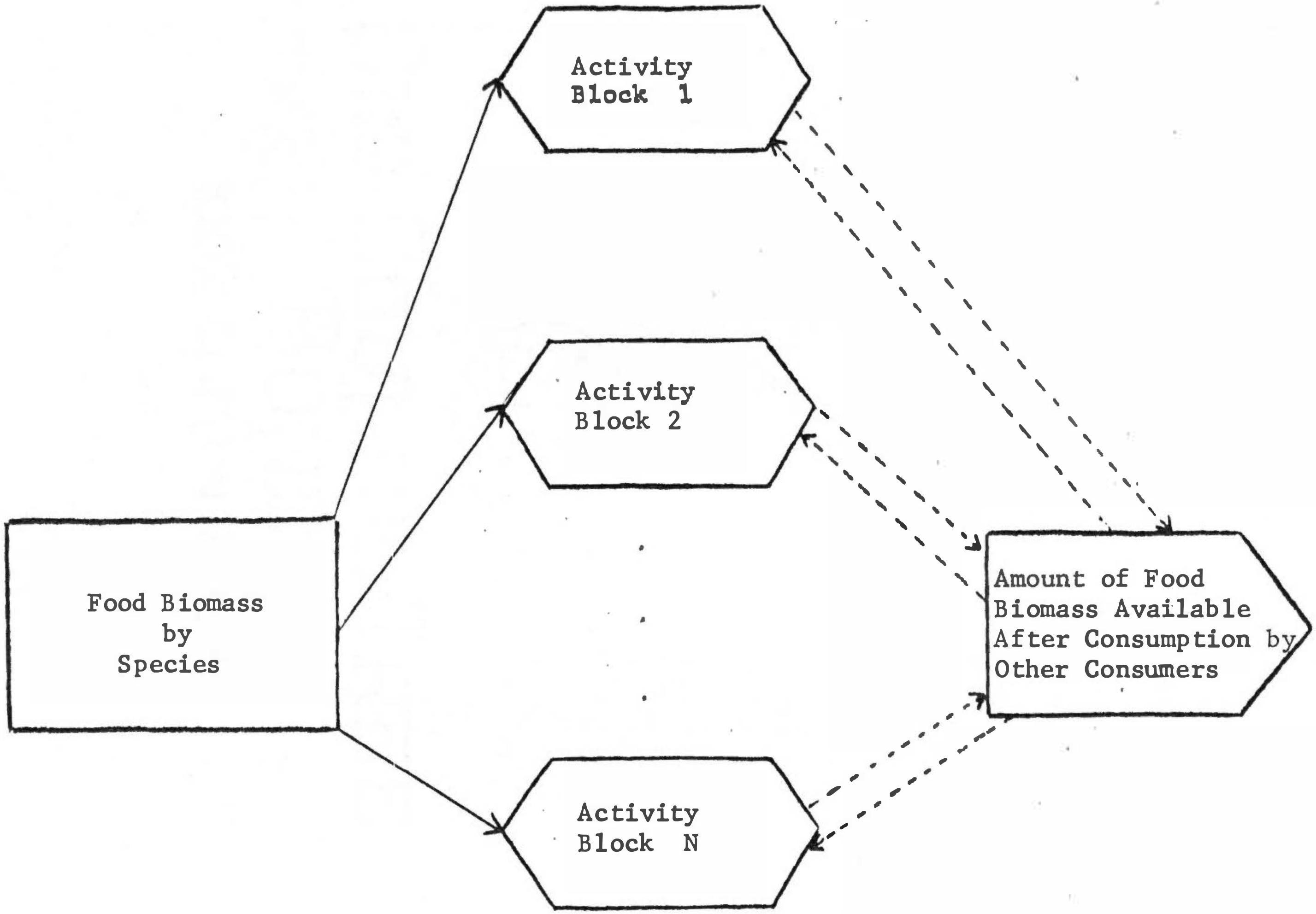

Figure 3. Box and arrow diagram showing flow of biomass to consumers. Each activity block represents one consumer.

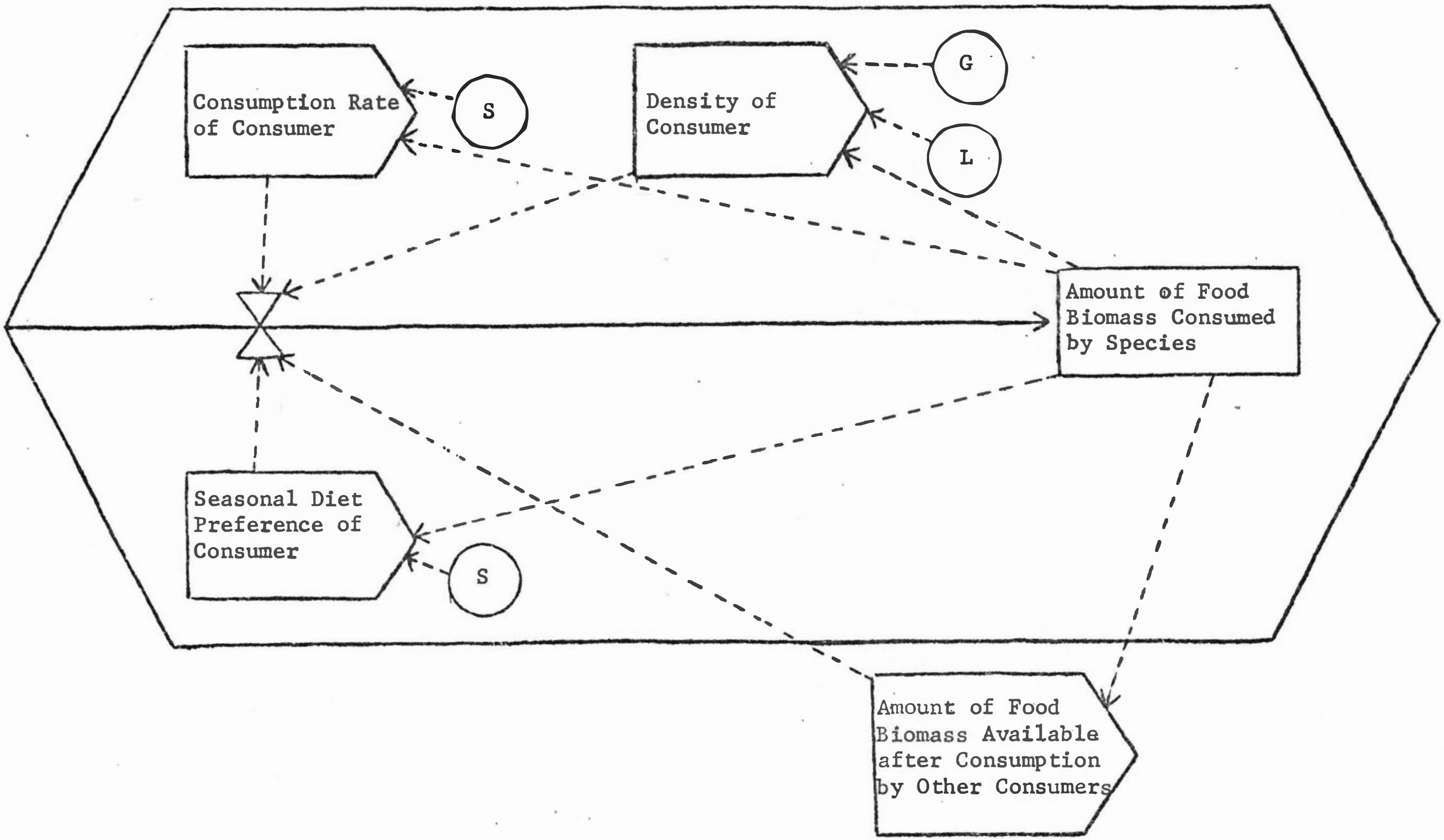

Figure 4. Expansion of activity block from Fig. 3. The flow of biomass into one consumer and the parameters controlling the rate of flow are shown. (S-Season; G-Gain; L-Loss)

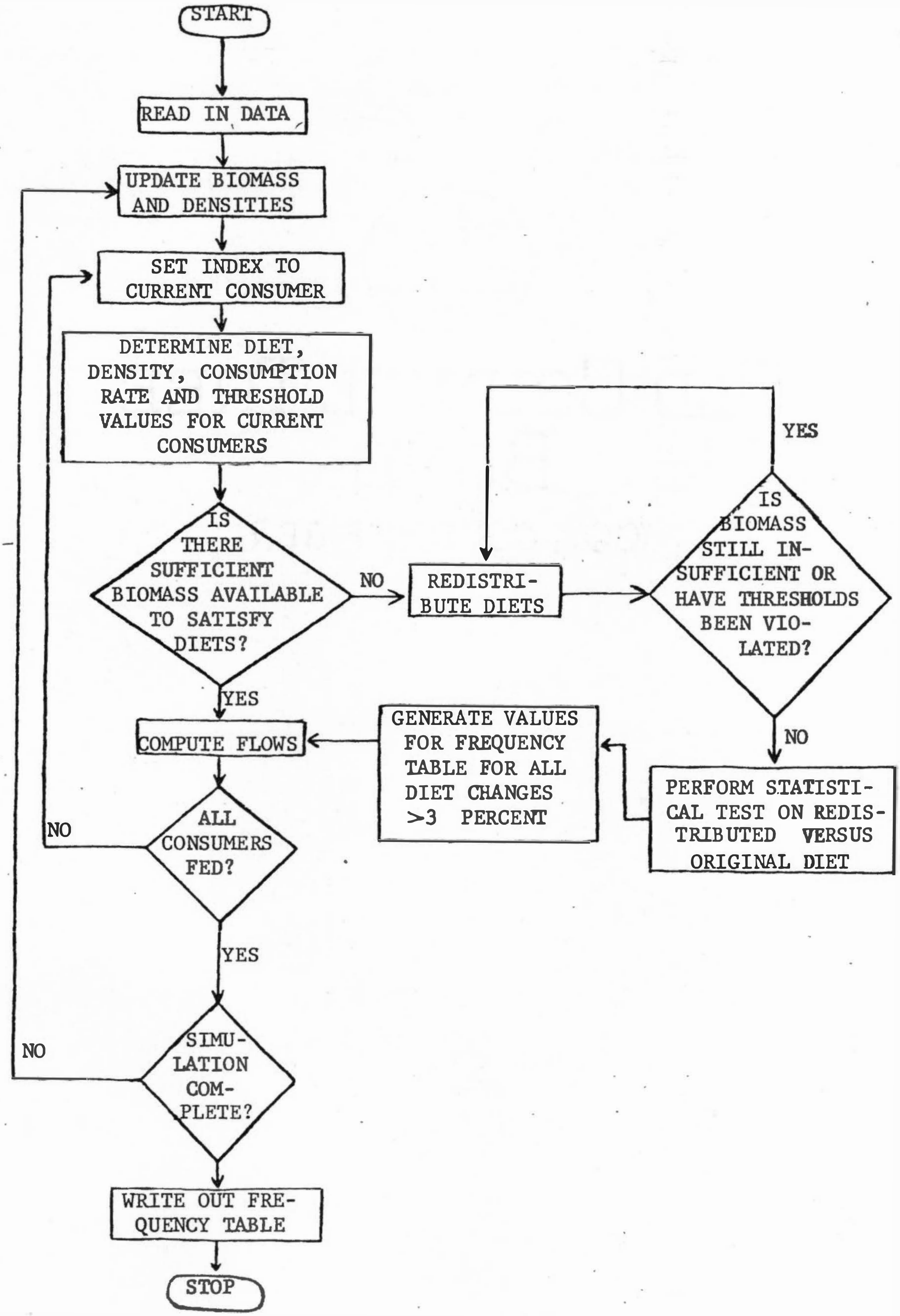

Figure 5. Flowchart of computer program of dietary competition in the Great Smoky Mountains National Park.

prior to every simulation timestep; it updated production data of foods and population densities of consumers. START and CYCLE were automatically called by the SIMCOMP programming system and did not have to be called from the main part of the program (Appendix C).

TAB2 is a function subprogram which served as both a linear interpolation and table retrieval routine.

Subroutine TFLO determined if the amount of biomass available by food species was sufficient to satisfy the dietary requirements of the current consumer. If there was insufficient biomass of a particular plant species then subroutine FLO was called. FLO increased the proportions of the other plants in the diet. FLO tested the new diet to insure that there was sufficient biomass available to fulfill that diet's requirements and to insure that no food item exceeded its threshold value in the diet. If either of these occurred, another redistribution took place with subsequent testing and redistribution as needed. Eventually, this process approached a diet considered feasible for the consumer.

Subroutine DLIET served to pass dietary changes greater than one percent which had occurred in FLO to subroutine SRANK. SRANK is an IBM scientific subroutine package and performs a Spearman's rank correlation on the redistributed diet versus the original diet. This allowed determination of whether the rank order of foods in the redistributed diet was significantly different from the rank order of foods in the original diet.

SRANK utilized subroutines RANK and TIE, which are also IBM scientific subroutine packages. RANK served to rank a vector of values and TIE computed a correction factor for tied ranks. Both were necessary for calculation of the correlation coefficient.

Subroutines RANDOM and RANDU are IBM packages which served as the random number generator. RANDOM calculated normally distributed random real numbers from a distribution with a given mean and standard deviation. RANDU, which was called by RANDOM, generated uniformly distributed real numbers.

Subroutine TRADI subtracted the percentages various foods comprised in the original diet of a consumer from the percentages those foods comprised after the diet was redistributed in subroutine FLO. The number of dietary changes occurring (both increases and decreases) greater than three percent were summed. TRADI also summed the percentages of these changes.

Subroutine CYCL2 was called at the end of each simulation timestep, and functioned primarily to write the frequency tables generated in TRADI.

Reliability and Hypothesis Testing

The model was numerically tested to insure reliability by using a hand calculator to compute selected segments of output. After the program was shown to be reliable and functioning correctly, hypotheses were tested using the results of SRANK and TRADI. The significance of the correlation coefficient was tested using the proper table in Siegel (1956).

The frequency and magnitude of dietary changes greater than three percent, as determined by TRADI, proved useful. These changes were counted for each consumer, and seven frequency tables were generated for each simulation. Gilbert (1973) chose three percent because he believed this allowed for variation in the diet while being sensitive to significant changes. TRADI gave an indication of which consumers were having their diets stressed by competition.

<u>Simulation Period and Timestep</u>

Biomass flows were simulated for five years. The first month of a simulated year was assumed to be September because this simplified the manner in which the production values were updated in subroutine CYCLE. The first year was used to "prime" the model and the dietary changes which took place during that year were not analyzed in model output. This priming was necessary because of the manner in which biomass was handled. CYCLE fed in the entire annual net production of a food item the first month that item became available. The consumers were then assumed to feed from this biomass until they had consumed all of it or until it was no longer seasonally available at which time CYCLE removed any remaining biomass of that particular food item from the model. In those cases where a food item was assumed to be present for the entire year, the food was never removed except by overconsumption. All foods were renewed every twelve months, though at different times, throughout the year. Those food items which were available for consumption in the late summer-early fall period overlapped the ending and beginning of a simulated year. Rather than guessing how much biomass of these foods was available the first September, no biomass of any given food item was made available the first year until the season of production of that food item was reached. The start of the second year was chosen as the start of the actual feeding period and biomass flows and dietary changes were analyzed for the latter four years of the five year simulation. In all simulations run, the first year was kept the same to provide a common starting point for comparison purposes.

The model was conceptualized on a monthly basis, but a monthly timestep was found to be unsatisfactory for simulation (Gilbert 1973). Gilbert tried several different time intervals and determined that a two week simulation timestep represented his feeding regime more precisely. A two week timestep was chosen for this study.

Random Number Generator

As long as the random number generator was called in the same order the same sequence of random numbers was generated in each simulation. Direct comparisons were possible between all simulations because all production and density values varied randomly using the same sequence of random numbers, except for those values being experimentally manipulated. For example, the annual net production of a given food item during the third year of Simulation A was equal to the production of that item during the third year of Simulation B, even though the values were chosen randomly.

III. SIMULATIONS

It was not possible to simulate a feeding regime in which the consumers fed simultaneously from the available biomass. Instead, the manner in which the model was conceptualized necessitated a consecutive feeding order, and an investigation into whether different feeding orders yielded different results was needed. The original feeding order was wild turkey, European wild hog, black bear, sciurids, white-tailed deer, canonical rodent, and raccoon. To determine if feeding the consumers in different orders affected the output of the model significantly, four simulations with the original feeding order and three randomly chosen orders were run. No significant differences were found and the original order was kept for all subsequent simulations.

A series of simulations was run to assess the impact of the European wild hog and the canonical order of sciurids on the Park ecosystem. In the first simulation all food production and consumer density values were chosen randomly. In subsequent simulations wild hog density and sciurid density values were experimentally manipulated. High hog densities were simulated by doubling the randomly chosen hog numbers, and low hog densities were simulated by assuming no hogs were present in the Park. High sciurid densities were simulated by assuming they were present at the maximum allowable density for the second and third year of the four year comparison period. Low sciurid densities were simulated similarly. Those runs in which all food production values were determined randomly were considered to be simulations of "average" food availability conditions.

It is not uncommon in the Southern Appalachians to have two consecutive poor mast years preceded by and followed by good to excellent years. Since mast is a crucial dietary component of all consumers' diets in the model a series of simulations was run to investigate the hog and sciurid impact on other consumers under these simulated conditions of mast availability. The first simulation of this set varied mast experimentally with all other food production values and all density values varied randomly. A good mast crop (100 kg/ha), two poor mast crops (17 kg/ha), and an excellent mast crop (120 kg/ha) were simulated.

High and low hog and sciurid densities under these mast conditions were then simulated in the manner described.

Gilbert (1973) found his model sensitive to changes in the estimated edible factor. A simulation was run in which the factor was reduced from 75 to 50 percent with all values varied randomly to determine if this version of the model was sensitive to such changes.

CHAPTER III

RESULTS

I. AVAILABILITY OF FOODS UNDER NORMAL CONDITIONS

Determining the relative abundance of the 24 food items was aided by examination of the frequency tables generated by subroutine TRADI. Table 6 depicts the total number of increases and decreases greater than three percent which occurred in the diets of all seven consumers during the simulation in which all density and production values were varied randomly. The summed percentages of these increases and decreases are also shown. These percentages are the four year cumulative total of the percentage changes (both increases and decreases) greater than three percent occurring in the diets of the consumers. Increases mean that a food was abundant and decreases imply that a food was scarce. Some foods (e.g. mast) showed both increases and decreases suggesting they were abundant sometimes and scarce at other times.

Mast was scarcest showing 236 decreases totaling 7131 percent. These decreases usually began occurring in the late fall and early winter. In the early fall mast was usually abundant. All 124 increases recorded for this food occurred during this time. The length of time of abundance and the beginning of scarcities was dependent on the size of the mast crop. With a very poor mast crop (17 kg dry weight/ha) the entire crop was gone within three months regardless of consumer density.

A total of 144 decreases occurred with fungi. Only 17 increases were recorded and these occurred in April when fungi were most abundant. Except for this very brief period in early spring fungi was always scarce.

Table 6. Frequency and summed percentages for changes in diets which exceeded three percent due to redistribution of diets. Figures are from simulation using randomly chosen production and density values.

Food species	Number of increases	Total percentage of increases	Number of decreases	Total percentage of decreases
Honeysuckle	0	0	0	0
Grasses and Sedges	76	968	0	0
Fungi	17	165	144	2039
Rhododendron	15	112	0	0
Mountain Laurel	16	113	0	0
Wintergreen	0	0	0	0
Galax	16	77	0	0
Blueberry Browse	0	0	0	0
Sheep Sorrel	0	0	0	0
Mast	124	1513	236	7131
Animal	111	1692	0	0
Garbage	0	0	0	0
Roots	18	289	0	0
Cherry	0	0	20	254
Dogwood	0	0	0	0
Yellow Poplar Fruits	0	0	16	54
Red Maple Seeds	0	0	20	77
Squawroot Forage	0	0	15	297
Apple	0	0	46	766
Juneberry	0	0	23	146
Mayapple	0	0	23	1099
Yellow Poplar Browse	0	0	20	118
Red Maple Browse	0	0	0	0
Oak Browse	0	0	0	0
Wild Grape	0	0	118	705
Persimmon	0	0	55	894
Blackberry	0	0	16	92
Blueberry	16	337	8	49
Squawroot Fruits	0	0	0	0
Huckleberry	0	0	16	100

All fruits, with the exception of blueberry, were always scarce. There was never enough cherry (20 decreases), persimmon (55 decreases), or wild grape (118 decreases) in the fall. Apple (46 decreases) was always scarce during the spring and summer, and blackberry (16 decreases) and huckleberry (16 decreases) were always rare in the summer and early fall. No increases were recorded for any of the above fruits. Blueberry was abundant in the early summer (16 increases) but became scarce as summer waned (8 decreases).

Other foods which were scarce were yellow poplar fruits, red maple seeds, squawroot forage, juneberry, and yellow poplar browse.

Grasses and sedges and animal matter were always abundant showing 76 and 111 increases respectively with no decreases. Rhododendron (15 increases), mountain laurel (16 increases), galax (16 increases) and roots (18 increases) were also always present in amounts more than sufficient to satisfy the demand.

Honeysuckle, wintergreen, blueberry browse, sheep sorrel, garbage, dogwood fruits, red maple browse, and oak browse showed neither increases nor decreases. These foods were never scarce but the consumers could not increase the percentages of the diets they comprised because of threshold restrictions.

Availability of Foods when Mast Production was Varied

When mast was experimentally manipulated, and all other parameters varied randomly, the same pattern of food abundance resulted (Table 7). Mast and fungi were scarcest followed by the fruits. Grasses and sedges and animal foods were the most abundant.

Table 7. Frequency and summed percentages in diets which exceeded three percent due to redistribution of diets. Values are from simulation in which mast was experimentally manipulated.

Food species	Number of increases	Total percentage of increases	Number of decreases	Total percentage of decreases
Honeysuckle	0	0	0	0
Grasses and Sedges	76	859	0	0
Fungi	15	119	144	2040
Rhododendron	15	110	0	0
Mountain Laurel	15	110	0	0
Wintergreen	0	0	0	0
Galax	15	72	0	0
Blueberry Browse	0	0	0	0
Sheep Sorrel	0	0	0	0
Mast	122	1384	239	7207
Animal	110	1682	0	0
Garbage	0	0	0	0
Roots	18	285	0	0
Cherry	0	0	20	254
Dogwood	0	0	0	0
Yellow Poplar Fruits	0	0	16	54
Red Maple Seeds	0	0	20	77
Squawroot Forage	0	0	15	297
Apple	0	0	46	766
Juneberry	0	0	23	145
Mayapple	0	0	23	1099
Yellow Poplar Browse	2	6	20	119
Red Maple Browse	0	0	0	0
Oak Browse	0	0	0	0
Wild Grape	0	0	118	705
Persimmon	0	0	55	894
Blackberry	0	0	16	92
Blueberry	17	361	8	49
Squawroot Fruits	0	0	0	0
Huckleberry	0	0	16	100

II. CONSUMERS AND FOODS

The seven consumer-specific frequency tables generated during the simulation in which all parameters were varied randomly (Tables 8 through 14) yielded information on those foods the consumers were stressing the most.

Wild Turkey

The wild turkey was unable to obtain sufficient mast, wild grape, blackberry, and huckleberry (Table 8). Mast showed 53 decreases totaling 1165 percent versus 30 increases totaling 105 percent, whereas wild grape showed 59 decreases versus no increases making them the most stressed items in the turkey diet. The turkeys were able to find more than enough grass (55 increases) and animal foods (36 increases). Sheep sorrel and dogwood were never stressed.

Wild Hog

The wild hog (Table 9) was never able to find sufficient mast, apple, blueberry, or huckleberry. Mast (37 decreases) and apple (23 decreases) were the two foods the hog had the most trouble finding. Grasses, blueberry browse, roots, and garbage were never scarce, but the hog was unable to increase consumption of these foods because of threshold restrictions.

Black Bear

The black bear (Table 10) found cherry (20 decreases), squawroot forage (15 decreases) and wild grape (12 decreases) all scarce. But the bear usually found enough mast (18 increases versus 2 decreases) to satisfy its dietary demands. Blueberry with 16 increases was also abundant. The other foods in the bear diet were never stressed.

Table 8. Frequency and percentage of changes in wild turkey diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Grasses	55	881	0	0
Mast	30	105	53	1165
Animal	36	361	0	0
Sheep Sorrel	0	0	0	0
Dogwood	0	0	0	0
Wild Grape	0	0	59	295
Blackberry	0	0	8	33
Huckleberry	0	0	8	39

Table 9. Frequency and percentage of changes in wild hog diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Grasses	0	0	0	0
Blueberry Browse	0	0	0	0
Mast	0	0	37	922
Roots	0	0	0	0
Garbage	0	0	0	0
Apple	0	0	23	560
Blueberry	0	0	8	49
Huckleberry	0	0	8	61

Table 10. Frequency and percentage of changes in black bear diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Grass	0	0	0	0
Mast	18	272	2	94
Garbage	0	0	0	0
Animal	0	0	0	0
Cherry	0	0	20	254
Squawroot Forage	0	0	15	297
Wild Grape	0	0	12	39
Blueberry	16	337	0	0
Juneberry	0	0	0	0
Huckleberry	0	0	0	0
Blackberry	0	0	0	0
Squawroot Fruits	0	0	0	0

Table 11. Frequency and percentage of changes in sciurid diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Fungi	16	137	41	743
Mast	30	634	40	2410
Red Maple Seeds	0	0	20	77
Apple	0	0	23	206
Mayapple	0	0	23	1099

Table 12. Frequency and percentage of changes in white-tailed deer diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Grasses	21	87	0	0
Fungi	0	0	50	483
Rhododendron	15	112	0	0
Mountain Laurel	16	113	0	0
Wintergreen	0	0	0	0
Galax	16	77	0	0
Mast	0	0	27	520
Yellow Poplar Fruits	0	0	16	54
Yellow Poplar Browse	0	0	20	119
Red Maple Browse	0	0	0	0
Wild Grape	0	0	0	0
Oak Browse	0	0	0	0
Apple	0	0	0	0
Honeysuckle	0	0	0	0

Table 13. Frequency and percentage of changes in canonical rodent diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Fungi	1	28	53	814
Mast	20	370	21	644
Blackberry	0	0	8	59

Table 14. Frequency and percentage of changes in raccoon diet which exceeded three percent. Values are from simulation in which all production and density values were randomly chosen.

Food species	Number of increases	Percentage of increases	Number of decreases	Percentage of decreases
Mast	26	132	56	1376
Animal	75	1331	0	0
Wild Grape	0	0	47	410
Persimmon	0	0	55	894
Roots	18	289	0	0
Juneberry	0	0	23	145

Canonical Sciurid

The canonical sciurid (Table 11) was unable to satisfy any of its dietary requirements. Apple, mayapple, and red maple seeds were always scarce with only decreases and no increases recorded. Mast (40 decreases versus 30 increases) and fungi (41 decreases versus 16 increases) were also scarce.

White-Tailed Deer

The deer (Table 12) found fungi (50 decreases), mast (27 decreases), yellow poplar fruits (16 decreases) and yellow poplar browse (20 decreases) scarce. No increases were recorded for these foods implying they were never abundant for the deer. Grasses (21 increases), rhododendron (15 increases), mountain laurel (16 increases), and galax (16 increases) were always abundant. Wintergreen, red maple browse, oak browse, and honeysuckle were never scarce but threshold restrictions prevented any increases. Wild grape and apple were scarce but made up such a small part of the diet (less than three percent) that their dietary changes were not counted by subroutine TRADI.

Canonical Rodent

The canonical rodent (Table 13) was unable to find sufficient fungi, mast, or blackberry, Mast showed 20 increases totaling 370 percent versus 21 decreases totaling 644 percent. Fungi was very scarce with one increase versus 53 decreases. It should be remembered that this consumer was a "sink" serving to drain off realistic amounts of important foods making them unavailable to others. The results should not be interpreted as indicating these consumers are actually stressed in this manner.

Raccoon

Wild grape (47 decreases), persimmon (55 decreases), and juneberry (23 decreases) were always too scarce to fulfill the raccoon's dietary requirements (Table 14). No increases were recorded for any of the above foods. Mast was also stressed (26 increases versus 56 decreases). Animal and roots (75 increases and 18 increases respectively) were very abundant.

III. BIOMASS FLOWS

Selected graphical illustrations of biomass flows (Figs. 6 through 11) reveal how much biomass the consumers ate relative to each other. The sciurids ate 10 to 20 times more biomass than the other consumers (Figs. 7, 8, 9, 10). All of these graphs were computer generated. The computer determined the proper scaling for the axes insuring that all data points would be represented. In Figs. 8 and 10 the computer had to scale the vertical axis so large to accomodate the sciurids that the other consumers were grouped along the horizontal axis making it difficult to determine the interactions among them. The wild turkey consumed the least amount of biomass (Fig. 11) eating .25 and .50 times less than the other consumers.

IV. MANIPULATING WILD HOG DENSITY

Simulations in which wild hog density was experimentally manipulated showed that the total number of increases in the diets of the consumers greater than three percent was roughly equal (Tables 15 and 16). In the simulation in which all density and production values were varied randomly the number of increases was 409 (Table 15). When hogs were removed, the

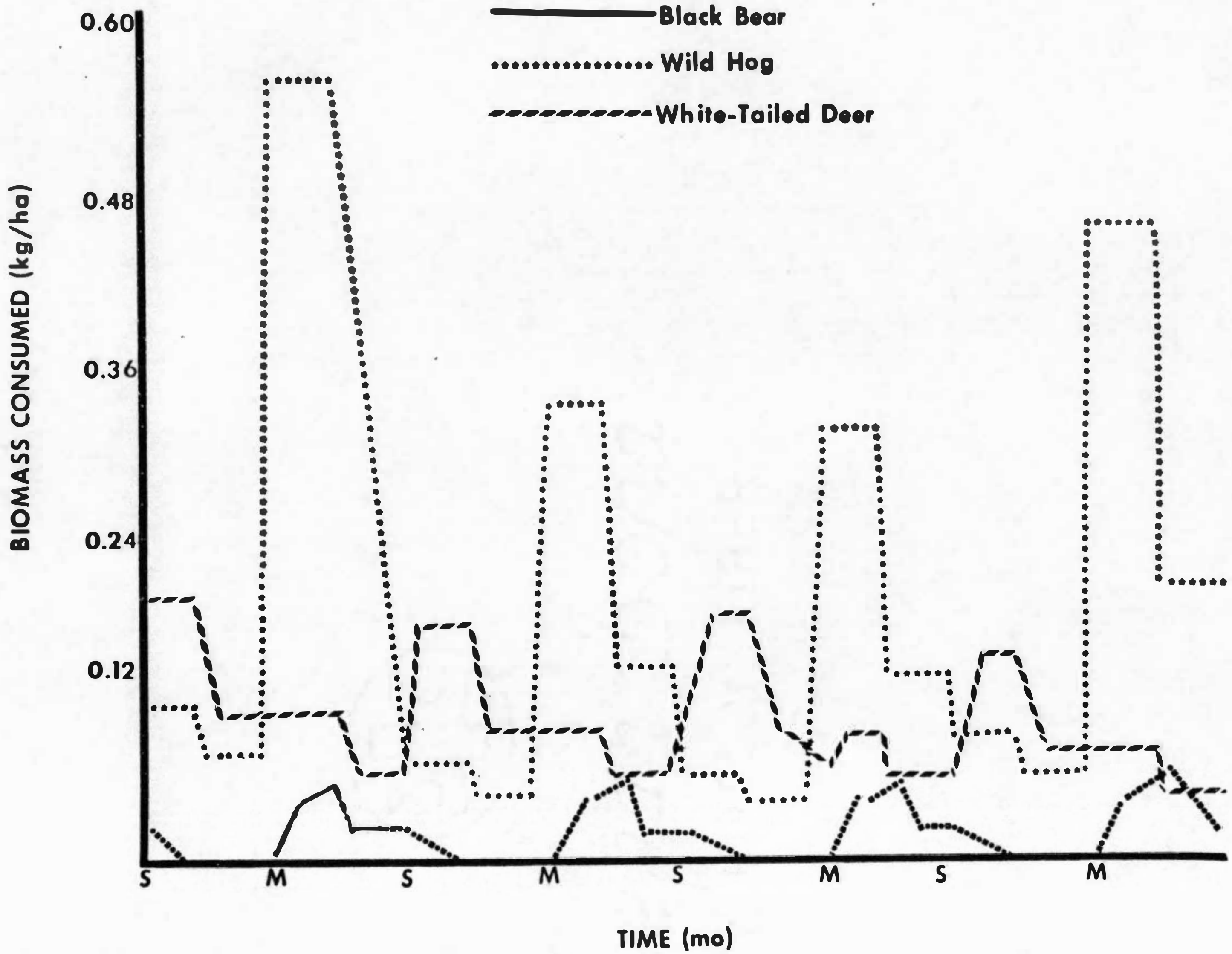

Figure 6. Flow of grass through black bear, wild hog, and white-tailed deer. All production and density values were chosen randomly. (S-September, M-March)

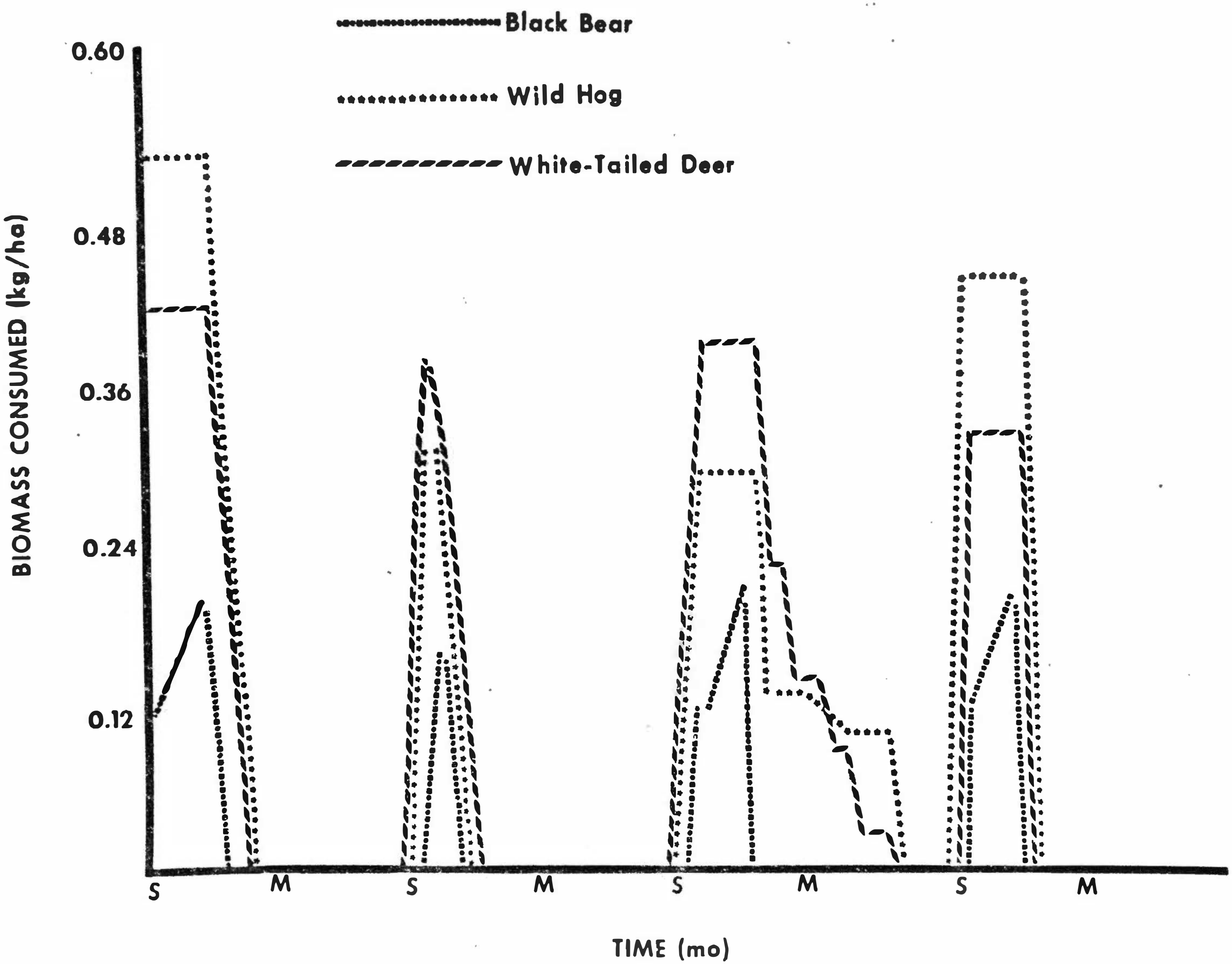

Figure 7. Flow of mast through black bear, wild hog, and white-tailed deer. All production and density values were chosen randomly. (S-September, M-March)

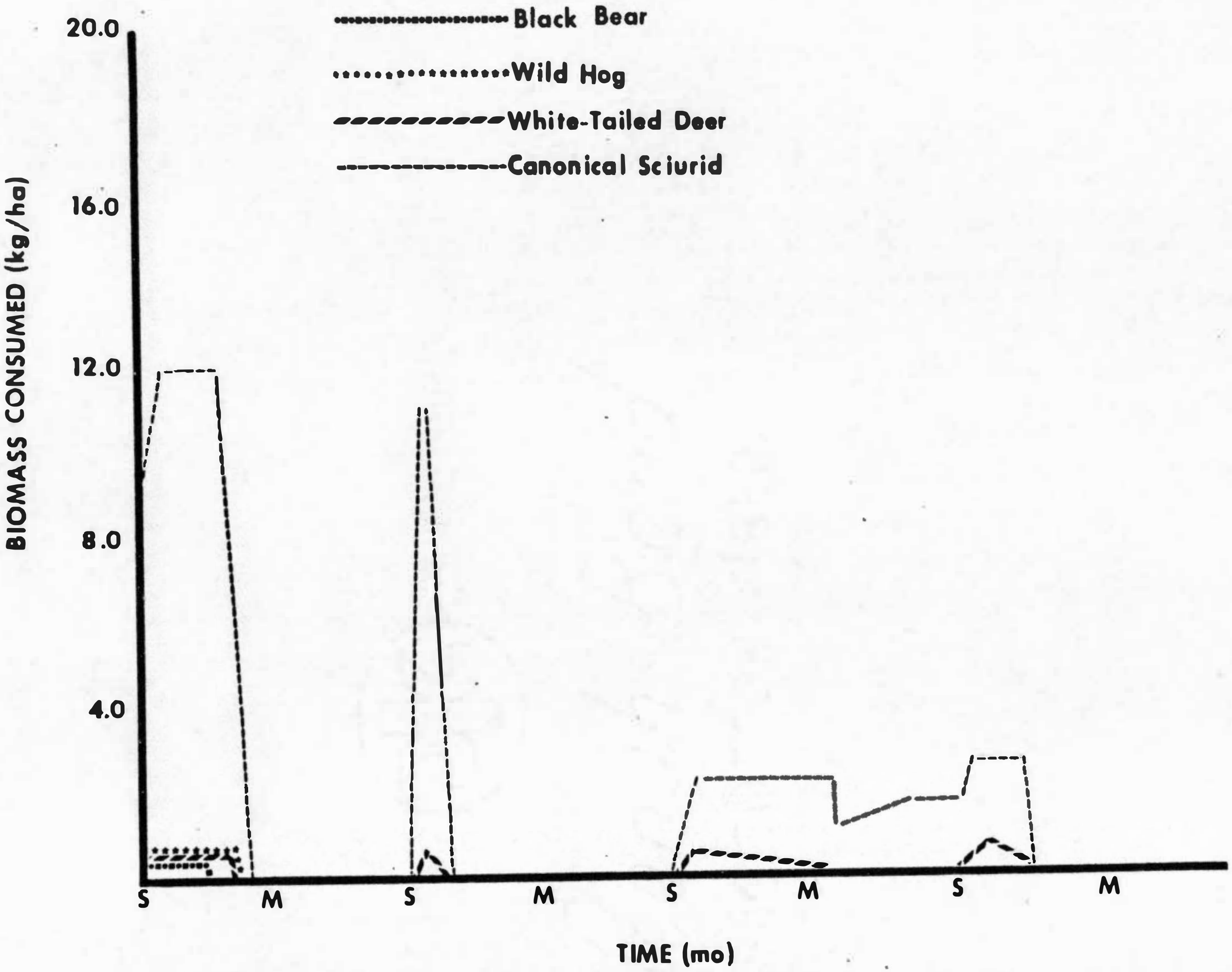

Figure 8. Flow of mast through black bear, wild hog, white-tailed deer, and canonical sciurid. All production and density values were chosen randomly. (S-September, M-March)

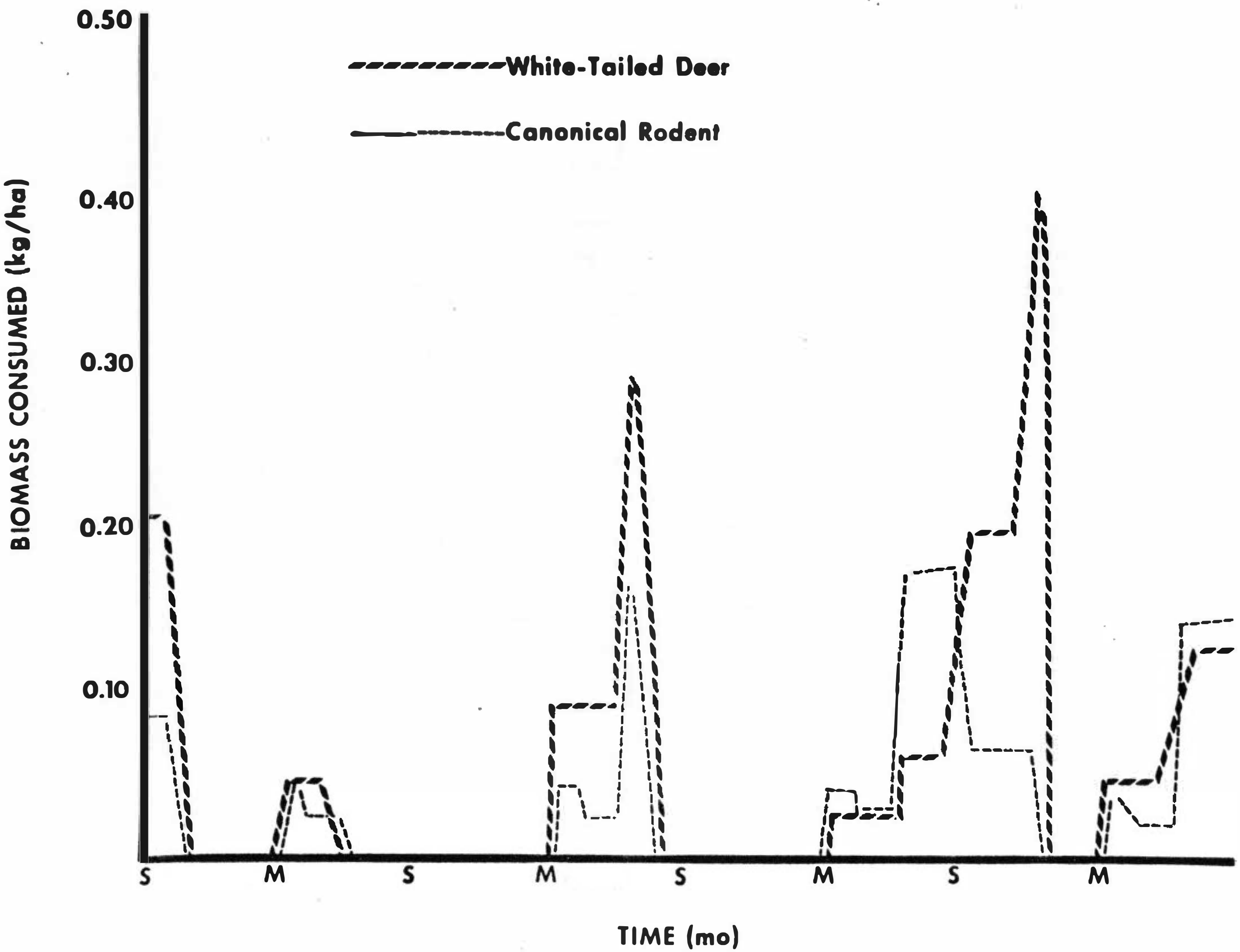

Figure 9. Flow of fungi through white-tailed deer and canonical rodent. All production and density values were chosen randomly. (S-September, M-March)

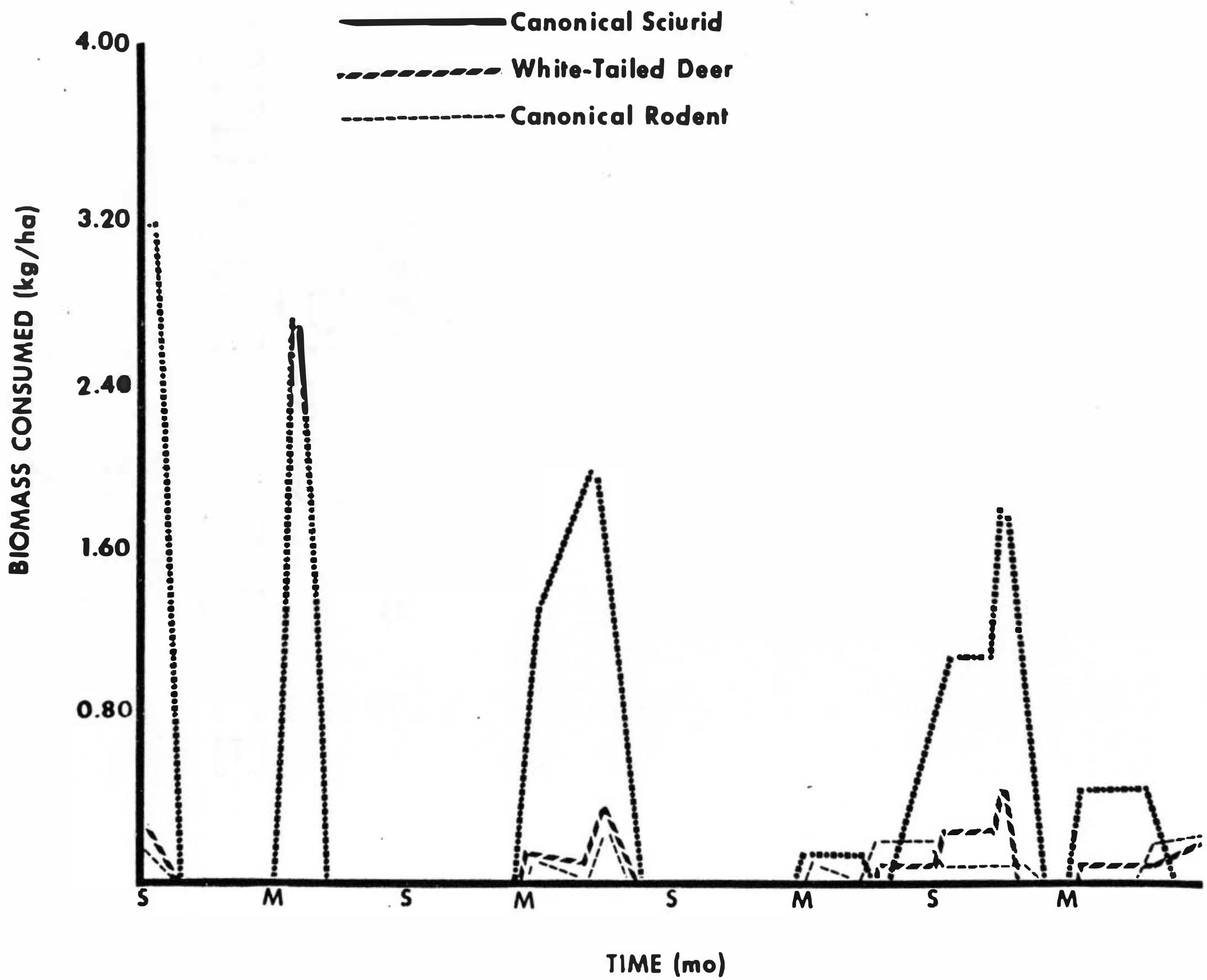

Figure 10. Flow of fungi through canonical sciurid, white-tailed deer, and canonical rodent. All production and density values were chosen randomly. (S-September, M-March)

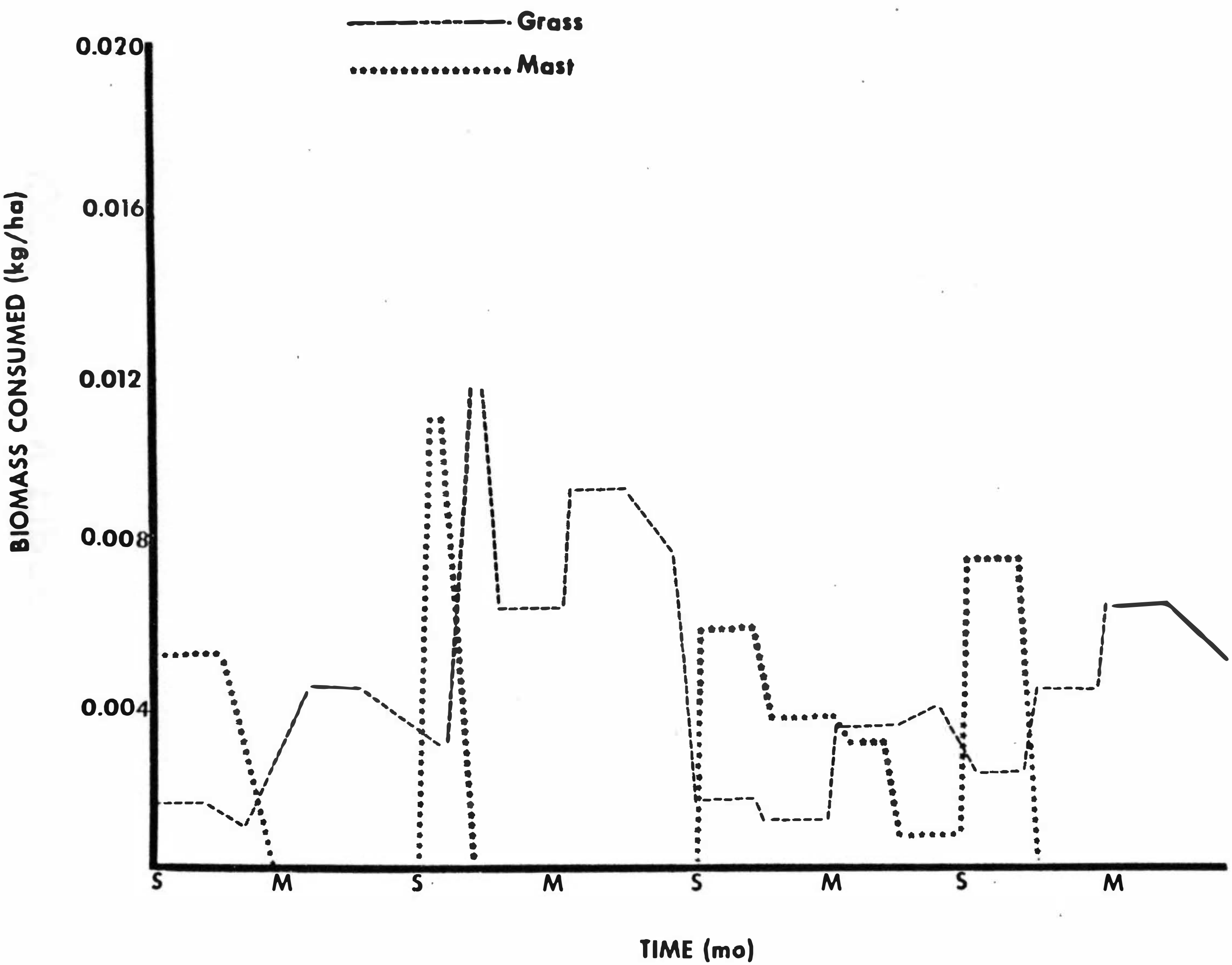

Figure 11. Flow of mast and grass through wild turkey. All production and density values were chosen randomly. (S-September, M-March)

Table 15. Frequency of changes in diets of consumers at different simulated wild hog densities. Changes in wild hog diet are not included. Values are from simulation in which production and density values were varied randomly.

	Normal hog densities		No hogs		Hogs 2x normal	
Food species	Increase	Decrease	Increase	Decrease	Increase	Decrease
Grasses and Sedges	76	0	74	0	77	0
Fungi	17	144	17	144	17	144
Rhododendron	15	0	15	0	15	0
Mountain Laurel	16	0	15	0	16	0
Galax	16	0	16	0	16	0
Mast	124	198	127	194	122	205
Animal	111	0	109	0	113	0
Roots	18	0	18	0	18	0
Cherry	0	20	0	20	0	20
Yellow Poplar Fruits	0	16	0	16	0	16
Red Maple Seeds	0	20	0	20	0	20
Squawroot Forage	0	15	0	15	0	15
Apple	0	23	0	23	0	23
Juneberry	0	23	0	23	0	23
Mayapple	0	23	0	23	0	23
Yellow Poplar Browse	0	20	0	20	0	20
Wild Grape	0	118	0	118	0	118
Persimmon	0	55	0	55	0	55
Blackberry	0	16	0	16	0	16
Blueberry	16	0	16	0	16	0
Huckleberry	0	8	0	8	0	8
Total	409	699	407	695	410	706

Table 16. Frequency of changes in diets of consumers at different simulated wild hog densities. Changes in wild hog diet are not included. Values are from simulation in which mast was experimentally manipulated.

Food species	Normal hog densities		No hogs		Hogs 2x normal	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
Grasses and Sedges	76	0	75	0	77	0
Fungi	15	144	15	144	15	144
Rhododendron	15	0	15	0	15	0
Mountain Laurel	15	0	15	0	16	0
Galax	15	0	15	0	16	0
Mast	122	202	126	196	120	205
Animal	110	0	109	0	111	0
Roots	18	0	18	0	18	0
Cherry	0	20	0	20	0	20
Yellow Poplar Fruits	0	16	0	16	0	16
Red Maple Seeds	0	20	0	20	0	20
Squawroot Forage	0	15	0	15	0	15
Apple	0	23	0	23	0	23
Juneberry	0	23	0	23	0	23
Mayapple	0	23	0	23	0	23
Yellow Poplar Browse	0	20	0	20	0	20
Wild Grape	0	118	0	118	0	118
Persimmon	0	55	0	55	0	55
Blackberry	0	16	0	16	0	16
Blueberry	17	6	17	0	17	0
Huckleberry	0	8	0	8	0	8
Total	403	703	405	697	405	706

number of increases was 407 and when hog density was doubled the number of increases was 410.

The number of increases exhibited by foods on an individual basis was also roughly equal. Mast showed the greatest difference between simulations with 124 increases for average hog densities, 127 for no hogs, and 122 for doubled hog densities. The number of increases in mast decreased as hog density rose. Grasses and sedges, rhododendron, mountain laurel, galax, and animal foods all showed differences between simulations with the general trend being for the number of increases for these foods to increase as hog density rose. The other foods showed no differences.

The number of decreases in the diets did not differ much regardless of simulated hog density (Table 15). The number of decreases shown in Table 15 is for six consumers with the wild hog excluded. This was done to allow direct comparison within Table 15. Table 16 was treated the same way. There were 699 decreases when density and production values were allowed to vary randomly; 695 when no hogs were present; and 706 when hog density was doubled.

Mast showed 198 decreases under average conditions, 194 when no hogs were present, and 205 when hog density was doubled. The number of decreases for the other foods did not change with changing hog density.

This same trend of changing food availability with changing wild hog density was seen in the set of simulations in which mast and hog density were experimentally manipulated (Table 16).

The amount of mast biomass consumed by black bear and white-tailed deer did not change in response to changing hog density (Figs. 7, and

12 through 16). Regardless of hog density the black bear always consumed a maximum of about .2 kg/ha and the deer consumed a maximum of about .4 kg/ha. The number of significant changes as determined by Spearman's rank correlation analysis were always roughly equal (around 75) regardless of hog density.

V. RESULTS OF MANIPULATING SCIURID DENSITY

The sciurids consumed large amounts of mast necessitating many changes in the diets of the other consumers (Table 17). The total number of increases in the diet greater than three percent occurring under low sciurid densities (1.5 sciurids/ha) was lower than those occurring under high sciurid densities (37 sciurids/ha). When all production values were chosen randomly there was a total of 381 decreases under low sciurid densities, and 435 increases in the simulation of high sciurid densities. In the simulation in which mast was experimentally manipulated there were 373 increases under low sciurid densities and 400 increases under high sciurid densities. There were 669 decreases and 903 decreases respectively for the simulations of low and high sciurid density and average production values, and 657 and 843 decreases respectively for the simulations of low and high sciurid density with mast experimentally manipulated (Table 17).

Many foods were affected by the change in sciurid density with mast, fungi, grasses and sedges, and animal foods being affected the most. The general trend was for mast and fungi consumption to decrease as sciurid density increased and the consumption of the other foods listed above to increase as sciurid density increased. Mast consumption by all consumers was particularly affected by the change in sciurid

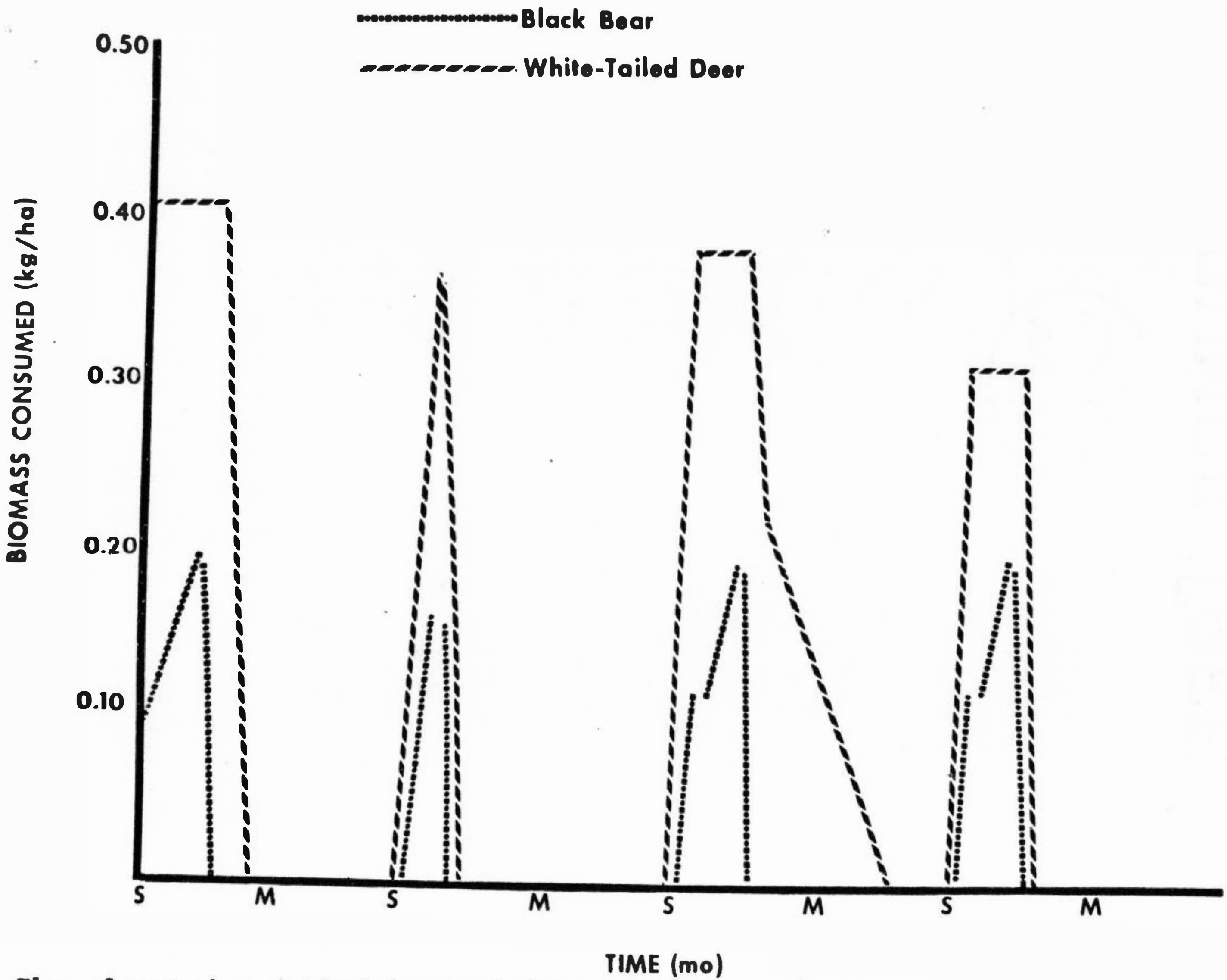

Figure 12. Flow of mast through black bear and white-tailed deer. Hog density was set to zero. (S-September, M-March)

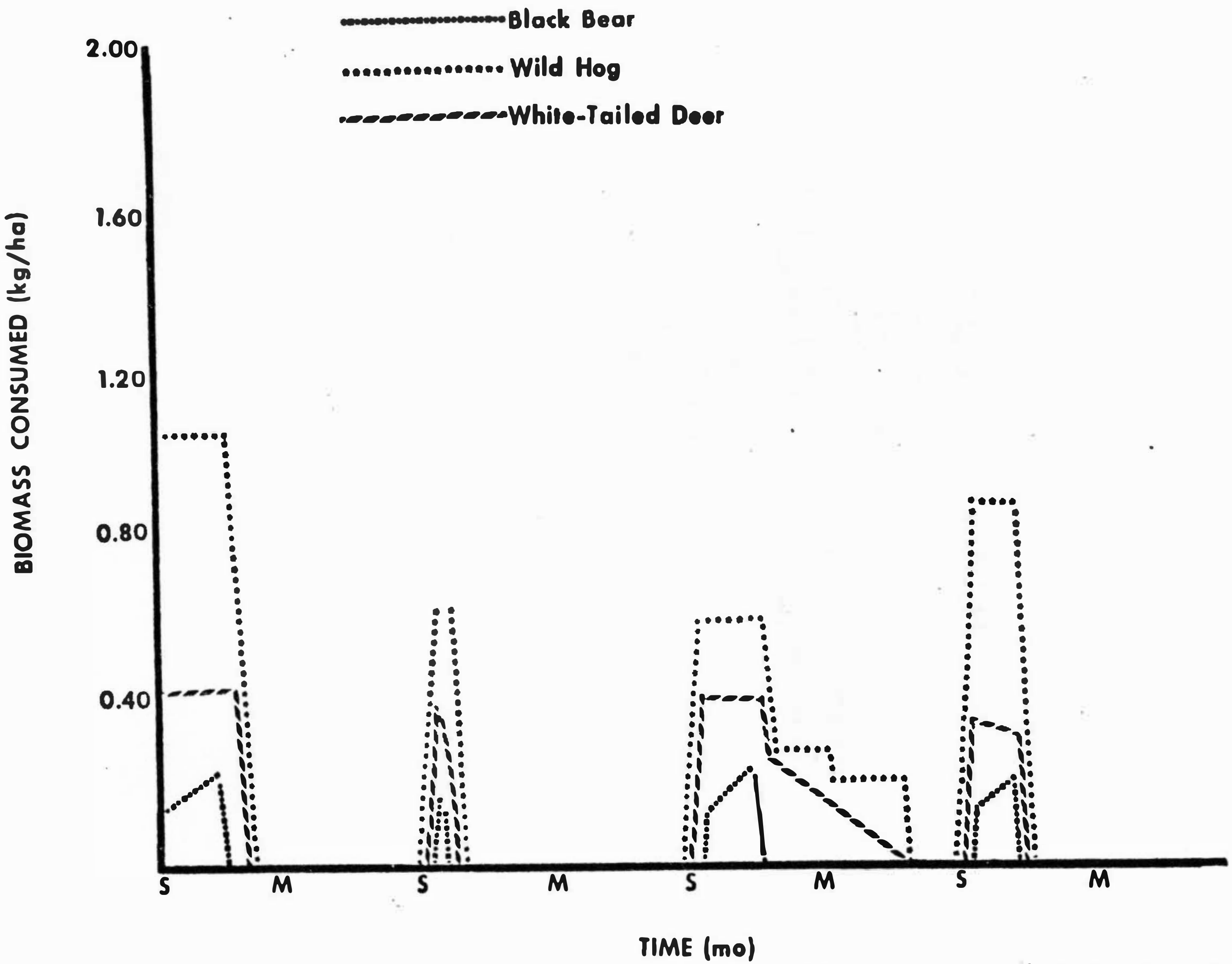

Figure 13. Flow of mast through black bear, wild hog, and white-tailed deer. Hog density was twice normal. (S-September, M-March)

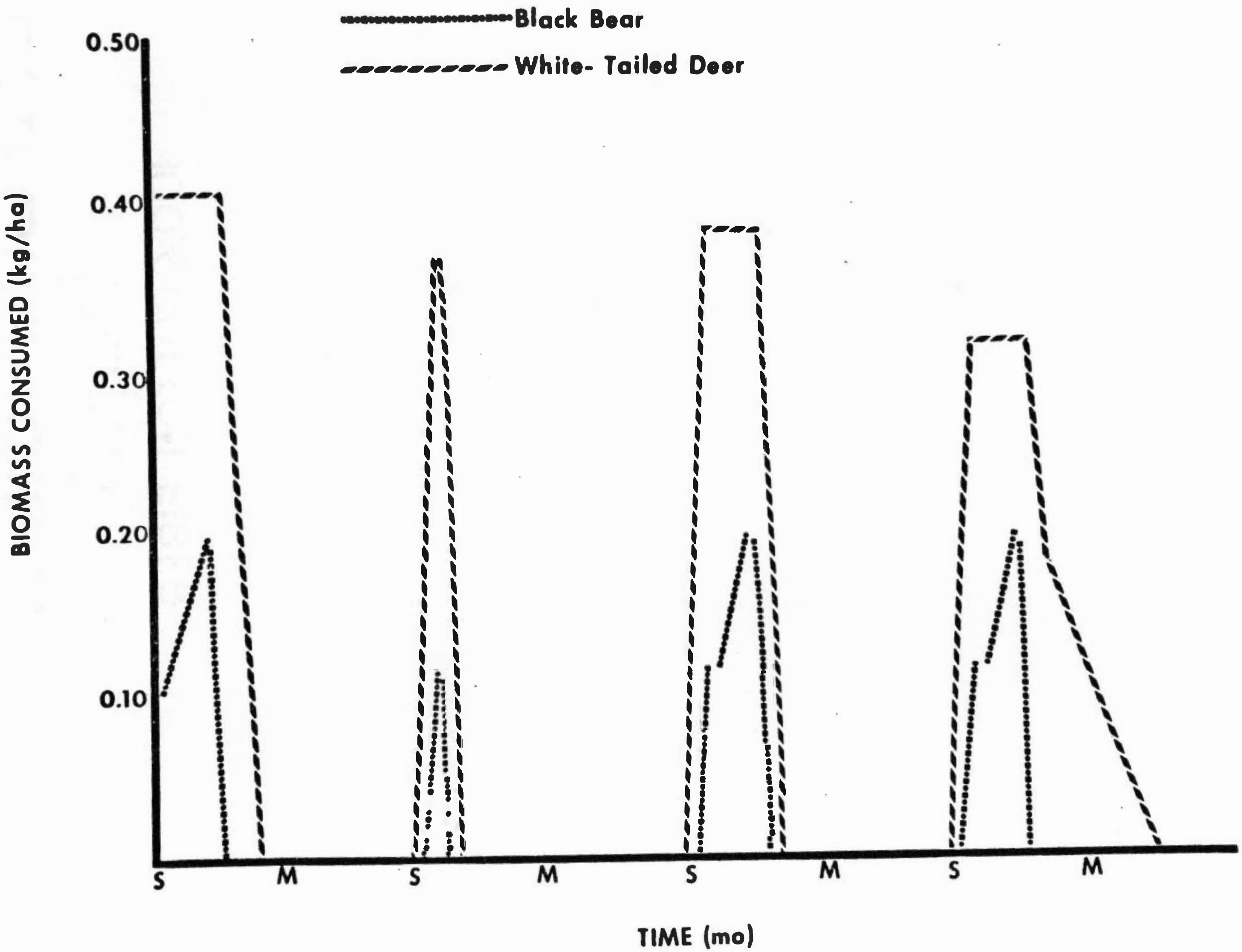

Figure 14. Flow of mast through black bear and white-tailed deer. Hog density was set to zero and mast was experimentally manipulated. (S-September, M-March)

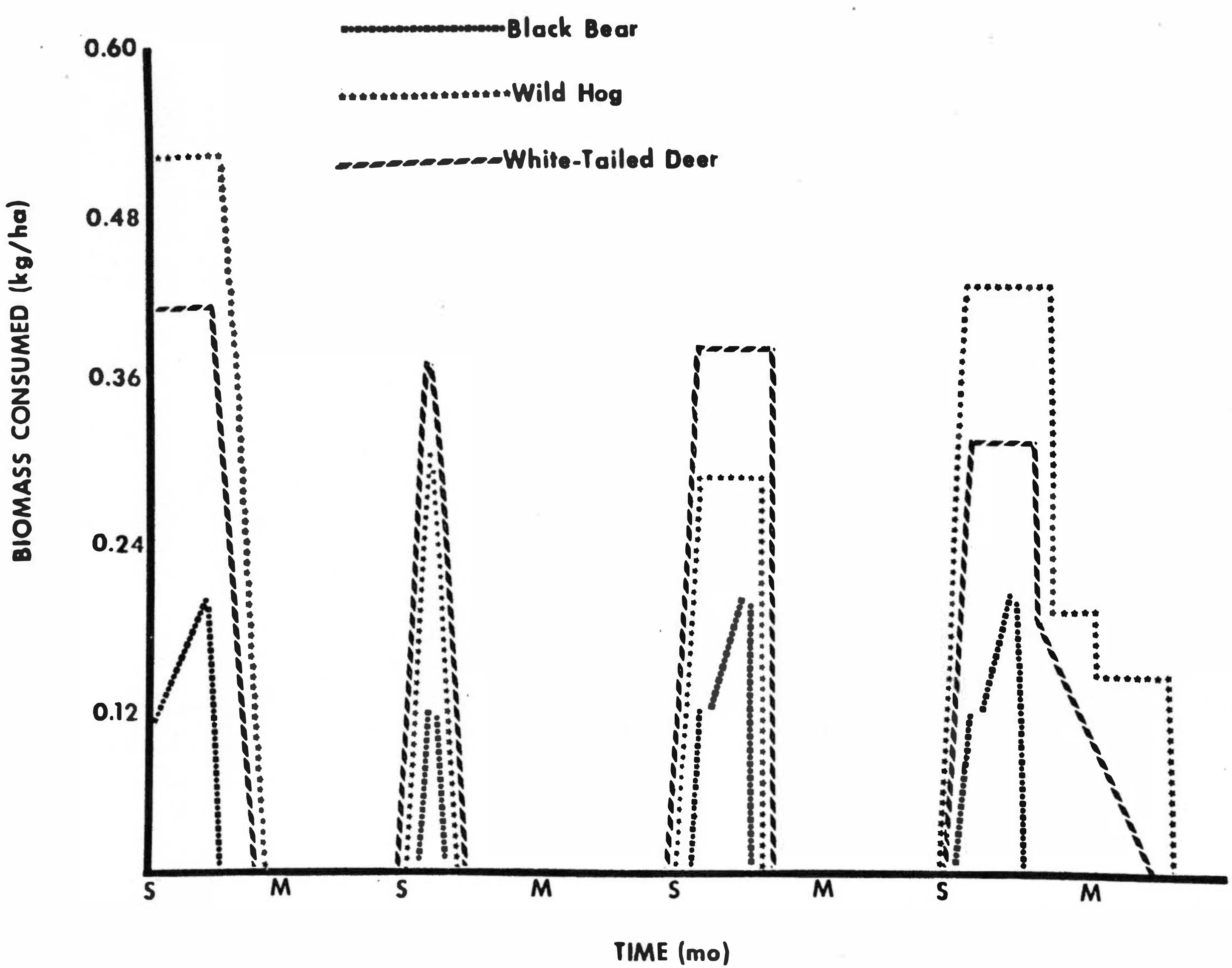

Figure 15. Flow of mast through black bear, wild hog, and white-tailed deer. Mast was experimentally manipulated. (S-September, M-March)

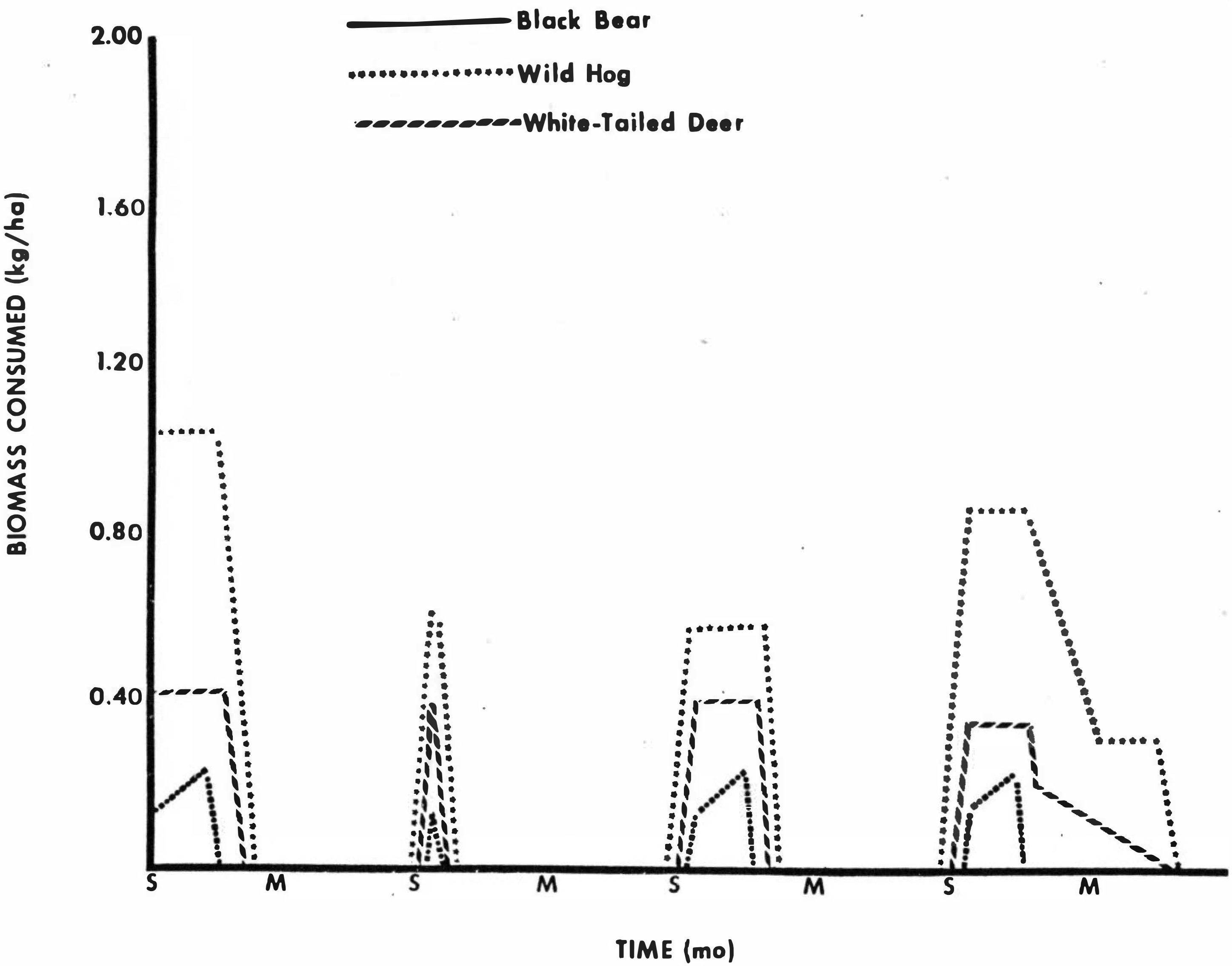

Figure 16. Flow of mast through black bear, wild hog, and white-tailed deer. Hog density was twice normal and mast was experimentally manipulated. (S-September, M-March)

Table 17. Frequency of changes in diets of consumers under different simulated sciurid densities.

Food species	Normal simulation				Mast experimentally manipulated			
	Low sciurid		High sciurid		Low sciurid		High sciurid	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
Grasses and Sedges	67	0	96	0	65	0	80	0
Fungi	17	97	16	178	15	94	10	178
Rhododendron	13	0	16	0	11	0	15	0
Mountain Laurel	11	0	22	0	9	0	15	0
Galax	11	0	22	0	9	0	15	0
Mast	132	181	88	326	139	169	114	266
Animal	97	0	134	0	92	0	114	0
Roots	17	0	24	0	16	0	18	0
Cherry	0	20	0	20	0	20	0	20
Yellow Poplar Fruits	0	16	0	16	0	16	0	16
Red Maple Seeds	1	15	0	23	2	18	0	23
Squawroot Forage	0	15	0	15	0	15	0	15
Apple	0	46	0	46	0	46	0	46
Juneberry	0	23	0	23	0	23	0	23
Mayapple	0	23	0	23	0	23	0	23
Yellow Poplar Browse	0	20	0	20	0	20	0	20
Wild Grape	0	118	0	118	0	118	0	118
Persimmon	0	55	0	55	0	55	0	55
Blackberry	0	16	0	16	0	16	0	16
Blueberry	15	8	17	8	15	8	19	8
Huckleberry	0	16	0	16	0	16	0	16
Total	381	669	435	903	373	657	400	843

density. A total of 181 decreases in mast consumption greater than three percent occurred when low sciurid densities and average production values were simulated versus 326 decreases in mast consumption under the same production values and high sciurid densities.

In the simulations in which all production values were chosen randomly there were four more decreases in the black bear diet under high sciurid densities than under low sciurid densities. There were 25, 23, and 29 more decreases under the same conditions for turkey, hog, and raccoon respectively and 50 more decreases under those conditions for deer. In the simulations in which mast was experimentally manipulated there were six more decreases in the bear diet under high sciurid density as compared to low sciurid density; there were 15 more decreases each for turkey, hog and raccoon, and 46 more for deer.

VI. ESTIMATED EDIBLE FACTOR

Although Gilbert (1973) found his model sensitive to changes of only 5 percent in the estimated edible factor (EEF), changes of 25 percent in the EEF in this version of the model failed to produce any noticeable change in output as determined by Spearman's rank correlation test.

The frequency tables revealed that the number of changes in the diets remained approximately the same with about 410 increases and 775 decreases greater than 3 percent, regardless of whether interactive feeding was simulated with an EEF of 50 percent or an EEF of 75 percent.

CHAPTER IV

DISCUSSION

I. MEASURES OF COMPETITION

Most attempts to quantify competition for food resources in the past have borrowed heavily from quantitative plant ecology. Various indices of similarity, coefficients of association, and coefficients of community have been used for this purpose (Hansen et al. 1973 and Hansen and Reid 1975). An idea of the similarity of the diets of a group of consumers is indicated by these indices. Examples of these methods can be found in any good quantitative text (Kershaw 1973 and Southwood 1966). These methods are able to give only an indication of potential competition; they are unable to provide any measure of how competition is affecting the consumers. A similarity index might indicate extensive overlap in the diets of a set of consumers, but if the foods constituting that overlap are present in large amounts, or if they comprise a small unimportant part of the diet, the index would be indicating a high probability of competition where none was occurring.

To arrive at an understanding of the competitive interactions among a group of consumers, information must be gathered not only on the similarity of the diets, but also on consumer density, food availability, and consumption rates. Ideally, information should also be amassed on population and vegetation dynamics of the community. The model described is a step in this direction. Consumer density, consumption rates, food availability, and seasonal food habits are all considered in an attempt to describe the interactive feeding of a group of consumers. A random number generator provides for crude population and vegetation dynamics.

II. COMPETITION IN THE PARK

Mast is the key food in the diets of the consumers and is the focal point for any dietary competition which might occur. Matschke (1964) has reported on the importance of mast for the reproductive success of the wild hog, and Scott (1973) and Henry and Conley (1972) have shown the importance of mast in the hog's diet. Black bears need mast in the fall to help lay down the layer of fat required for their winter dormancy. Mast is vital for the growth and reproductive performance of white-tailed deer (Harlow and Tyson 1959), and wild turkey, raccoon, and sciurids are extremely dependent on this source of food as verified by the food habits studies conducted on them (Appendix A). Although quantitative examination of rodent food habits has yet to be done on a large scale seasonal basis in the south, the importance of mast to various rodents is evident. Hamilton (1941) reported finding nearly a peck of nuts (beech) stored by a pair of *Peromyscus*. Wildlife managers have long accepted the importance of mast to such species as deer, turkey, and squirrels (Goodrum et al. 1971 and Shaw 1971).

In the model mast was abundant from September to November, but sometimes remained abundant until December. The length of time was dependent on the size of the mast crop, but even in excellent years (120 kg/ha) mast was not abundant enough to satisfy the demands of the consumers on an annual basis. The scarcity of mast resulted in dietary shifts to compensate for the shortages. Most consumers compensated, or attempted to compensate, by turning to different and/or abundant alternate foods.

Wild Turkey

The wild turkey increased their reliance on grasses and animal foods in the presence of mast shortages. Grasses, animal foods, sheep sorrel, and dogwood fruits were always abundant (Table 8, p. 34). There are so few turkey in the Park, and their needs are so small relative to the other consumers, that it is plausible to speculate they are usually able to cope with the problem of finding enough to eat. The wild turkey certainly had no adverse effect on the other consumers.

Wild Hog

The wild hog was unable to obtain enough mast, apple, blueberry, and huckleberry (Table 9, p.35). Sufficient amounts of roots, grasses, and blueberry browse, and garbage were available to fulfill their respective dietary components, but they were being fed on at their threshold values and the hog could not increase consumption of these foods to supplement other inadequacies.

Scott (1973) found the hog relied heavily on both grasses and roots. In the spring grasses accounted for 60 percent of the diet, and in the winter roots comprised 60 percent (Appendix A). Grasses and roots were both more important on an annual basis than mast. Mast is the single most important food in the fall (Scott 1973 and Henry and Conley 1972). If the hog can get sufficient mast in the fall to insure a good reproductive performance (Matschke 1964) then it can probably cope the rest of the year by relying on roots and grasses. The increases in mast consumption (Table 9, p. 35) all occurred in the fall, and it appears that the wild hog in the Park is usually able to make it in all but the worst mast years.

The results of simulations in which hog density was experimentally manipulated indicate the hog is not an important component as far as dietary competition is concerned. The number of increases and decreases greater than three percent, the number of significant dietary changes as determined by analysis of Spearman's rank correlation coefficient, and the biomass consumed by the other consumers remained roughly the same regardless of hog density.

Black Bear

The black bear (Table 10, p. 36) was not unduly stressed by food shortages although it was unable to obtain enough cherry, wild grape, and squaw-root forage. Mast and blueberry were never so scarce as to be unavailable to the bear. The black bear was the only consumer able to find adequate amounts of mast. The black bear also had no trouble finding sufficient huckleberry and blackberry.

Even under high sciurid densities the bear was able to obtain mast more often than not (16 increases versus 4 decreases). The black bear removes itself from competitive interactions for several months every year. There needs to be only enough mast to satisfy the bears' needs for two to two and one-half months in the fall prior to their winter sleep. On awakening in the spring the bear turns to the grasses and herbs (Beeman 1971) and although the herbs were unidentified and could not be included in the model, grasses were shown to never be scarce. Most of the herbs upon which the bear feeds in the spring are probably also abundant enough to satisfy the bear's requirements. Another aspect of bear ecology that was not included in the model but serves nonetheless to give the bear a competitive advantage is that they are capable of arboreal feeding (Pelton, personal communication). It appears the bear will usually fare better than the other consumers in meeting its dietary requirements and will be stressed in regard to mast only during rather severe shortages. The bear does not compete with the other consumers.

Canonical Sciurid

The canonical sciurid was unable to obtain enough of its foods (Table 11, p. 37). Caution must be exercised in interpreting the results because the sciurids in the Park certainly rely on more than five foods. The importance of mayapple in the summer diet of squirrels and chipmunks in the Park is probably less than that assumed (48 percent of the diet), and their reliance on various seeds probably more.

High sciurid densities clearly proved detrimental to the other consumers, and the canonical order of sciurids proved to be the key to competition in the Park. The sciurids clearly consumed most of the mast in the model, but their effect may have been overestimated. The failure of the model to account for arboreal feeding results in greater sciurid competition than possibly exists, because the mast estimates used were corrected for arboreal feeding, and squirrels are known to get part of their mast requirements through arboreal feeding. Even though this placed more stress on the Park ecosystem than may actually exist, it does not invalidate any of the conclusions. If less stress is being applied by the sciurids, then more food is available. For example, if the wild hog is not a factor in the model under conditions of abnormal stress it surely is not a factor under conditions of less stress. In addition, another assumption may have served to offset the increased sciurid competition in the model. No estimates were available on the amount of mast stored by sciurids and rodents. It was assumed that none was stored, and it is probable that this assumption offsets the assumptions of no arboreal feeding, although how much is not known.

The black bear was harmed the least by sciurid competition, and the white-tailed deer the most, with raccoon, turkey, and hog all being affected equally as shown by the differences in the number of decreases occurring in the diets greater than three percent.

White-Tailed Deer

The white-tailed deer was unable to obtain sufficient mast, but compensated for this shortage by increased utilization of grasses, rhododendron, and mountain laurel (Table 12, p. 38). Rhododendron and mountain laurel are known to be toxic but Harlow and Hooper (1971) found rhododendron comprised about 25 percent of the diet during January and February. Grasses comprised another 20 percent of the diet during those same months. There is some evidence indicating grasses may be more important in the Park than the model supposes. The segment of the Park to which this study was restricted contained Cades Cove, a 1012 ha area devoted primarily to pasturage. Deer are known to utilize this grassy area for food at all times, but even more heavily during times of food shortage (Fox and Pelton 1973). Most of the deer in this area can be found within a short distance of the Cove, particularly in the winter. The deer did not adversely affect the other consumers.

Raccoon

The raccoon is the most carnivorous of all the consumers considered and is able to make up for mast shortages by relying on animal foods (Table 13, p. 39). It is doubtful if they would ever be severely harmed by all but an almost complete mast failure. They do not compete with the other consumers.

Canonical Rodent

Since this consumer acted only as a "sink" its competitive interactions cannot be examined.

Conclusions

There has been concern expressed over impact of the wild hog on the native animals and plants in the Park. Bratton (1974) presented evidence indicating the hog may be adversely affecting the herbs and flowers because of its rooting habits. There has been much speculation, with little subsequent work, on whether or not the hog is harming other consumers in the Park. The National Park Service has been attempting to control the hog population by shooting and trapping, but it has been unsuccessful in halting its spread. Since the hog is being intensively managed by the Tennessee Wildlife Resources Agency in Tellico Wildlife Management Area southwest of the Park, it appears the hog is in East Tennessee to stay. The model presented is the first attempt to examine what may actually be happening between the hog and other consumers in the Park.

The results of the model indicate the wild hog is not a serious competitor and instead focuses attention on the sciurids as the major competitors. High sciurid densities result in relatively serious mast shortages necessitating major dietary shifts. But the other consumers may not be as seriously affected in the Park as the model predicts due to factors mentioned above.

The black bear fares the best of all consumers not being stressed even under high sciurid densities. But all of the consumers differ in their food habits enough, or share foods abundant enough to preclude competition, that they are capable of coping with the problem of finding enough to eat. Stress of a serious nature probably is not encountered except during severe and/or prolonged shortages of shared foods, mast in particular.

Summary

The European wild hog did not compete with the other consumers for food although it was unable to satisfy its dietary requirements. The canonical order of sciurids was the primary competitor requiring large amounts of biomass relative to the other consumers. The black bear fared the best of all consumers. It was usually able to obtain sufficient mast and blueberry to satisfy its needs, even when the other consumers could not. The winter dormancy period, during which time the bear removes itself from the Park ecosystem, is the major reason the bear is able to cope so well. All consumers appear capable of finding sufficient food even in the face of shortages. This is probably due to two factors. First, the diets differ enough that some important alternative foods are not focal points of competition. Second, the major alternative foods (e.g. browse, roots, animals, and grasses) are present in abundant amounts. Only in the cases of severe and/or prolonged shortages of important foods (e.g. mast) would the consumers really suffer.

III. SUGGESTIONS FOR FUTURE RESEARCH

This model has solved no problems nor settled any issues. It has been the first attempt to investigate interactive feeding in the Great Smoky Mountains National Park. Currently, a great deal of work is being done by many people in the development of a management plan for the Park. The management of wildlife is an important component of that plan. If we are to manage the wildlife wisely we need to know which factors significantly affect it. This model has been a crude attempt to do that, and the results indicate that this way of viewing interactive feeding in the Park has promise as a management tool. The model has indicated gaps in our knowledge, gaps that must be filled if we are ever to manage wildlife in the Park in a manner which will provide the greatest benefit to all concerned.

Research Needs

1. Monthly food habits must be researched on all relevant species in the Park. Even those species which have already been examined should be re-evaluated. Beeman (1971) found about 33 percent of the spring diet of black bear was unidentified green herbs. Microhistological techniques could help identify much of this material. The rodents and sciurids are in special need of examination. So far not one published study on the seasonal food habits of the chipmunk is available in a form which could be utilized in this model.

2. The amount of food wasted and stored must be investigated. Rodents can store surprisingly large amounts of mast making it unavailable to other consumers (Hamilton 1941), and the storing habits of the sciurids are well known. The amount of food obtained by arboreal feeding should be investigated.

3. The amount of food consumed by the relevant species must be investigated. Consumption rates of the consumers included in this model are known to vary seasonally.

4. Population ecology studies must be commenced on all relevant animal species. We need to know not only densities but dynamics. A start has been made on the black bear (Marcum 1974) and the wild hog (Duncan 1974), but much remains to be done.

5. The dynamics of the vegetation must be investigated. Monthly net production estimates and knowledge of trends in production of all important food species are needed. Mast and fungi production are of particular importance. Nutrition and energy content and dynamics should be investigated.

IV. MODEL IMPROVEMENTS

There are several improvements which can be added to the model which should make it both more realistic and more useful. Adding population and vegetation dynamics submodels would be beneficial. A weather component could be built into the vegetation submodel to simulate more accurately the effect of such random events as a late spring frost and its effects on mast production.

Consideration of foods from an energy standpoint instead of a biomass standpoint is a next step. Nutrition should be considered also.

In its present form the model might indicate that dietary requirements were being fulfilled from a biomass standpoint with no stress being applied, whereas the actual biomass might be energy deficient and consumers could be starving to death. Considering the diets from an energy standpoint would allow animal metabolism to be taken into consideration.

V. PERSONAL WORTH OF MODELLING ENDEAVOR

The systems analytical approach to natural resource management has been criticized by many researchers used to the more conventional techniques. Most of the criticisms do not stand up under close examination. It is often argued that natural systems are too complex and that it is impossible and therefore ridiculous to attempt to build predictive models of those systems. But as Forrester (1971) points out, mathematical and simulation models are no more unrealistic than the mental models we have been struggling with for years and the former models have the added advantage of having their components rigorously defined. The problem appears to have been largely a lack of communication between the pro and con groups, and those practitioners of the systems approach must accept a large part of the blame. They have failed in many cases not only to explicitly state the limitations of their models but to properly document their work (Mar 1974).

When I began my work toward an ecology degree, I, too, had my doubts about the validity of the systems approach and this lack of communication was a major reason for this. This study has convinced me of the usefulness of this tool. The interactions among seven consumers competing for 24 foods could not be studied by any other method. Regardless of the final goal of any work in the area of natural resource management, the preliminary steps should include a model. The model may be nothing more than a box and arrow diagram, but regardless, it is of immense help in delineating potential problem areas early in the research.

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APPENDICES

APPENDIX A

TABLE A-1

SEASONAL DIET OF WILD TURKEY

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Mast	53	53	53	31	31	31	28	28	28	5	5	5
Grasses and Sedges	11	11	11	6	6	6	31	31	31	21	21	21
Wild Grapes	5	5	5	5	5	5				4	4	4
Dogwood				15	15	15						
Blackberries										4	4	4
Rumex acetosella										12	12	12
Huckleberry										5	5	5
Animal	6	6	6	5	5	5	2	2	2	11	11	11

Source: Korshgen (1967).

TABLE A-2

SEASONAL DIET OF RACCOON

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Mast	19	21	18	27	48	44	21	21	18	16	15	16
Persimmon	37	36	20	6	4	4				1	1	5
Roots			4	1		4	1	3		4		
Juneberry										6	7	6
Wild Grape	11	13	6							7	8	8
Animal	16	16	14	14	29	18	67	69	64	51	54	51

Sources: Schoonover and Marshall (1951), Baker et al. (1945), Johnson (1970).

TABLE A-3

SEASONAL DIET OF WHITE-TAILED DEER

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Grasses	14	20	20	14	8	8	6	6	6	6	6	6
Yellow Poplar Browse							4	9	9			
Honeysuckle	5	5	5	7	9	9	7	4	4	2	2	2
Yellow Poplar Fruits							1	3	3			
Oak Browse										6	7	7
Mast	44	44	44	25	15	15	9	2	2			
Wild Grape	1	1	1							1	1	1
Fungi	8	8	8	7	6	6	4	2	2	19	20	20
Red Maple Browse										14	15	15
Rhododendron	6	6	6	17	24	24	13					
Mountain Laurel	1	1	1	2	3	3	2					
Wintergreen	2	2	2	2	1	1						
Galax	2	2	2	4	6	6	3					
Apple	3	3	3	1				1	1			

Source: Harlow and Hooper (1971).

TABLE A-4

SEASONAL DIET OF CANONICAL SCIURID

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Mast	64	64	64	80	80	80	43	43	43	3	3	3
Fungi	27	27	27	13	13	13	3	3	3			
Red Maple Seed							4	4	4			
Apple										9	9	9
Mayapple										48	48	48

Source: Dudderar (1967).

TABLE A-5

SEASONAL DIET OF BLACK BEAR

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Blueberry	3	1									11	11
Blackberry	15	7									12	12
Squawroot Fruits	3	1									20	20
Squawroot Forage							5	10	10	10	20	20
Huckleberry	3	2	1								14	14
Juneberry								2	2	2	1	1
Black Cherry	18	12	6									
Mast	21	39	55									
Wild Grape	3	3	4									
Grasses	3	1					12	24	24	24	4	4
Garbage	7	5	4				2	4	4	4	9	9
Animal	8	7	7								5	5

Source: Beeman (1971).

TABLE A-6

SEASONAL DIET OF WILD HOG

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Grasses	11	11	11	7	7	7	61	61	61	25	25	25
Mast	57	57	57	25	25	25	19	19	19			
Apple										25	25	25
Roots	27	27	27	61	61	61				11	11	11
Huckleberry										8	8	8
Blueberry Browse										6	6	6
Blueberry										6	6	6
Garbage	4	4	4									

Source: Scott (1973).

TABLE A-7

SEASONAL DIET OF CANONICAL RODENT

Food species	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Fungi	25	25	25	10	10	10	5	5	5	16	16	16
Mast	50	50	50	25	25	25						
Blackberry										7	7	7

Source: Martin, et al. (1951), Linzey and Linzey (1973), and J. O. Whittaker (1963, 1966).

APPENDIX B

LIST OF COMMON NAMES AND SCIENTIFIC NAMES OF PLANT FOODS USED IN MODEL

Common Name	Scientific Name
Honeysuckle	*Lonicera japonica*
Fungi	Agaricaceae, Boletaceae
Grasses	Gramineae
Rhododendron	*Rhododendron* spp.
Mountain Laurel	*Kalmia latifolia*
Wintergreen	*Gaultheria procumbens*
Galax	*Galax aphylla*
Blueberry	*Vaccinium* spp.
Sheep Sorrel	*Rumex acetosella*
Mast	*Quercus* spp., *Carya* spp., *Aesculus octandra*
Cherry	*Prunus* spp.
Dogwood	*Cornus florida*
Yellow Poplar	*Liriodendron tulipifera*
Red Maple	*Acer rubrum*
Wild Grape	*Vitis* spp.
Persimmon	*Diospyros virginiana*
Blackberry	*Rubus* spp.
Huckleberry	*Gaylussacia* spp.
Squawroot	*Conopholis americana*
Juneberry	*Amelanchier* spp.
Mayapple	*Podophyllum peltatum*
Apple	*Malus* spp.

APPENDIX C

SOURCE LISTING OF SIMCOMP PROGRAM

```
C
C.....A PRELIMINARY MODEL OF DIETARY COMPETITION IN THE GREAT
C.....SMOKY MOUNTAINS NATIONAL PARK.
C.....THE MAIN PART OF THE PROGRAM FOLLOWS.
C.....FIRST, ASSIGN NECCESSARY STORAGE SPACE.
C
*STORAGE
      COMMON/PROD/PCATA(50)
      COMMON/CPCID/WTPCID(50),CRPCID(50),DRPCID(50),BRPCID(50),
     -         SCPCID(50),RCPCID(50),WHPCID(50)
      COMMON/CDEN/WTN,CRN,BRN,SCN(2),RCN,WHN,DRN
      COMMON/EDIB/EDWT(50),EDRC(50),EDDR(50),EDCR(50),EDBR(50),EDSC(50),
     -             EDWH(50)
      COMMON/CONS/WTFC,ORFC,CRFC,BRFC,RCFC,WHFC,SCFC(2),BRF(13)
      COMMON/TOTL/WTTOT,ORTOT,CRTOT,BRTOT,SCTOT,RCTOT,WHTOT
      COMMON/CONM/WTFCM,ORFCM,CRFCM,BRFCM,SCFCM(2),RCFCM,WHFCM,
     -             SCFM
      COMMON/EXTR/AVAIL,PCID(50),THRES(50),ZX(50),PR,RP,OOT,NN,F,
     -       SAVM(50),NO(50,8),DNEG(50,8),AVA(50),FFF(50),
     -       OPOS(50,8),WASTE,T,TF,JZ,TK,JK,IX,NPD(50,8),
     -       MAX(75),MIN(75),S(75),AM(75),RN(75),SWASTE(2)
      COMMON/FLU/F1(50),F2(50),F3(50),F4(50),F5(50),F6(50),F7(50)
      COMMON/PCWT/WTMT(12),WTGR(12),WTGP(12),WTDW(12),WTAN(12),
     -       WTBY(12),WTRX(12),WTHK(12)
      COMMON/HPWT/HPWTMT(12),HPWTGR(12),HPWTGP(12),HPWTDW(12),
     -             HPWTAN(12),HPWTBY(12),HPWTRX(12),HPWTHK(12)
      COMMON/PCOR/ORPB(12),DRHS(12),DRPF(12),OROB(12),ORMT(12),
     -       DRGP(12),DRFG(12),DRMB(12),ORRH(12),DRML(12),DRWG(12),
     -       DRGX(12),DRAP(12),DRGR(12)
      COMMON/HPOR/HPORPB(12),HPDRHS(12),HPDRPF(12),HPDROB(12),
     -             HPORMT(12),HPDRGP(12),HPDRFG(12),HPDRMB(12),
     -             HPORRH(12),HPDRML(12),HPORWG(12),HPDRGX(12),
     -             HPORAP(12),HPDRGR(12)
      COMMON/PCBR/BRBL(12),BRBY(12),BRSB(12),BRHK(12),BRAN(12),
     -       BRJB(12),BRGG(12),BRCH(12),BRMT(12),BRGP(12),BRGR(12),
     -       BRSF(12)
      COMMON/HPBR/HPBRBL(12),HPBRBY(12),HPBRSB(12),HPBRHK(12),
     -             HPBRAN(12),HPBRGG(12),HPBRCH(12),HPBRMT(12),
     -             HPBRGP(12),HPBRGR(12),HPBRSF(12),HPBRJB(12)
      COMMON/PCCR/CRFG(12),CRMT(12),CRBY(12)
      COMMON/HPCR/HPCRFG(12),HPCRMT(12),HPCRBY(12)
      COMMON/PCWH/WHGR(12),WHMT(12),WHAP(12),WHRT(12),WHHK(12),
     -       WHBB(12),WHBL(12),WHGG(12)
      COMMON/HPWH/HPWHGR(12),HPWHMT(12),HPWHAP(12),HPWHRT(12),
     -             HPWHHK(12),HPWHBL(12),HPWHBB(12),HPWHGG(12)
      COMMON/PCSC/SCMT(12),SCFG(12),SCMS(12),SCMA(12),SCAP(12)
      COMMON/HPSC/HPSCMT(12),HPSCFG(12),HPSCMS(12),HPSCMA(12),HPSCAP(12)
      COMMON/PCRC/RCMT(12),RCPM(12),RCAN(12),RCRT(12),RCJB(12),RCGP(12)
      COMMON/HPRC/HPRCMT(12),HPRCPM(12),HPRCAN(12),HPRCRT(12),
     -             HPRCJB(12),HPRCGP(12)
      REAL NO,NPO,MAX,MIN
*************************************************************************************

*FLOW
C
C.....DESCRIPTIONS OF THE STATE VARIABLES CONTAINING THE BIOMASS DATA OF THE
C.....RESPECTIVE FOODS FOLLOW.
C
C.....X(1) = HONEYSUCKLE - LONICERA JAPONICA
```

```
C.....X(2) = MISCELLANEOUS GRASSES - POACEAE, DIGITARIA, AND SO ON
C.....X(3) = FUNGI - ENDOGONE, ETC.
C.....X(4) = RHODODENDRON SP.
C.....X(5) = MOUNTAIN LAUREL - KALMIA LATIFOLIA
C.....X(6) = WINTERGREEN - GAULTHERIA PROCUMBENS
C.....X(7) = GALAX - GALAX APHYLLA
C.....X(8) = BLUEBERRY BROWSE - VACCINNIUM SP.
C.....X(9) = SHEEP SORREL - RUMEX ACETOSELLA
C.....X(17) = MAST - QUERCUS, CARYA, ETC.
C.....X(18) = ANIMAL (VERTEBRATE AND INVERTEBRATE)
C.....X(19) = GARBAGE
C.....X(20) = ROOTS
C.....X(21) = OTHER
C.....X(22) = CHERRY - PRUNUS
C.....X(23) = DOGWOOD - CORNUS FLORIDA
C.....X(24) = YELLOW POPLAR FRUITS - LIRIODENDRON TULIPIFERA
C.....X(25) = RED MAPLE SEEDS - ACER RUBRUM
C.....X(26) = SQUAWROOT FORAGE - CONOPHOLIS AMERICANA
C.....X(27) = APPLE - MALUS
C.....X(28) = JUNEBERRY - AMELANCHIER SP.
C.....X(29) = MAYAPPLE - PODOPHYLLUM PELTATUM
C.....X(30) = YELLOW POPLAR BROWSE - LIRIODENDRON TULIPIFERA
C.....X(31) = RED MAPLE BROWSE - ACER RUBURM
C.....X(32) = OAK BROWSE - QUERCUS SP.
C.....X(33) = GRAPE - VITIS SP.
C.....X(34) = PERSIMMON - DIOSPYROS VIRGINIANA
C.....X(35) = BLACKBERRY - RUBUS SP.
C.....X(36) = BLUEBERRY FRUITS - VACCINIUM
C.....X(37) = SQUAWROOT FRUITS - CONOPHOLIS AMERICANA
C.....X(38) = HUCKLEBERRY - GAYLUSSACIA SP.
C
C.....FOLLOWING ARE DESCRIPTIONS OF THE CONSUMPTION RATE STATE VARIABLES
C
C.....X(40) : WILD HOG - BLUEBERRY FRUITS
C.....X(41) : BEAR - BLUEBERRY FRUITS
C.....X(42) : TURKEY - HUCKLEBERRY
C.....X(43) : WILD HOG - HUCKLEBERRY
C.....X(44) : BEAR - HUCKLEBERRY
C.....X(60) : WILD TURKEY - GRASS(MISC)
C.....X(61) : WILD HOG - GRASS(MISC)
C.....X(62) : BEAR - GRASS(MISC)
C.....X(63) : SCIURIDS - FUNGI
C.....X(64) : DEER - FUNGI
C.....X(65) : RODENTS - FUNGI
C.....X(67) : DEER - GRASS
C.....X(80) : TURKEY - MAST
C.....X(81) : WILD HOG - MAST
C.....X(82) : BEAR - MAST
C.....X(83) : SCIURIDS - MAST
C.....X(84) : DEER - MAST
C.....X(85) : RODENTS - MAST
C.....X(86) : RACCOON - MAST
C.....X(87) : WILD HOG - GARBAGE
C.....X(88) : BEAR - GARBAGE
C.....X(89) : WILD HOG - APPLE
C.....X(90) : SCIURIDS - APPLE
C.....X(91) : DEER - APPLE
C.....X(92) : TURKEY - GRAPE
C.....X(93) : BEAR - GRAPE
C.....X(94) : RACCOON - GRAPE
C.....X(95) : TURKEY - BLACKBERRY
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```
C.....X(96) : BEAR - BLACKBERRY
C.....X(97) : RODENTS - BLACKBERRY
C
C.....COMPUTE FLOW OF BIOMASS.
C
C.....THESE FIRST FLOW DESCRIPTIONS WILL ALLOW FOR PLOTTING OF SPECIES-SPECIFIC
C.....CONSUMPTION RATES IN KG/HA/MO.  FOR EXAMPLE, THE FLOW DESCRIPTION
C.....(60,99). WILL FLOW THE AMOUNT OF BIOMASS IN STATE VARIABLE 60 INTO
C.....STATE VARIABLE 99, WHICH IS A SINK.  STATE VARIABLE 60 IS THE TURKEY
C.....GRASS CONSUMPTION STATE VARIABLE.  LATER IN THE PROGRAM GRASS IS FLOWED
C.....INTO STATE VARIABLE 60.  BY EMPTYING IT BEFORE EACH SIMULATION TIMESTEP
C.....I CAN PLOT THE AMOUNT OF GRASS THAT FLOWS THROUGH THE WILD TURKEY.
C
(60,99).
      F = F1(2)
(61,99).
      F = F2(2)
(62,99).
      F = F3(2)
(67,99).
      F = F5(2)
(63,99).
      F = F4(3)
(64,99).
      F = F5(3)
(65,99).
      F = F6(3)
(80,99).
      F = F1(17)
(81,99).
      F = F2(17)
(82,99).
      F = F3(17)
(83,99)
      F = F4(17)
(84,99).
      F = F5(17)
(85,99).
      F = F6(17)
(86,99).
      F = F7(17)
(87,99).
      F = F2(19)
(88,99).
      F = F3(19)
(89,99).
      F = F2(27)
(90,99).
      F = F4(27)
(91,99).
      F = F5(27)
(92,99).
      F = F1(33)
(93,99).
      F = F3(33)
(94,99).
      F = F7(33)
(95,99).
      F = F1(35)
(96,99).
      F = F3(35)
```

```
(37,99).
      F = F6(35)
(40,99).
      F = F2(36)
(41,99).
      F = F3(36)
(42,99).
      F = F1(38)
(43,99).
      F = F2(38)
(44,99).
      F = F3(38)
C
C.....IKT IS INDEX DESIGNATING CURRENT CONSUMER.
C.....IKT = 1 : WILD TURKEY - MELEAGRIS GALLAPAVO
C.....IKT = 2 : WILD HOG - SUS SCROFA
C.....IKT = 3 : BLACK BEAR - URSUS AMERICANUS
C.....IKT = 4 : SCIUPIDS - SCIURIS CAROLINENSIS,TAMIASCIURIS HUDSONICUS,
C.....          AND TAMIAS STRIATUS
C.....IKT = 5 : WHITE-TAILED DEER - ODOCOILEUS VIRGINIANUS
C.....IKT = 6 : RODENTS - PEROMYSCUS AND NAPAEOZAPUS
C.....IKT = 7 : RACCOON - PROCYON LOTOR
C
C.....TURKEY
C
(2,60).
      IKT = 1
C
C.....INDEX DIET ARRAY TO 0.0
C
      DO 1000 I=1,NN
         PCID(I) = 0.0
 1000 CONTINUE
C
C.....CREATE DIET ARRAY FOR CURRENT CONSUMER.
C
      PCID(2) = TAB2(WTGR,DDT,1.,12.,1.)
      PCID(9) = TAB2(WTRX,DDT,1.,12.,1.)
      PCID(17) = TAB2(WTMT,DDT,1.,12.,1.)
      PCID(18) = TAB2(WTAN,DDT,1.,12.,1.)
      PCID(23) = TAB2(WTDW,DDT,1.,12.,1.)
      PCID(33) = TAB2(WTGP,DDT,1.,12.,1.)
      PCID(35) = TAB2(WTBY,DDT,1.,12.,1.)
      PCID(38) = TAB2(WTHK,DDT,1.,12.,1.)
      DO 10 I=1,NN
         PCID(I) = PCID(I)/100.0
   10 CONTINUE
C
C.....FIND AMOUNT OF FOOD EATEN BY CURRENT CONSUMER.
C
      WASTE = 0.5 * (WTFC * WTN)
      WTFCM = (WTFC * WTN + WASTE)
C
C.....FIND MAXIMUM PERCENT POSSIBLE IN DIET AT CURRENT DT.
C
      DO 1010 I=1,NN
         THRES(I) = 0.0
 1010 CONTINUE
      THRES(2) = TAB2(HPWTGR,DDT,1.,12.,1.)
      THRES(9) = TAB2(HPWTRX,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPWTMT,DDT,1.,12.,1.)
```

```
      THRES(18) = TAB2(HPWTAN,DDT,1.,12.,1.)
      THRES(23) = TAB2(HPWTCW,DDT,1.,12.,1.)
      THRES(33) = TAB2(HPWTGP,DDT,1.,12.,1.)
      THRES(35) = TAB2(HPWTBY,DDT,1.,12.,1.)
      THRES(38) = TAB2(HPWTHK,DDT,1.,12.,1.)
      DO 15 I=1,NN
         THRES(I) = THRES(I)/100.0
   15 CONTINUE
C
C.....CALL SUBROUTINE TFLO TO COMPUTE TEMPORARY FLOWS.  THIS WILL
C.....ENSURE THAT DIET IS FILLED AS MUCH AS POSSIBLE.
C
      CALL TFLO(EDWT,WTFCM,IKT)
      WTTOT = 0.0
      DO 1020 I=1,NN
         WTPCID(I) = PCID(I)
         WTTOT = WTPCID(I) + WTTOT
 1020 CONTINUE
C
C.....CALCULATE THE FLOWS
C
      F1(2) = WTFCM * WTPCID(2)
      F = F1(2)
(9,51).
      F1(9) = WTFCM * WTPCID(9)
      F = F1(9)
(17,80).
      F1(17) = WTFCM * WTPCID(17)
      F = F1(17)
(18,51).
      F1(18) = WTFCM * WTPCID(18)
      F = F1(18)
(23,51).
      F1(23) = WTFCM * WTPCID(23)
      F = F1(23)
(33,92).
      F1(33) = WTFCM * WTPCID(33)
      F = F1(33)
(35,55).
      F1(35) = WTFCM * WTPCID(35)
      F = F1(35)
(38,42).
      F1(38) = WTFCM * WTPCID(38)
      F = F1(38)
(21,51).
      F1(21) = (1. - WTTOT) * WTFCM
      F = F1(21)
C
C.....WILD HOG
C
(2,61).
      IKT = 2
      DO 2000 I=1,NN
         PCID(I) =0.0
 2000 CONTINUE
      PCID(2) = TAB2(WHGR,DDT,1.,12.,1.)
      PCID(8) = TAB2(WHBR,DDT,1.,12.,1.)
      PCID(17) = TAB2(WHMT,DDT,1.,12.,1.)
      PCID(19) = TAB2(WHGG,DDT,1.,12.,1.)
      PCID(20) = TAB2(WHRT,DDT,1.,12.,1.)
      PCID(27) = TAB2(WHAP,DDT,1.,12.,1.)
```

```
      PCID(36) = TAB2(WHBL,DDT,1.,12.,1.)
      PCID(38) = TAB2(WHHK,DDT,1.,12.,1.)
      DO 20 I=1,NN
         PCID(I) = PCID(I)/100.0
   20 CONTINUE
      WASTE = 0.5 * (WHN * WHFC)
      WHFCM = (WHFC * WHN + WASTE)
      DO 2010 I=1,NN
         THRES(I) = 0.0
 2010 CONTINUE
      THRES(2) = TAB2(HPWHGR,DDT,1.,12.,1.)
      THRES(8) = TAB2(HPWHBB,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPWHMT,DDT,1.,12.,1.)
      THRES(19) = TAB2(HPWHGG,DDT,1.,12.,1.)
      THRES(20) = TAB2(HPWHRT,DDT,1.,12.,1.)
      THRES(27) = TAB2(HPWHAP,DDT,1.,12.,1.)
      THRES(36) = TAB2(HPWHBL,DDT,1.,12.,1.)
      THRES(38) = TAB2(HPWHHK,DDT,1.,12.,1.)
      DO 25 I=1,NN
         THRES(I) = THRES(I)/100.0
   25 CONTINUE
      CALL TFLO(EDWH,WHFCM,IKT)
      WHTOT = 0.0
      DO 2020 I=1,NN
         WHPCID(I) = PCID(I)
         WHTOT = WHPCID(I) + WHTOT
 2020 CONTINUE
      F2(2) = WHFCM * WHPCID(2)
      F = F2(2)
(8,52).
      F2(8) = WHFCM * WHPCID(8)
      F = F2(8)
(17,81).
      F2(17) = WHFCM * WHPCID(17)
      F = F2(17)
(19,87).
      F2(19) = WHFCM * WHPCID(19)
      F = F2(19)
(20,52).
      F2(20) = WHFCM * WHPCID(20)
      F = F2(20)
(27,89).
      F2(27) = WHFCM * WHPCID(27)
      F = F2(27)
(36,40).
      F2(36) = WHFCM * WHPCID(36)
      F = F2(36)
(38,43).
      F2(38) = WHFCM * WHPCID(38)
      F = F2(38)
(21,52).
      F2(21) = (1. - WHTOT) * WHFCM
      F = F2(21)
C
C.....BLACK BEAR
C
(2,62).
      IKT = 3
      DO 3000 I=1,NN
         PCID(I) = 0.0
 3000 CONTINUE
```

```
      IF ((T .GT. 3.0) .AND. (T .LT. 7.5)) GO TO 30
      PCID(2) = TAB2(BRGR,DDT,1.,12.,1.)
      PCID(17) = TAB2(BRMT,DDT,1.,12.,1.)
      PCID(18) = TAB2(BRAN,DDT,1.,12.,1.)
      PCID(19) = TAB2(BRGG,DDT,1.,12.,1.)
      PCID(22) = TAB2(BRCH,DDT,1.,12.,1.)
      PCID(26) = TAB2(BRSF,DDT,1.,12.,1.)
      PCID(28) = TAB2(BRJB,DDT,1.,12.,1.)
      PCID(33) = TAB2(BRGP,DDT,1.,12.,1.)
      PCID(35) = TAB2(BRBY,DDT,1.,12.,1.)
      PCID(36) = TAB2(BRBL,DDT,1.,12.,1.)
      PCID(37) = TAB2(BRSB,DDT,1.,12.,1.)
      PCID(38) = TAB2(BRHK,DDT,1.,12.,1.)
      DO 32 I=1,NN
         PCID(I) = PCID(I)/100.0
   32 CONTINUE
C
C.....BLACK BEAR CONSUMPTION RATE WILL BE RETRIEVED FROM A TABLE FUNCTION.
C
      BRFC = TAB2(BRF,DDT,1.,12.,1.)
      WASTE = 0.5 * (BRFC*BRN)
      BRFCM = BRFC * BRN + WASTE
      DO 3010 I=1,NN
         THRES(I) = 0.0
 3010 CONTINUE
      THRES(2) = TAB2(HPBRGR,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPBRMT,DDT,1.,12.,1.)
      THRES(18) = TAB2(HPBRAN,DDT,1.,12.,1.)
      THRES(19) = TAB2(HPBRGG,DDT,1.,12.,1.)
      THRES(22) = TAB2(HPBRCH,DDT,1.,12.,1.)
      THRES(26) = TAB2(HPBRSF,DDT,1.,12.,1.)
      THRES(28) = TAB2(HPBRJB,DDT,1.,12.,1.)
      THRES(33) = TAB2(HPBRGP,DDT,1.,12.,1.)
      THRES(35) = TAB2(HPBRBY,DDT,1.,12.,1.)
      THRES(36) = TAB2(HPBRBL,DDT,1.,12.,1.)
      THRES(37) = TAB2(HPBRSB,DDT,1.,12.,1.)
      THRES(38) = TAB2(HPBRHK,DDT,1.,12.,1.)
      DO 35 I=1,NN
         THRES(I) = THRES(I)/100.0
   35 CONTINUE
      CALL TFLO(EDBR,BRFCM,IKT)
      GO TO 31
   30 BRFCM = 0.0
   31 CONTINUE
      BRTOT = 0.0
      DO 3030 I=1,NN
         BRPCID(I) = PCID(I)
         BRTOT = BRPCID(I) + BRTOT
 3030 CONTINUE
      F3(2) = BRFCM * BRPCID(2)
      F = F3(2)
(17,82).
      F3(17) = BRFCM * BRPCID(17)
      F = F3(17)
(18,53).
      F3(18) = BRFCM * BRPCID(18)
      F = F3(18)
(19,88).
      F3(19) = BRFCM * BRPCID(19)
      F = F3(19)
(22,53).
```

```
      F3(22) = BRFCM * BRPCID(22)
      F = F3(22)
(26,53).
      F3(26) = BRFCM * BRPCID(26)
      F = F3(26)
(28,53).
      F3(28) = BRFCM * BRPCID(28)
      F = F3(28)
(33,53).
      F3(33) = BRFCM * BRPCID(33)
      F = F3(33)
(35,56).
      F3(35) = BRFCM * BRPCID(35)
      F = F3(35)
(36,41).
      F3(36) = BRFCM * BRPCID(36)
      F = F3(36)
(37,53).
      F3(37) = BRFCM * BRPCID(37)
      F = F3(37)
(38,44).
      F3(38) = BRFCM * BRPCID(38)
      F = F3(38)
(21,53).
      F3(21) = (1.- BRTDT) * BRFCM
      F = F3(21)
C
C.....SCIURIDS
C.....SCFCM(1) AND SCFC(1) ARE CHIPMUNKS.
C.....SCFCM(2) AND SCFC(2) ARE SQUIRRELS
C
(3,63).
      IKT = 4
      DO 4000 I=1,NN
         PCID(I) = 0.0
 4000 CONTINUE
      PCID(3) = TAB2(SCFG,DDT,1.,12.,1.)
      PCID(17) = TAB2(SCMT,DDT,1.,12.,1.)
      PCID(25) = TAB2(SCMS,DDT,1.,12.,1.)
      PCID(27) = TAB2(SCAP,DDT,1.,12.,1.)
      PCID(29) = TAB2(SCMA,DDT,1.,12.,1.)
      DO 40 I=1,NN
         PCID(I) = PCID(I)/100.0
   40 CONTINUE
      DO 41 J=1,2
         SWASTE(J) = 0.5 * (SCFC(J)*SCN(J))
         SCFCM(J) = SCFC(J) * SCN(J) + SWASTE(J)
   41 CONTINUE
C
C.....REDUCE CHIPMUNK CONSUMPTION RATE BY 85% DURING THE WINTER.
C
      IF ((T .GE. 3.0) .OR. (T .LT. 7.0)) SCFCM(1) = SCFCM(1) * 0.15
      DO 4010 I=1,NN
         THRES(I) =0.0
 4010 CONTINUE
      THRES(3) = TAB2(HPSCFG,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPSCMT,DDT,1.,12.,1.)
      THRES(25) = TAB2(HPSCMS,DDT,1.,12.,1.)
      THRES(27) = TAB2(HPSCAP,DDT,1.,12.,1.)
      THRES(29) = TAB2(HPSCMA,DDT,1.,12.,1.)
      DO 45 I=1,NN
```

```
         THRES(I) = THRES(I)/100.0
   45 CONTINUE
      SCFM = SCFCM(1) + SCFCM(2)
      CALL TFLO(EDSC,SCFM,IKT)
      SCTOT = 0.0
      DO 4030 I=1,NN
         SCPCID(I) = PCID(I)
         SCTOT = SCPCID(I) + SCTOT
 4030 CONTINUE
      F4(3) = SCFM * SCPCID(3)
      F = F4(3)
(17,83).
      F4(17) = SCFM * SCPCID(17)
      F = F4(17)
(25,54).
      F4(25) = SCFM * SCPCID(25)
      F = F4(25)
(27,90).
      F4(27) = SCFM * SCPCID(27)
      F = F4(27)
(29,54).
      F4(29) = SCFM * SCPCID(29)
      F = F4(29)
(21,54).
      F4(21) = (1.0 - SCTOT) * SCFM
      F = F4(21)
C
C.....DEER
C
(1,55).
      IKT = 5
      DO 5000 I=1,NN
         PCID(I) = 0.0
 5000 CONTINUE
      PCID(1) = TAB2(DRHS,DDT,1.,12.,1.)
      PCID(2) = TAB2(DRGR,DDT,1.,12.,1.)
      PCID(3) = TAB2(DRFG,DDT,1.,12.,1.)
      PCID(4) = TAB2(DRRH,DDT,1.,12.,1.)
      PCID(5) = TAB2(DRML,DDT,1.,12.,1.)
      PCID(6) = TAB2(DRWG,DDT,1.,12.,1.)
      PCID(7) = TAB2(DRGX,DDT,1.,12.,1.)
      PCID(17) = TAB2(DRMT,DDT,1.,12.,1.)
      PCID(24) = TAB2(DRPF,DDT,1.,12.,1.)
      PCID(27) = TAB2(DRAP,DDT,1.,12.,1.)
      PCID(30) = TAB2(DRPB,DDT,1.,12.,1.)
      PCID(31) = TAB2(DRMB,DDT,1.,12.,1.)
      PCID(32) = TAB2(DROB,DDT,1.,12.,1.)
      DO 50 I=1,NN
         PCID(I) = PCID(I)/100.0
   50 CONTINUE
      WASTE = 0.5 * (DRN * DRFC)
      DRFCM = (DRFC * DRN + WASTE)
      DO 5010 I=1,NN
         THRES(I) = 0.0
 5010 CONTINUE
      THRES(1) = TAB2(HPDRHS,DDT,1.,12.,1.)
      THRES(2) = TAB2(HPDRGR,DDT,1.,12.,1.)
      THRES(3) = TAB2(HPDRFG,DDT,1.,12.,1.)
      THRES(4) = TAB2(HPDRRH,DDT,1.,12.,1.)
      THRES(5) = TAB2(HPDRML,DDT,1.,12.,1.)
      THRES(6) = TAB2(HPDRWG,DDT,1.,12.,1.)
```

```
      THRES(7) = TAB2(HPDRGX,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPDRMT,DDT,1.,12.,1.)
      THRES(24) = TAB2(HPDRPF,DDT,1.,12.,1.)
      THRES(27) = TAB2(HPDRAP,DDT,1.,12.,1.)
      THRES(30) = TAB2(HPDRPB,DDT,1.,12.,1.)
      THRES(31) = TAB2(HPDRMB,DDT,1.,12.,1.)
      THRES(32) = TAB2(HPDRCB,DDT,1.,12.,1.)
      DO 55 I=1,NN
         THRES(I) = THRES(I)/100.0
   55 CONTINUE
      CALL TFLO(ERDR,DRFCM,IKT)
      DRTOT = 0.0
      DO 5030 I=1,NN
         DRPCID(I) = PCID(I)
         DRTOT = DRPCID(I) + DRTOT
 5030 CONTINUE
      F5(1) = DRFCM * DRPCID(1)
      F = F5(1)
(2,67).
      F5(2) = DRPCID(2) * DRFCM
      F = F5(2)
(3,64).
      F5(3) = DRFCM * DRPCID(3)
      F = F5(3)
(4,55).
      F5(4) = DRFCM * DRPCID(4)
      F = F5(4)
(5,55).
      F5(5) = DRFCM * DRPCID(5)
      F = F5(5)
(6,55).
      F5(6) = DRFCM * DRPCID(6)
      F = F5(6)
(7,55).
      F5(7) = DRFCM * DRPCID(7)
      F = F5(7)
(17,84).
      F5(17) = DRFCM * DRPCID(17)
      F = F5(17)
(24,55).
      F5(24) = DRFCM * DRPCID(24)
      F = F5(24)
(27,91).
      F5(27) = DRFCM * DRPCID(27)
      F = F5(27)
(30,55).
      F5(30) = DRFCM * DRPCID(30)
      F = F5(30)
(31,55).
      F5(31) = DRFCM * DRPCID(31)
      F = F5(31)
(32,55).
      F5(32) = DRFCM * DRPCID(32)
      F = F5(32)
(21,55).
      F5(21) = DRFCM * (1. - DRTOT)
      F = F5(21)
C
C.....CANONICAL RODENT
C
(3,65).
```

```
      IKT = 6
      DO 6000 I=1,NN
         PCID(I) = 0.0
 6000 CONTINUE
      PCID(3) = TAB2(CRFG,DDT,1.,12.,1.)
      PCID(17) = TAB2(CRMT,DDT,1.,12.,1.)
      PCID(35) = TAB2(CRBY,DDT,1.,12.,1.)
      DO 60 I=1,NN
         PCID(I) = PCID(I)/100.0
   60 CONTINUE
      WASTE = 0.5 * (CRFC * CRN)
      CRFCM = (CRFC * CRN + WASTE)
      DO 6010 I=1,NN
         THRES(I) = 0.0
 6010 CONTINUE
      THRES(3) = TAB2(HPCRFG,DDT,1.,12.,1.)
      THRES(17) = TAB2(HPCRMT,DDT,1.,12.,1.)
      THRES(35) = TAB2(HPCRBY,DDT,1.,12.,1.)
      DO 65 I=1,NN
         THRES(I) = THRES(I)/100.0
   65 CONTINUE
      CALL TFLO(EDCR,CRFCM,IKT)
      CRTOT = 0.0
      DO 6030 I=1,NN
         CRPCID(I) = PCID(I)
         CRTOT = CRPCID(I) + CRTOT
 6030 CONTINUE
      F6(3) = CRFCM * CRPCID(3)
      F = F6(3)
(17,E5).
      F6(17) = CRFCM * CRPCID(17)
      F = F6(17)
(35,57).
      F6(35) = CRFCM * CRPCID(35)
      F = F6(35)
(21,56).
      F6(21) = CRFCM * (1. - CRTOT)
      F = F6(21)
C
C....RACCCON
C
(17,86).
      IKT = 7
      DO 7000 I=1,NN
         PCID(I) = 0.0
 7000 CONTINUE
      PCID(17) = TAB2(RCMT,DDT,1.,12.,1.)
      PCID(18) = TAB2(RCAN,DDT,1.,12.,1.)
      PCID(20) = TAB2(RCRT,DDT,1.,12.,1.)
      PCID(28) = TAB2(RCJB,DDT,1.,12.,1.)
      PCID(33) = TAB2(RCGP,DDT,1.,12.,1.)
      PCID(34) = TAB2(RCPM,DDT,1.,12.,1.)
      DO 70 I=1,NN
         PCID(I) = PCID(I)/100.0
   70 CONTINUE
      WASTE = 0.5 * (RCFC * RCN)
      RCFCM = (RCFC * RCN + WASTE)
      DO 7010 I=1,NN
         THRES(I) = 0.0
 7010 CONTINUE
      THRES(17) = TAB2(HPRCMT,DDT,1.,12.,1.)
```

```
      THRES(18) = TAB2(HPRCAN,DDT,1.,12.,1.)
      THRES(20) = TAB2(HPRCRT,DDT,1.,12.,1.)
      THRES(28) = TAB2(HPRCJB,DDT,1.,12.,1.)
      THRES(33) = TAB2(HPRCGP,DDT,1.,12.,1.)
      THRES(34) = TAB2(HPRCPM,DDT,1.,12.,1.)
      DO 75 I=1,NN
         THRES(I) = THRES(I)/100.0
   75 CONTINUE
      CALL TFLO(EDRC,RCFCM,IKT)
      RCTOT = 0.0
      DO 7020 I=1,NN
         RCPCID(I) = PCID(I)
         RCTOT = RCPCID(I) + RCTOT
 7020 CONTINUE
      F7(17) = RCFCM * RCPCID(17)
      F = F7(17)
(18,57).
      F7(18) = RCFCM * RCPCID(18)
      F = F7(18)
(20,57).
      F7(20) = RCFCM * RCPCID(20)
      F = F7(20)
(28,57).
      F7(28) = RCFCM * RCPCID(28)
      F = F7(28)
(33,54).
      F7(33) = RCFCM * RCPCID(33)
      F = F7(33)
(34,57).
      F7(34) = RCFCM * RCPCID(34)
      F = F7(34)
(21,57).
      F7(21) = RCFCM * (1. - RCTOT)
      F = F7(21)
      CALL CYCL2
**********************************************************************************


*ROUTINES
      SUBROUTINE CYCLE
C
C.....CYCLE WILL ASSIGN AND UPDATE PRODUCTION DATA.
C
      T = TIME
   99 IF (T .GE. 13.0) GO TO 100
      GO TO 200
  100 T = T - 12.0
      GO TO 99
  200 CONTINUE
      JK = JK + 1
C
C.....THE FIRST 13 FOOD ITEMS ARE PRESENT 12 MONTHS OF THE YEAR.  THE.
C.....FIRST MONTH OF THE SIMULATED YEAR IS SEPTEMBER.
C.....NOTE THAT STATE VARIABLES 2 (GRASSES) AND 3 (FUNGI) ARE PRESENT 12 MONTHS
C.....OF THE YEAR, BUT THAT I AM NOT FEEDING THEM IN UNTIL APRIL.
C
      IF (T .NE. 1.0) GO TO 1110
      CALL RANDOM(1)
      X(1) = PDATA(1) * RN(1)
      GO TO 1120
 1110 X(1) = X(1)
```

```
 1120 CONTINUE
      DO 1130 I=2,3
         IF (JK .LT. 13) GO TO 93
         IF (T .NE. 7.0) GO TO 90
         CALL RANDOM(I)
      X(I) = PDATA(I) * RN(I)
         GO TO 93
   90    X(I) = X(I)
   93    CONTINUE
 1130 CONTINUE
      DO 1000 I=4,9
         IF (T .NE. 1.0) GO TO 111
         CALL RANDOM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 112
  111    X(I) = X(I)
  112    CONTINUE
 1000 CONTINUE
      IF (T .NE. 1.0) GO TO 117
      CALL RANDOM(17)
      X(17) = RN(17)
      GC TO 118
  117 X(17) = X(17)
  118 CONTINUE
      DO 1001 I=18,20
         IF (T .NE. 1.0) GO TO 113
         CALL RANDCM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 114
  113    X(I) = X(I)
  114    CONTINUE
 1001 CONTINUE
      X(21) = PDATA(21)
C
C.....THE NEXT TWO FOOD ITEMS ARE PRESENT FROM SEPTEMBER TO FEBRUARY.
C
      DO 2000 I=22,23
         IF (T .EQ. 1.0) GO TO 10
         IF (T .LT. 7.0) GO TO 11
         X(I) = 0.0
         GC TO 12
   10    CALL RANOOM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 12
   11    X(I) = X(I)
   12    CONTINUE
 2000 CONTINUE
C
C.....THE NEXT THREE FOOD ITEMS ARE PRESENT MARCH - JUNE.
C
      DO 3000 I=24,26
         IF (T .EQ. 7.0) GO TO 20
         IF ((T .GT. 7.0) .AND. (T .LT. 11.0)) GO TO 21
         X(I) = 0.0
         GO TO 22
   20    CALL RANDOM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 22
   21    X(I) = X(I)
   22    CONTINUE
 3000 CONTINUE
```

```
C
C.....THE NEXT TWO ARE PRESENT MARCH - AUGUST.
C
      DO 4000 I=27,28
         IF (T .EQ. 7.0) GO TO 30
         IF ((T .GT. 7.0) .AND. (T .LE. 12.5)) GO TO 31
         X(I) = 0.0
         GO TO 32
   30    CALL RANDOM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 32
   31    X(I) = X(I)
   32    CONTINUE
 4000 CONTINUE
C
C.....THE NEXT FOOD IS PRESENT JUNE -AUGUST.
C
      IF (T .EQ. 10.0) GO TO 40
      IF ((T .GT. 10.0) .AND. (T .LE. 12.5)) GO TO 41
      X(29) = 0.0
      GO TO 42
   40 CALL RANDOM(29)
      X(29) = PDATA(29) * RN(29)
      GO TO 42
   41 X(29) = X(29)
   42 CONTINUE
C
C.....THE NEXT THREE FOOD ITEMS ARE PRESENT APRIL - SEPTEMBER.
C
      DO 5000 I=30,32
         IF (JK .LT. 15) GO TO 53
         IF (T .EQ. 8.0) GO TO 51
         IF (((T .GT. 8.0) .AND. (T .LE. 12.5)) .OR.(T .EQ. 1.0)
     ¬   .OR. (T .EQ. 1.5)) GO TO 52
         X(I) = 0.0
         GO TO 53
   51    CALL RANDOM(I)
         X(I) = PDATA(I) * RN(I)
         GO TO 53
   52    X(I) = X(I)
   53    CONTINUE
 5000 CONTINUE
C
C.....THE NEXT FOOD IS PRESENT JUNE - NOVEMBER.
C
      IF (JK .LT. 19) GO TO 63
      IF (T .EQ. 10.0) GO TO 61
      IF (((T .GT. 10.0) .AND. (T .LE. 12.5)) .OR.
     ¬((T .GE. 1.0) .AND. (T .LT. 4.0))) GO TO 62
      X(33) = 0.0
      GO TO 63
   61 CALL RANDOM(33)
      X(33) = PDATA(33) * RN(33)
      GO TO 63
   62 X(33) = X(33)
   63 CONTINUE
C
C.....THE NEXT FOOD IS PRESENT JUNE - FEBRUARY
C
      IF (JK .LT. 19) GO TO 73
      IF (T .EQ. 10.0) GO TO 71
```

```
      IF (((T .GT. 10.0) .AND. (T .LE. 12.5)) .OR.
     -((T .GE. 1.0) .AND. (T .LT. 7.0))) GO TO 72
      X(34) = 0.0
      GC TO 73
   71 CALL RANDOM(34)
      X(34) = PDATA(34) * RN(34)
      GO TO 73
   72 X(34) = X(34)
   73 CCNTINUE
C
C.....THE NEXT FOUR FOOD ITEMS ARE PRESENT JULY - OCTOBER.
C
      DC 7000 I=35,38
         IF (JK .LT. 21) GO TO 83
         IF (T .EQ. 11.0) GO TO 81
         IF (((T .GT. 11.0) .AND. (T .LE. 12.5)) .OR.
     -   ((T .GE. 1.0) .AND. (T .LT. 3.0))) GO TO 82
         X(I) = 0.0
         GC TO 83
   81    CALL RANDCM(I)
         X(I) = PDATA(I) * RN(I)
         GC TO 83
   82    X(I) = X(I)
   83    CCNTINUE
 7000 CCNTINUE
      X(99) = 0.0
      X(21) = 1.0E20
C
C.....FIND DENSITY OF CONSUMERS AT START OF EACH SIMULATED YEAR.
C
      IF (T .NE. 1.0) GO TO 333
      CALL RANDOM(40)
      WTN = RN(40)
      CALL RANDOM(41)
      DRN = DRN * RN(41)
      WRITE (6,4441) DRN
 4441 FORMAT (' ','***** DRN = ',F10.7,' *****')
      CALL RANDCM(42)
      WHN = RN(42)
      CALL RANDOM(43)
      CRN = RN(43)
      CALL RANDOM(44)
      SCN(1) = RN(44)
      CALL RANDOM(45)
      SCN(2) = RN(45)
      CALL RANDCM(46)
      RCN = RN(46)
  333 CCNTINUE
C
C.....FIND PLACE IN YEARLY TABLE W/R TO CURRENT DT - TABLES MONTHLY BASED 12
C
      TK = TK + 1.0
   98 IF (TK .GT. 24.0) GO TO 201
      GC TC 301
  201 TK = TK - 24.0
      GC TO 98
  301 CCNTINUE
      IF (JK .EQ. 1) GO TO 5
      JZ = (JK/2) * 2
      IF (JK-JZ) 5,6,5
    5 DDT = (TK + 1.0)/2.0
```

```
      GO TC 7
    6 DDT = TK/2.0
    7 CCNTINUE
C
C.....ZX KEEPS TRACK OF LEVEL AS IT DECREASES OVER TIME.
C
      DC 2 I=1,NN
         IF (X(I) .LE. 0.0) X(I) = 0.0
         ZX(I) = X(I)
    2 CONTINUE
      RETURN
      END
*****************************************************************************************
      SUBRCUTINE CYCL2
C
C.....PRINT TIMING
C
      PR = 0.0
      RP = RP + DT
      IF (RP .NE. DTPR) GO TO 2
    1 RP = 0.0
      PR = 1.0
C
C.....CYCL2 PRINTS FREQUENCY TABLE FROM TRADI AT END OF SIMULATION
C
    2 IF (TIME .LT. TEND) GO TO 105
      DC 109 J=1,7
         WRITE (6,102)
  102    FORMAT(1H1,10X,'ND',10X,'DNEG',10X,'NPD',10X,'DPOS')
         WRITE (6,103) (ND(I,J),DNEG(I,J),NPD(I,J),DPOS(I,J),I=1,38)
  103    FORMAT (4(4X,F10.4))
  109 CCNTINUE
  105 RETURN
      END
*****************************************************************************************
      FUNCTION TAB2(A,B,C,D,E)
      DIMENSION A(1)
C
C.....LINEAR INTERPOLATION ROUTINE
C
C.....A - TABLE NAME
C.....B - CURRENT LOOK UP VALUE - OFTEN TIME
C.....C - MINIMUM TABLE ENTRY (INDEPENDENT VARIABLE)
C.....D - MAXIMUM TABLE ENTRY (INDEPENDENT VARIABLE)
C.....E - INTERVAL BETWEEN TABLE VALUES.
C
      F = E
      LI = 0
      IF (B .GT. C) GO TO 2
      TAB2 = A(1)
      RETURN
    2 IF (B .LT. D) GO TO 7
      L = (D-C)/E
      IF (A(L+1) .EQ. 9.99) GO TO 7
      TAB2 = A(L+1)
      RETURN
    7 K = (B-C)/E
```

```
      GO TC 7
    6 DOT = TK/2.0
    7 CCNTINUE
C
C.....ZX KEEPS TRACK OF LEVEL AS IT DECREASES OVER TIME.
C
      DC 2 I=1,NA
         IF (X(I) .LE. 0.0) X(I) = 0.0
         ZX(I) = X(I)
    2 CONTINUE
      RETURN
      END
*************************************************************************************

      SUBRCUTINE CYCL2
C
C.....PRINT TIMING
C
      PR = 0.0
      RP = RP + DT
      IF (RP .NE. DTPR) GO TO 2
    1 RP = 0.0
      PR = 1.0
C
C.....CYCL2 PRINTS FREQUENCY TABLE FROM TRADI AT END OF SIMULATION
C
    2 IF (TIME .LT. TEND) GO TO 105
      DC 109 J=1,7
         WRITE (6,102)
  102    FORMAT(1H1,10X,'ND',10X,'DNEG',10X,'NPD',10X,'DPOS')
         WRITE (6,103) (ND(I,J),DNEG(I,J),NPD(I,J),DPOS(I,J),I=1,38)
  103    FORMAT (4(4X,F10.4))
  109 CCNTINUE
  105 RETURN
      END
*************************************************************************************

      FUNCTION TAB2(A,B,C,D,E)
      DIMENSION A(1)
C
C.....LINEAR INTERPOLATION ROUTINE
C
C.....A - TABLE NAME
C.....B - CURRENT LOOK UP VALUE - OFTEN TIME
C.....C - MINIMUM TABLE ENTRY (INDEPENDENT VARIABLE)
C.....D - MAXIMUM TABLE ENTRY (INDEPENDENT VARIABLE)
C.....E - INTERVAL BETWEEN TABLE VALUES.
C
      F = E
      LI = 0
      IF (B .GT. C) GO TO 2
      TAB2 = A(1)
      RETURN
    2 IF (B .LT. D) GO TO 7
      L = (D-C)/E
      IF (A(L+1) .EQ. 9.99) GO TO 7
      TAB2 = A(L+1)
      RETURN
    7 K = (B-C)/E
```

```
      I = K+1
      J = I+1
C
C.....9.99 IMPLIES NO DATA FOR A TABLE - MUST INCREASE INTERPOLATION INTERVAL
C
    3 IF (A(J) .NE. 9.99) GO TO 5
      J = J+1
      F = F+E
      GO TO 3
    5 IF (A(I) .NE. 9.99) GO TO 10
      I = I-1
      LI = LI+1
      F = F+E
      GO TO 5
   10 TAB2 = (A(J)-A(I))/F * (B+LI-C-K*E) + A(I)
      RETURN
      END
*********************************************************************************

      SUBROUTINE TFLO(EDBL,NUM,IKT)
C
C.....TFLO COMPUTES TEMPORARY FLOWS AND ENSURES DIET FILLED AS MUCH AS POSSIBLE.
C
      DIMENSION EDBL(50),TPIC(50)
      DATA PCT,PCT1,PCT2,PCT3/'PCID','AVA ',' TF ',' ZX '/
      REAL NUM
      IF (PR .NE. 1.0) GO TO 19
      WRITE(6,5555) PCT,(PCID(I),I=1,NN)
C
C.....TEST INTERPOLATED DIETS TO INSURE THEY CONTAIN NOT MORE THAN 100 PCT.
C
   19 TPC = 0.0
      DO 8 I=1,NN
         TPC = TPC + PCID(I)
    8 CONTINUE
      IF (TPC .LE. 1.0) GO TO 9
      TST = 1.0/TPC
      DO 7 I=1,NN
         PCID(I) = PCID(I)*TST
    7 CONTINUE
      IF (PR .NE. 1.0) GO TO 9
      WRITE (6,5555) PCT,(PCID(I),I=1,NN)
    9 DO 111 I=1,NN
   11    TPIC(I) = PCID(I)
C
C.....SAVM - SAVES ORIGINAL PCT IN DIET FOR STATISTICS.
C
         SAVM(I) = PCID(I)
  111 CONTINUE
      FLG = 0.0
      DO 5 K=1,NN
         IF (K .NE. 21) GO TO 15
   14    AVA(21) = 0.0
         GO TO 5
C
C.....TF - TEMPORARY FLOW COMPUTATION.
C
   15    TF = NUM*PCID(K)*DT
         IF (ZX(K) .GE. 0.0) GO TO 777
         IF (JK .LT. 25) GO TO 13
```

```
          WRITE (6,12) K,ZX(K)
   12     FORMAT(1H0,9X,'ZX(',I2,')',5X,E10.4)
   13     ZX(K) = 0.0
C
C.....AVAILABLE BIOMASS COMPUTATION.
C
  777     AVAIL = ZX(K)*EDBL(K)
          AVA(K) = AVAIL
C
C.....TEST TO SEE IF NORMAL FLOW EXCEEDS AVAILABLE - IF SO CALL SUBROUTINE FLO
C.....AND ADJUST DIET TO AVAILABLE BY SPECIES.
C
          IF (AVAIL .GE. TF) GO TO 5
          CALL FLO(EDBL,K,TPIC,NUM,IKT)
          FLG = 1.0
    5 CONTINUE
   17 DO 10 I=1,NN
          TF = PCID(I)*NUM*DT
          ZX(I) = ZX(I)-TF
          FFF(I) = TF
   10 CONTINUE
      IF (PR .NE. 1.0) GO TO 33
      WRITE(6,5555) PCT1,(AVA(I),I=1,NN)
      WRITE(6,5555) PCT2,(FFF(I),I=1,NN)
      WRITE(6,5555) PCT3,(ZX(I),I=1,NN)
C
C.....I DO NOT WANT TO RUN ANY OF THE STATISTICAL TEST OR SUM DIETARY
C.....CHANGES UNTIL THE SECOND YEAR
C
   33 IF (JK .LT. 25) FLG = 0.0
C
C.....DLIET TESTS ADJUSTED DIET TO SEE IF SIGNIFICANTLY DIFFERENT FROM NORMAL
C.....NORMAL USING SPEARMAN RANK CORRELATION COEFFICIENT.
C
      IF (FLG .EQ. 1.0) CALL DLIET(IKT)
      RETURN
 5555 FORMAT (1H0,4X,A5,8(2X,E11.4),4(/10X,8(2X,E11.4)))
      END
*****************************************************************************


      SUBROUTINE FLO(EDBL,K,TPIC,NUM,IKT)
      DIMENSION EDBL(50),TPIC(50)
      REAL NUM
C
C.....THRES - THRESHOLD - GREATEST PERCENTAGE OF A SPECIES AT GIVEN TIME OF YEAR
C.....EDBL- PCT OF AVAIL FORAGE THAT IS EDIBLE BY A GIVEN CONSUMER.
C.....AVAIL - FORAGE AVIALABLE
C.....TF - TEMPORARY FLOW BEING VALIDATED OR ALTERED
C.....K - NO. OF FLOW
C
C.....RECOMPUTE DIET PCTS DUE TO SPECIES DEPLETION
C
C.....PCT OF ORIGINAL FLOW SATISFIED BY DEPLETED SPECIES K.
C
C.....TT AND TTT ARE PCT NOT ACCOUNTED FOR.
C
      TT = ((TF-AVAIL)/TF) * PCID(K)
      PCID(K) = PCID(K)-TT
      TPIC(K) = 0.0
      AT = 0.0
```

```
C
C.....FIND PCT OF DIET OF ALL SPECIES EXCEPT DEPLETED ONE.
C
      DO 10 I=1,NN
         IF (TPIC(I) .EQ. 0.0) GO TO 10
         AT = AT+PCID(I)
   10 CONTINUE
C
C.....RECOMPUTED PCTS DUE TO SPECIES DEPLETION.
C
      DO 20 I=1,NN
         IF (TPIC(I) .EQ. 0.0) GO TO 20
         TPIC(I) = (TPIC(I)/AT) * TT + PCID(I)
   20 CONTINUE
C
C.....TEST FOR NEW PCTS GREATER THAN THRESHOLDS AND READJUST ANY THAT EXCEEDED
C.....AVAILABLE.
C
   19 DO 30 I=1,NN
         IF (TPIC(I) .EQ. 0.0) GO TO 30
         TF = TPIC(I)*NUM*DT
         AVAIL = ECBL(I)*ZX(I)
         IF (AVAIL .GE. TF) GO TO 17
         TTT = ((TF-AVAIL)/TF)*TPIC(I)
         PCID(I) = TPIC(I)-TTT
         TPIC(I) = 0.0
         GO TO 18
   17    IF (TPIC(I) .LE. THRES(I)) GO TO 30
   21    TTT = TPIC(I) - THRES(I)
         PCID(I) = THRES(I)
         TPIC(I) = 0.0
   18    AAT = 0.0
         DO 28 J=1,NN
            IF (TPIC(J) .EQ. 0.0) GO TO 28
   25       AAT = AAT+TPIC(J)
   28    CONTINUE
         DO 29 J=1,NN
            IF (TPIC(J) .EQ. 0.0) GO TO 29
   24       TPIC(J) = (TPIC(J)/AAT) * TTT + TPIC(J)
   29    CONTINUE
         GO TO 19
   30 CONTINUE
      DO 40 I=1,NN
         IF (TPIC(I) .EQ. 0.0) GO TO 40
         PCID(I) = TPIC(I)
   40 CONTINUE
      RETURN
      END
******************************************************************************

      SUBROUTINE OLIET(IKT)
      DIMENSION A(50),B(50),R(100)
      NR = 0
      N = 0
C
C.....PASS ONLY DIET COMPONENTS GREATER THAN 1 PERCENT TO SPRHO FOR
C.....CORRELATION.
C
      DO 10 I=1,NN
         IF (SAVM(I) .LT. 0.01) GO TO 10
```

```
          N = N+1
          A(N) = SAVM(I)
          B(N) = PCID(I)
   10 CONTINUE
C
C.....IF N .LE. 4 SPEARMANS RANK CORRELATION IS A WASTE OF TIME.
C
      IF (N .LE. 4) GO TO 8
      CALL SRANK(A,B,R,N,RS,H,NDF,NR,IKT)
      WRITE (6,9) RS,H,NDF
    9 FORMAT (1H0,9X,'=== RS === ',F10.4,5X,'=== H === ',F10.4,5X,'===
     ¬NDF === ',I4)
      GO TO 11
    8 WRITE (6,1) IKT,N
    1 FORMAT('0','***** IKT = ',I2,' *** N = ',I2,' *****')
   11 CALL TRADI(IKT)
      RETURN
      END
********************************************************************************


      SUBROUTINE SRANK(A,B,R,N,RS,H,NDF,NR,IKT)
      DIMENSION A(1),B(1),R(1)
C
C.....SPEARMAN RANK CORRELATION.
C.....IBM SCIENTIFIC SUBROUTINE PACKAGE.
C
    2 FNNN = N*N*N-N
      IF (NR - 1) 5,10,5
    5 CALL RANK(A,R,N)
      CALL RANK (B,R(N+1),N)
      GO TO 40
   10 DO 20 I=1,N
         R(I) = A(I)
   20 CONTINUE
      DO 30 I=1,N
         J = I+N
         R(J) = B(I)
   30 CONTINUE
   40 D = 0.0
      DO 50 I=1,N
         J = I+N
         D = D + (R(I)-R(J)) * (R(I)-R(J))
   50 CONTINUE
      KT = 1
      CALL TIE(R,N,KT,TSA)
      CALL TIE(R(N+1),N,KT,TSB)
      IF (TSA) 60,55,60
   55 IF (TSB) 60,57,60
   57 RS = 1.0 - (6.0*D/FNNN)
      GO TO 75
   60 YX = (FNNN/12.0) - TSA
      Y = YX+TSA-TSB
      RS = (YX+Y-D)/(2.0*(SQRT(YX*Y)))
   75 IF (RS-1.0) 76,74,74
   74 H = 99.0
      GO TO 80
   76 H = RS * SQRT(FLOAT(N-2)/(1.0-RS*RS))
   80 NDF = N-2
      RETURN
      END
```

```
*******************************************************************************

      SUBROUTINE RANK(A,R,N)
      DIMENSION A(1),R(1)
C
C.....RANK IS AN IBM SCIENTIFIC SUBROUTINE PACKAGE SUBROUTINE WHOSE
C.....PURPOSE IS TO RANK A VECTOR OF VALUES.
C.....A - INPUT VECTOR OF N VALUES
C.....R - OUTPUT VECTOR OF LENGTH N.  SMALLEST VALUE IS RANKED 1,
C.....     LARGEST IS RANKED N.  TIES ARE ASSIGNED AVERAGE OF TIED RANKS.
C.....N - NUMBER OF VALUES
C
C.....INITIALIZATION
C
      DO 10 I=1,N
         R(I) = 0.0
   10 CONTINUE
C
C.....FIND RANK OF DATA.
C
      DO 100 I=1,N
C
C.....TEST WHETHER DATA POINT IS ALREADY RANKED.
C
         IF (R(I)) 20,20,100
C
C.....DATA POINT TO BE RANKED.
C
   20    SMALL = 0.0
         EQUAL = 0.0
         SA = A(I)
         DO 50 J=1,N
            IF (A(J)-SA) 30,40,50
C
C.....COUNT NUMBER OF DATA POINTS WHICH ARE SMALLER.
C
   30       SMALL = SMALL+1.0
            GO TO 50
C
C.....COUNT NUMBER OF DATA POINTS WHICH ARE EQUAL
C
   40       EQUAL = EQUAL+1.0
            R(J) = -1.0
   50    CONTINUE
C
C.....TEST FOR TIE
C
         IF (EQUAL-1.0) 60,60,70
C
C.....STORE RANK OF DATA POINT WHERE NO TIE
C
   60    R(I) = SMALL+1.0
         GO TO 100
C
C.....CALCULATE RANK OF TIED DATA POINTS
C
   70    P = SMALL + (EQUAL+1.0) * 0.5
         DO 90 J=1,N
            IF (R(J)+1.0) 90,80,90
   80       R(J) = P
```

```
   90    CONTINUE
  100 CCNTINUE
      RETURN
      ENC
************************************************************************************

      SUBRCUTINE TIE(R,N,KT,H)
      DIMENSION R(1)
C
C.....TIE IS AN IBM SCIENTIFIC SUBROUTINE PACKAGE.  ITS PURPOSE IS TO
C.....CALCULATE CORRECTION FACTOR DUE TO TIES.
C.....R - INPUT VECTCR OF RANKS OF LENGTH N CONTAINING VALUES 1 TO N.
C.....N - NUMBER OF RANKED VALUES
C.....KT - INPUT CODE FOR CALCULATION OF CORRECTION FACTOR
C.....           1 - SCLVE ECUATION 1
C.....           2 - SOLVE ECUATION 2
C.....H - CORRECTION (OUTPUT)
C.....        EQUATICN 1  H = SUM(CT**3 - CT)/12
C.....        EQUATICN 2  H = SUM(CT*(CT-1)/2)
C.....     WHERE CT IS THE NUMBER OF OBSERVATIONS TIED FOR A GIVEN RANK
C
C.....INITIALIZATION
C
      H = 0.0
      Y = 0.0
    5 G = 1.0E38
      IND = 0
C
C.....FIND NEXT LARGEST RANK
C
      DO 30 I=1,N
         IF (R(I)-Y) 30,30,10
   10    IF (R(I)-G) 20,30,30
   20    G = R(I)
         IND = IND+1
   30 CCNTINUE
C
C.....IF ALL RANKS HAVE BEEN TESTED RETURN
C
      IF (IND) 90,90,40
   40 Y = G
      CT = 0.0
C
C.....COUNT TIES
C
      DO 60 I=1,N
         IF (R(I)-G) 60,50,60
   50    CT = CT+1.0
   60 CCNTINUE
C
C.....CALCULATE THE CORRECTION FACTOR
C
      IF (CT) 70,5,7C
   70 IF (KT-1) 75,80,75
   75 H = H + CT * (CT-1.0)/2.0
      GO TO 5
   80 H = H + (CT*CT*CT-CT)/12.0
      GO TO 5
   90 RETURN
      END
```

```
*******************************************************************************

      SUBROUTINE TRADI(IKT)
C
C.....TRACI COMPUTES FREQUENCY OF DIFFERENCES GREATER THAN 3 PERCENT IN
C.....REDISTRIBUTED DIET FROM NORMAL DIET AND TOTALS THE MAGNITUDE OF THESE
C.....DIFFERENCED.
C
      DO 10 I=1,NN
         DIF = PCID(I) - SAVM(I)
         IF (ABS(DIF) .LE. 0.03) GO TO 10
    2    IF (DIF) 1,10,3
    1    DNEG(I,IKT) = DNEG(I,IKT)+DIF
         ND(I,IKT) = ND(I,IKT)+1.0
         GO TO 10
    3    DPOS(I,IKT) = DPOS(I,IKT)+DIF
         NPD(I,IKT) = NPD(I,IKT)+1.0
   10 CONTINUE
      RETURN
      END
*******************************************************************************

      SUBROUTINE RANDU(IY,YFL)
C.....RANDU IS AN IBM SCIENTIFIC SUBROUTINE.  IT COMPUTES UNIFORMLY DISTRIBUTED
C.....RANDOM REAL NUMBERS BETWEEN 0 AND 1.0 AND RANDOM INTEGERS BETWEEN
C.....0 AND 2**31.  EACH ENTRY USES AS INPUT AN INTEGER RANDOM NUMBER
C.....AND PRODUCES A NEW INTEGER AND REAL RANDOM NUMBER.
C
C.....THE METHOD USED IS THE POWER RESIDUE METHOD .
C.....IY - A RESULTANT INTEGER RANDOM NUMBER REQUIRED FOR THE NEXT ENTRY
C.....       TO THIS SUBROUTINE.
C
C.....YFL - THE RELULTANT UNIFORMLY DIST. FLOATING POINT RANDOM NUMBER
C
      IY = IX * 65539
      IF(IY) 5,6,6
    5 IY = IY + 2147483647 + 1
    6 YFL = IY
      YFL = YFL * 0.4656613E-9
      RETURN
      END
*******************************************************************************

      SUBROUTINE RANDOM(I)
C
C.....RANDOM IS AN IBM SCIENTIFIC SUBROUTINE PACKAGE SUBROUTINE.
C.....IT COMPUTES A NORMALLY DISTRIBUTED RANDOM NUMBER WITH A GIVEN MEAN
C.....AND STANDARD DEVIATION.
C
C.....IT USES 12 UNIFORM RANDOM NUMBERS TO COMPUTE NORMAL RANDOM NUMBERS
C.....BY CENTRAL LIMIT THEOREM.  THE RESULT IS THEN ADJUSTED TO MATCH THE GIVEN
C.....MEAN AND STANDARD DEVIATION.
C
    1 A = 0.0
      DO 57 L=1,12
         CALL RANDU(IY,Y)
         IX = IY
         A = A+Y
```

```
   57 CONTINUE
      RN(I) = (A-6.0) * S(I) + AM(I)
C
C.....IF THE RANDOM NUMBER IS LARGER THAN MAXIMUM VALUE ALLOWED OR SMALLER
C.....THAN MINIMUM GO BACK AND FIND ANOTHER RANDOM NUMBER
C
      IF ((RN(I) .LT. MIN(I)) .OR. (RN(I) .GT. MAX(I))) GO TO 1
      WRITE (6,58) I,RN(I)
   58 FORMAT ('0','****** RN(',I2,') = ',F12.7,' ******')
      RETURN
      END
**********************************************************************************


      SUBROUTINE START
C
C.....START WILL READ IN DATA
C
      READ(1,1000) (PDATA(I), I=1,38)
 1000 FORMAT(10E8.0)
      READ(1,1001) (EDSC(I),I=1,38)
      READ(1,1001) (EDPC(I),I=1,38)
      READ(1,1001) (EDWH(I),I=1,38)
      READ(1,1001) (EDWT(I),I=1,38)
      READ(1,1001) (EDCR(I),I=1,38)
      READ(1,1001) (EDCR(I),I=1,38)
      READ(1,1001) (EDBR(I),I=1,38)
      READ(1,1001) (MAX(I),I=1,46)
      READ(1,1001) (MIN(I),I=1,46)
      READ(1,1001) (S(I),I=1,46)
      READ(1,1001) (AM(I),I=1,39)
 1001 FORMAT (16F5.0)
      READ(1,1010) WTN,DRN,CRN,BRN,RCN,WHN,SCN(1),SCN(2)
 1010 FORMAT(8F8.0)
      READ(1,1011) WTFC,DRFC,CRFC,SCFC(1),SCFC(2),RCFC,WHFC
 1011 FORMAT(7F8.0)
      READ(1,1041) (BRF(I),I=1,13)
 1041 FORMAT(13F6.0)
      READ(1,1040) (HPWTMT(I), I=1,12)
      READ(1,1040) (HPWTGR(I), I=1,12)
      READ(1,1040) (HPWTGP(I), I=1,12)
      READ(1,1040) (HPWTDW(I), I=1,12)
      READ(1,1040) (HPWTAN(I), I=1,12)
      READ(1,1040) (HPWTBY(I), I=1,12)
      READ(1,1040) (HPWTRX(I), I=1,12)
      READ(1,1040) (HPWTHK(I), I=1,12)
      READ(1,1040) (HPDRGR(I), I=1,12)
      READ(1,1040) (HPDRPB(I), I=1,12)
      READ(1,1040) (HPDRHS(I), I=1,12)
      READ(1,1040) (HPDRPF(I), I=1,12)
      READ(1,1040) (HPDROB(I), I=1,12)
      READ(1,1040) (HPDRMT(I), I=1,12)
      READ(1,1040) (HPDRGP(I), I=1,12)
      READ(1,1040) (HPDRFG(I), I=1,12)
      READ(1,1040) (HPDRMB(I), I=1,12)
      READ(1,1040) (HPDRRH(I), I=1,12)
      READ(1,1040) (HPDRML(I), I=1,12)
      READ(1,1040) (HPDRWG(I), I=1,12)
      READ(1,1040) (HPDRGX(I), I=1,12)
      READ(1,1040) (HPDRAP(I), I=1,12)
      READ(1,1040) (HPBRBL(I), I=1,12)
```

```
READ(1,1040) (HPBRBY(I), I=1,12)
READ(1,1040) (HPBRSB(I), I=1,12)
READ(1,1040) (HPBRHK(I), I=1,12)
READ(1,1040) (HPBRAN(I), I=1,12)
READ(1,1040) (HPBRJB(I), I=1,12)
READ(1,1040) (HPBRGG(I), I=1,12)
READ(1,1040) (HPBRCH(I), I=1,12)
READ(1,1040) (HPBRMT(I), I=1,12)
READ(1,1040) (HPBRGP(I), I=1,12)
READ(1,1040) (HPBRGR(I), I=1,12)
READ(1,1040) (HPBRSF(I), I=1,12)
READ(1,1040) (HPWHGR(I), I=1,12)
READ(1,1040) (HPWHMT(I), I=1,12)
READ(1,1040) (HPWHAP(I), I=1,12)
READ(1,1040) (HPWHRT(I), I=1,12)
READ(1,1040) (HPWHHK(I), I=1,12)
READ(1,1040) (HPWHSB(I), I=1,12)
READ(1,1040) (HPWHBL(I), I=1,12)
READ(1,1040) (HPWHGG(I), I=1,12)
READ(1,1040) (HPSCMT(I), I=1,12)
READ(1,1040) (HPSCFG(I), I=1,12)
READ(1,1040) (HPSCMS(I), I=1,12)
READ(1,1040) (HPSCAP(I), I=1,12)
READ(1,1040) (HPSCMA(I), I=1,12)
READ(1,1040) (HPRCMT(I), I=1,12)
READ(1,1040) (HPRCPM(I), I=1,12)
READ(1,1040) (HPRCAN(I), I=1,12)
READ(1,1040) (HPRCRT(I), I=1,12)
READ(1,1040) (HPRCJB(I), I=1,12)
READ(1,1040) (HPRCGP(I), I=1,12)
READ(1,1040) (HPCRFG(I), I=1,12)
READ(1,1040) (HPCRMT(I), I=1,12)
READ(1,1040) (HPCRBY(I), I=1,12)
READ(1,1040) (WTMT(I), I=1,12)
READ(1,1040) (WTGR(I), I=1,12)
READ(1,1040) (WTGP(I), I=1,12)
READ(1,1040) (WTDW(I), I=1,12)
READ(1,1040) (WTAN(I), I=1,12)
READ(1,1040) (WTBY(I), I=1,12)
READ(1,1040) (WTRX(I), I=1,12)
READ(1,1040) (WTHK(I), I=1,12)
READ(1,1040) (DRGR(I), I=1,12)
READ(1,1040) (DRPB(I), I=1,12)
READ(1,1040) (DRHS(I), I=1,12)
READ(1,1040) (DRPF(I), I=1,12)
READ(1,1040) (DROB(I), I=1,12)
READ(1,1040) (DRMT(I), I=1,12)
READ(1,1040) (DRGP(I), I=1,12)
READ(1,1040) (DRFG(I), I=1,12)
READ(1,1040) (DRMB(I), I=1,12)
READ(1,1040) (DRRH(I), I=1,12)
READ(1,1040) (DRML(I), I=1,12)
READ(1,1040) (DRWG(I), I=1,12)
READ(1,1040) (DRGX(I), I=1,12)
READ(1,1040) (DRAP(I), I=1,12)
READ(1,1040) (BRBL(I), I=1,12)
READ(1,1040) (BRBY(I), I=1,12)
READ(1,1040) (BRSB(I), I=1,12)
READ(1,1040) (BRHK(I), I=1,12)
READ(1,1040) (BRAN(I), I=1,12)
READ(1,1040) (BRJB(I), I=1,12)
```

```
      READ(1,1040) (BRGG(I), I=1,12)
      READ(1,1040) (BRCH(I), I=1,12)
      READ(1,1040) (BRMT(I), I=1,12)
      READ(1,1040) (BRGP(I), I=1,12)
      READ(1,1040) (BRGR(I), I=1,12)
      READ(1,1040) (BRSF(I), I=1,12)
      READ(1,1040) (WHGR(I), I=1,12)
      READ(1,1040) (WHMT(I), I=1,12)
      READ(1,1040) (WHAP(I), I=1,12)
      READ(1,1040) (WHRT(I), I=1,12)
      READ(1,1040) (WHHK(I), I=1,12)
      READ(1,1040) (WHBB(I), I=1,12)
      READ(1,1040) (WHBL(I), I=1,12)
      READ(1,1040) (WHGG(I), I=1,12)
      READ(1,1040) (SCMT(I), I=1,12)
      READ(1,1040) (SCFG(I), I=1,12)
      READ(1,1040) (SCMS(I), I=1,12)
      READ(1,1040) (SCAP(I), I=1,12)
      READ(1,1040) (SCMA(I), I=1,12)
      READ(1,1040) (RCMT(I), I=1,12)
      READ(1,1040) (RCPM(I), I=1,12)
      READ(1,1040) (RCAN(I), I=1,12)
      READ(1,1040) (RCRT(I), I=1,12)
      READ(1,1040) (RCJB(I), I=1,12)
      READ(1,1040) (RCGP(I), I=1,12)
      READ(1,1040) (CRFG(I), I=1,12)
      READ(1,1040) (CRMT(I), I=1,12)
      READ(1,1040) (CRBY(I), I=1,12)
 1040 FORMAT(12F6.0)
      READ(1,1070) NN,TSTART,TEND,DT,DTPR,DTFL
 1070 FORMAT(I2,5F5.0)
C
C.....SET INITIAL VALUES FOR PR,RP,JK,TK,AND IX.  IX IS THE SEED FOR THE
C.....RANDOM NUMBER GENERATOR, RP AND PR ARE PRINT CONTROL DIRECTIVES,
C.....AND JK AND TK ARE COUNTERS.
C
      IX = 951123
      JK = 0
      TK = 0.0
      PR = 1.0
      RP = 0.0
      DO 50 I=1,NN
C
C.....THE FOLLOWING ARRAYS ARE INITIALIZED TO ZERO SO THAT FIRST FLOW
C.....DECLARATIONS IN THE MAIN PART OF THE PROGRAM CAN BE EXECUTED.
C
         F1(I) = 0.0
         F2(I) = 0.0
         F3(I) = 0.0
         F4(I) = 0.0
         F5(I) = 0.0
         F6(I) = 0.0
         F7(I) = 0.0
C
C.....CONVERT PRODUCTION DATA TO A PER HECTARE BASIS.
C.....THERE ARE 50,588 HECTARES IN THE AREA I AM MODELING.
C
         PDATA(I) = PDATA(I)/50588.0
         DO 51 J=1,7
C
C.....THE FOLLOWING ARRAYS ARE INITIALIZED TO ZERO FOR USE IN SUBROUTINE TRADI
```

```
C
             DNEG(I,J) = 0.0
             ND(I,J) = 0.0
             DPOS(I,J) = 0.0
             NPD(I,J) = 0.0
   51    CONTINUE
   50 CONTINUE
C
C.....SET AVERAGE VALUES FOR:
C.....AM(17) - MAST
C.....AM(40) - TURKEY
C.....AM(41) - DEER
C.....AM(42) - HOG
C.....AM(43) - RODENTS
C.....AM(44) - CHIPMUNK
C.....AM(45) - SQUIRRELS
C.....AM(46) - RACCOON
C.....THESE ARE NOT READ IN WITH A READ STATEMENT BECAUSE OF AWKWARDNESS OF
C.....HANDLING THAT WAY
C
      AM(17) = PDATA(17)
      AM(40) = WTN
      AM(41) = 1.0
      AM(42) = WHN
      AM(43) = CRN
      AM(44) = SCN(1)
      AM(45) = SCN(2)
      AM(46) = PCN
      RETURN
      END
*END
*****************************************************************************************
```

APPENDIX D

VARIABLES USED IN MODEL

The variables are grouped into similar categories (e.g. wild turkey diet, consumer density, etc.). Usually only the first variable in each category will be explained. Using the key letters presented below the reader should be able to decipher the other variables in each category because the variable names were chosen to facilitate rapid understanding of their meaning.

Key Letters	Meaning
WT	Wild Turkey
WH	Wild Hog
CR	Canonical Rodent
DR	White-Tailed Deer
BR	Black Bear
SC	Sciurids
RC	Raccoon
HS	Honeysuckle
GR	Grasses
FG	Fungi
RH	Rhododendron
ML	Mountain Laurel
WG	Wintergreen
GX	Galax
BB	Blueberry Browse
RX	Sheep Sorrel
MT	Mast
AN	Animal
GG	Garbage
RT	Roots
CH	Cherry
DW	Dogwood
PF	Yellow Poplar Fruits
MS	Red Maple Seeds
SF	Squawroot Forage
AP	Apple
JB	Juneberry
MA	Mayapple
PB	Yellow Poplar Browse
MB	Red Maple Browse
OB	Oak Browse
GP	Wild Grape
PM	Persimmon
BY	Blackberry
BL	Blueberry
HK	Huckleberry
SB	Squawroot Fruits

TABLE D-1

NAMES, MEANINGS, AND DIMENSIONS OF VARIABLES

Variable Name	Description	Dimension
WTMT WTGR WTGP WTDW WTAN WTBY WTRX WTHK	Percentage of mast in wild turkey diet.	Decimal Fraction
HPWTMT . . . HPWTHK	Highest percentage of mast in wild turkey diet.	Decimal Fraction
WHGR WHMT WHAP WHRT WHHK WHBB WHBL WHGG	Percentage of grass in wild hog diet.	Decimal Fraction
HPWHGR . . . HPWHGG	Highest percentage of grass in wild hog diet.	Decimal Fraction
BRBL BRBY BRSB BRHK BRAN BRJB BRGG BRCH BRMT BRGP BRGR BRSF	Percentage of blueberry in black bear diet.	Decimal Fraction

TABLE D-1 (continued)

Variable Name	Description	Dimension
HPBRBL . . . HPBRSF	Highest percentage of blueberry in black bear diet.	Decimal Fraction
DRPB DRHS DRPF DROB DRMT DRGP DRFG DRMB DRRH DRML DRWG DRGX DRAP DRGR	Percentage of yellow poplar browse in deer diet.	Decimal Fraction
HPDRPB . . . HPDRGR	Highest percentage of yellow poplar browse in deer diet.	Decimal Fraction
RCMT RCPM RCAN RCRT RCJB RCGP	Percentage of mast in raccoon diet.	Decimal Fraction
HPRCMT . . . HPRCGP	Highest percentage of mast in raccoon diet.	Decimal Fraction

TABLE D-1 (continued)

Variable Name	Description	Dimension
CRFG CRMT CRBY	Percentage of fungi in canonical rodent diet.	Decimal Fraction
HPCRFG . . . HPCRBY	Highest percentage of fungi in canonical rodent diet.	Decimal Fraction
SCMT SCFG SCMS SCMA SCAP	Percentage of mast in sciurid diet.	Decimal Fraction
HPSCMT . . . HPSCAP	Highest percentage of mast in squirrel diet.	Decimal Fraction
WTN WHN BRN SCN DRN DRN RCN	Number of wild turkeys present at current simulation time.	consumer/hectare
WTFC WHFC BRF SCFC DRFC CRFC RCFC	Amount of food consumed by one turkey in an average month.	kilograms/month

TABLE D-1 (continued)

Variable Name	Description	Dimension
WTFCM WHFCM BRFCM SCFCM DRFCM CRFCM RCRCM	Amount of food consumed by all turkeys in a month plus 50% added on for wastage.	kilograms/ month
EDWT EDWH EDBR EDSC EDDR EDCR EDRC	Percentage of plants edible by wild turkey.	Decimal Fraction
WTTOT DRTOT RCTOT WHTOT CRTOT BRTOT SCTOT	Total percentage of wild turkey diet represented by considered food species.	Decimal Fraction
PCID	Percentage of diet of current herbivore comprised by food species.	Decimal Fraction
TPIC	Dummy variable allowing use of PCID in subroutine.	
SCPCID	Percentage of diet of canonical sciurid comprised by food species.	
BRPCID WHPCID RCPCID CRPCID DRPCID WTPCID		

TABLE D-1 (continued)

Variable Name	Description	Dimension
PDATA	Production values for foods.	kilograms
AVAIL	Amount of food available to current consumer.	kilograms/hectare
AVA	Output variable for AVAIL.	
THRES	Threshold values for foods in diet.	Decimal Fraction
PR	Print control variable.	Dimensionless
RP	Print control variable.	Dimensionless
DDT	Month within the year.	$1 \leq DDT \leq 12$
SAVM	Saves original percent in diet for statistics.	Decimal Fraction
ND	Number of decreases in diet greater than three percent.	Dimensionless
NPD	Number of increases in diet greater than three percent.	Dimensionless
DNEG	Summed decreases in diet greater than three percent.	Decimal Fraction
DPOS	Summed increases in diet greater than three percent.	Decimal Fraction
WASTE	Amount of biomass wasted.	kilograms/hectare
SWASTE	Amount of biomass wasted by sciurids.	kilograms/hectare
TF	Temporary biomass flows.	kilograms/hectare
FFF	Output variable for TF.	kilograms/hectare
MAX	Maximum biomass values and density values.	Varied depending on which foods and consumers were being considered.
MIN	Minimum biomass values and density values.	
S	Standard deviation of distribution in which biomass values and density values were found.	
AM	Average biomass values and density values found.	
RN	Random numbers generated.	

TABLE D-1 (continued)

Variable Name	Description	Dimension
T	counter.	Dimensionless
JK	counters.	
JZ	counters.	
TK	counters	
IX	seed for random number generator.	
F1-F8	Flows of biomass to consumers.	kilograms/ hectare/ month
TIME	SIMCOMP variable which is current value of time.	~15 days
X	SIMCOMP variable which updated state variable levels.	kilograms/ hectare
ZX	Analogous to X. Used to save values of X.	kilograms/ hectare
DTPL	SIMCOMP variable which is time step for graphical output.	Dimensionless
DTPR	SIMCOMP variable which is time step for tabular output of state variables.	Dimensionless
DTFL	SIMCOMP variable which is time step for tabular output of flows.	Dimensionless
TSTART	SIMCOMP variable which is start of simulated time.	month
TEND	SIMCOMP variable which is end of simulated time.	month
DT	SIMCOMP variable which is time step of simulation.	15 days
F	SIMCOMP variable containing value of each flow.	kilograms/ hectare

VITA

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