Table 6.1 : Calculation of the White Rhino Carrying Capacity using the Modified Rainfall/Metabolic Mass Relationship. (T_h = Topographical Factor, P_h = Preference Factor and D_h = Diatary Importance Factor)

Estimated total area of reserve = 51500 ha.
Estimated area suitable for white rhino = 28000 ha.
Estimated carrying capacity = 1AU to 15 ha.
Rainfall = 620mm.

	Secondary grassland	Pediment grassland	Valley savanna	Hillside savanna	Thicket	Summit savanna
Area (ha)	3120	1630	7320	23366	7535	8500
Carrying capacity (ECC)	208	109	488	1558	502	567
T_h	1.0	1.0	1.0	0.1	1.0	0.5
P_h	0.9	0.7	0.8	0.1	1.0	0.4
D_h	0.7	0.6	0.7	0.9	0.9	0.7
Estimated carrying capacity (MCC_h)	153	50	307	16	530	100

Total permissible carrying capacity = 1156 AU's.
Carrying capacity of white rhino = 1156 - 720 = 436 AU's.

type was high, i.e. if the habitats supported a high proportion of palatable grass species and 0 is dominated by unpalatable species.

The carrying capacity estimate (1156 AU's) calculated using equation 6.6 was then substituted as "T" in equation 6.5. The new carrying capacity for white rhino was now estimated as 436 AU's or 175 animals. This is almost half of what was calculated using the previous method which estimated a white rhino grazing carrying capacity of 1011 grazing animal units. It is therefore recommended that a white rhino carrying capacity of 436 AU's be stocked in the reserve under the present grazing conditions. This estimate can be modified if either the relative herbivore densities are altered, or if the overall condition of the reserve increases.

The marked differences between these methods suggests the importance of taken strict caution when recommending carrying capacity stocking densities for multispecies systems.

The next section deals with another important aspect which was mentioned by Collinson and Goodman (1981), that of ability for herbivores to "overgraze" selected sites. For example, species which specialize in foraging in single patches or habitats throughout the entire year will exert a greater impact than species which show seasonal habitat differences.

6.4 The "Weighted Consumption" Model

6.4.1 Introduction and Aims

Studies involving complex ecosystems involve the analysis of a large number of ecological factors and their respective interactions. Ecological models are constructed for two different purposes (Maynard Smith, 1974), one practical and the other theoretical. Models with a practical purpose are called "simulations" and are used for predicting th haviours of various factors in the hope that they conform to the real world. The second type of models are constructed as a means of generating hypotheses. These models, commonly known as "sensitivity models" are less detailed and are constructed based only on the major ecological principles (Maynard Smith, 1974). The finer details of the system are omitted. These models are useful in defining goals and priorities of research (Jones, 1976).

The number of animals which can be stocked in a reserve is a function of both the resource availabilty and the herbivores' feeding requirements. The previous section outlined the importance of four main aspects in influencing its assessment. These were the primary production, which is a function of rainfall, topography, habitat type, and forage type. A fifth aspect, which was mentioned by Collinson and Goodman (1981) is the tendency of grazers to remain foraging on a particular habitat which I will refer to as the "minimum grazing threshold". The herbivores are assumed to forage in a habitat until a critically low plant biomass is reached. This level will vary for different species depending on their feeding habits. It could also be referred to as a measure of the herbivores' tendency to disperse between habitats in a patchy environment. For example, impala have been observed feeding in heavily utilized areas practically devoid of grass cover. The minimum grazing threshold for this species would therefore be very low. The white rhino, because of its large body size and preference for short grasslands (see chapter 4), may be typical of species having low threshold levels. Zebra, on the other hand, tend to select for the taller grasslands with higher plant biomasses (chapter 4). These species are characteristic of grazers with fairly high threshold levels.

The importance of these species characteristic threshold levels becomes apparent when relating them to the habitat's acceptable level of condition, i.e. the level beyond which plant growth ceases. If a species minimum threshold level is below that of the habitat's acceptable condition, then it is likely that the habitat will be grazed beyond a level at which recovery can occur.

The aim of the model was to investigate the possible consequences of varying the minimum grazing thresholds on the habitat's conditions. The model was programmed using the Apple version of UCSD Pascal.

6.4.2 Structure of the Model

6.4.2.1 Overview

The model has been based largely on the field data collected during the study (refer to chapters 3 and 4). It simulates the amount of plant biomass available at the end of each season in response to different animal densities and minimum grazing levels. The model was constructed using a simple "supply and demand" approach, the supply being the availability of plant forage, and the demand being the herbivores' requirements.

The supply or availability of the plant biomass was calculated for the different forage types (i.e. palatable, intermediate and unpalatable) within each of the five habitats (i.e. secondary grasslands, pediment grasslands, valley savannas, hillside savannas and thickets). The initial standing crops in each habitat, except the hillside savannas which were estimated, were based on the biomasses calculated using the Board method discussed in chapter 3. The primary production during each season was estimated using the regression equation calibrated by Rutherford (1980).

Primary Production = -113.0 + 5.48 Rainfall..........6.7

The rainfall data was generated either randomly or using actual figures measured in the reserve. Only actual rainfall data are used in the iterations.

The requirements of each herbivore species (e.g. white rhino, hartebeest, wildebeest, zebra and impala) was calculated as follows. First, the initial biomasses were read in. Then the consumption rates are calculated using the metabolic mass and daily intake relationship similar to that used by Sinclair (1977). The amount of plant biomass consumed from each dietary type in a habitat was calculated based firstly on the herbivores' habitat and dietary selection coefficients, (determined in chapter 4), and secondly on the white rhinos' minimum grazing thresholds.

The "condition indices" for each habitat were calculated by weighting each habitat and forage type by its importance to the white rhino. For instance the plant biomasses in the thickets will be weighted higher than the biomass in the hillside savannas. Similarly, the biomass of the palatable species are weighted higher than the unpalatable species. These weightings range from 0 to 1, 0 indicating poor condition and 1 indicating good condition. Table 6.2 summarizes these weighting factors. Although these condition indices are largely subjective, they do provide a means of gauging the impact of the herbivores under different conditions.

6.4.2.2 The Main Assumptions and Conditions

(i) The growth or production of the vegetation is driven by the rainfall alone.

(ii) The amount of grass biomass in a particular habitat cannot increase beyond a set maximum.

(iii) Competition between the grasses and between the grasses and trees does not inhibit grass production.

(iv) Previous grazing does not affect grass production.

(v) Only the five major herbivores can consume grass material.

(vi) Interspecific interactions between the herbivores occurs indirectly through the utilization of similar resources.

(vii) Movement between habitats is determined by the herbivores' distribution coefficients and their minimum feeding threshold levels.

(viii) The densities of the four associated grazers are fixed.

Table 6.2 : Weighting Coefficients (WC) used to estimate "habital condition". The Preference Indices (PI) for the forage type and habitat are calculated using equations similar to 4.5 and 4.6, respectively.

	Secondary grassland		Pediment grassland		Valley savanna		Hillside savanna		Thicket	
FORAGE TYPE	PI	WC	PI	WC	PI	WC	PI	WC	PI	WC
	1.5	0.6	1.5	0.6	2.0	0.8	0.0	0.0	2.5	1.0
Palatable	1.9	0.6	3.2	1.0	2.1	0.7	1.2	0.4	1.4	0.4
Intermediate	0.3	0.4	0.7	0.8	0.8	1.0	0.8	1.0	0.7	0.9
Unpalatable	4.0	1.0	0.3	0.1	0.3	0.1	0.0	0.0	0.0	0.0

$$\text{Habitat Weighting Coefficient} = \frac{\text{Preference Index for Habitat h}}{\text{Maximum Preference Index}}$$

$$\text{Dietary Weighting Coefficient}_h = \frac{\text{Preference Index for forage type i}}{\text{Maximum Preference Index for i}}$$

(ix) The annual cycle is divided up into four seasons, similar to those defined in chapter 4.

6.4.2.3 The Model

The model can be broken up into three major parts (see Figure 6.3). The first part calculates the plant biomass available to the herbivores at the beginning of each season. The second part calculates the total consumption of each forage type in each habitat. The third section then calculates the amount of biomass left over at the end of each season. Appendix M gives a listing of the program.

The amount of plant biomass available at the beginning of the season is calculated using the initial biomasses, read in (procedure READDATA) at the beginning of the program, and the production (procedure PRODUCTION) estimated from the Rainfall/primary production relationship. These values are then added together (procedure VEGETATION).

The amount consumed is then calculated for each forage type using the dietary preference indices determined for each species (procedure ANIMCONS). The total amount of plant biomass consumed by the herbivores is then subtracted from the amount available at the beginning of the season (procedure VEGCONS). These procedures calculate the total amount of plant biomass left at the end of the season.

The next part of the program concerns the comparison of these values with the minimum grazing threshold levels. If the amount of plant biomass left at the end of the season is less than the "minimum grazing threshold", then the program is re-run, but now using the modified distribution coefficients calculated in procedures MODMINDIST and MODDIST. These distribution coefficients are modified as follows. The animal biomass, in the habitat which has been grazed below the minimum threshold, is calculated so that only the minimum biomass is left at the end of

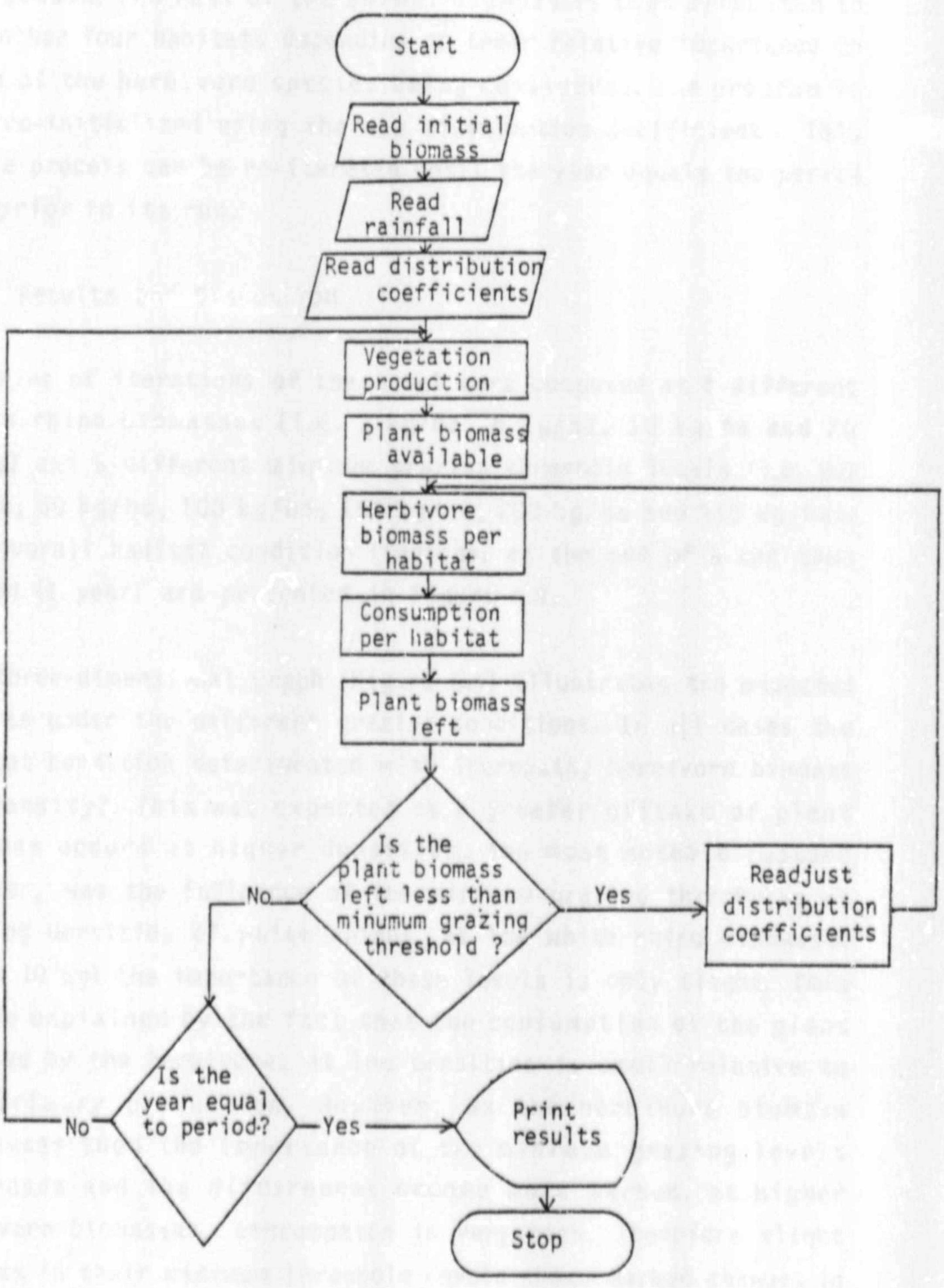


Figure 6.3 : Flow diagram illustrating the sequence of calculations for each seasonal interation of the model.

the season. The rest of the animal biomass is then allocated to the other four habitats depending on their relative importance to each of the herbivore species being considered. The program is now re-initialized using the new distribution coefficients. This whole process can be re-iterated until the year equals the period set prior to its run.

6.4.3 Results and Discussion

A series of iterations of the model were computed at 4 different white rhino biomasses (i.e. 2 kg/ha, 5 kg/ha, 10 kg/ha and 20 kg/ha) and 6 different minimum grazing threshold levels (i.e. 0.0 kg/ha, 50 kg/ha, 100 kg/ha, 150 kg/ha, 200 kg/ha and 250 kg/ha). The overall habitat condition (indices) at the end of a set time period (1 year) are presented in Figure 6.4.

The three-dimensional graph (Figure 6.4) illustrates the expected results under the different grazing conditions. In all cases the habitat condition deteriorated with increasing herbivore biomass (or density). This was expected as a greater offtake of plant biomass occurs at higher densities. The most notable feature however, was the influence of the minimum grazing thresholds at varying densities of white rhinos. At low white rhino biomasses (0.1×10^6kg) the importance of these levels is only slight. This can be explained by the fact that the consumption of the plant biomass by the herbivores at low densities is small relative to the primary production. However, as the herbivore biomass increases then the importance of the minimum grazing levels increases and the differences become more marked. At higher herbivore biomasses, consumption is very high. Therefore slight changes in their minimum threshold levels shows marked changes in the habitat's condition.

The main implications arising from these results become important when estimating carrying capacity densities of herbivores, which tend to select sites of low plant biomass. For example, species such as impala and white rhino will tend to show marked differences in their effects on the habitats as biomasses are

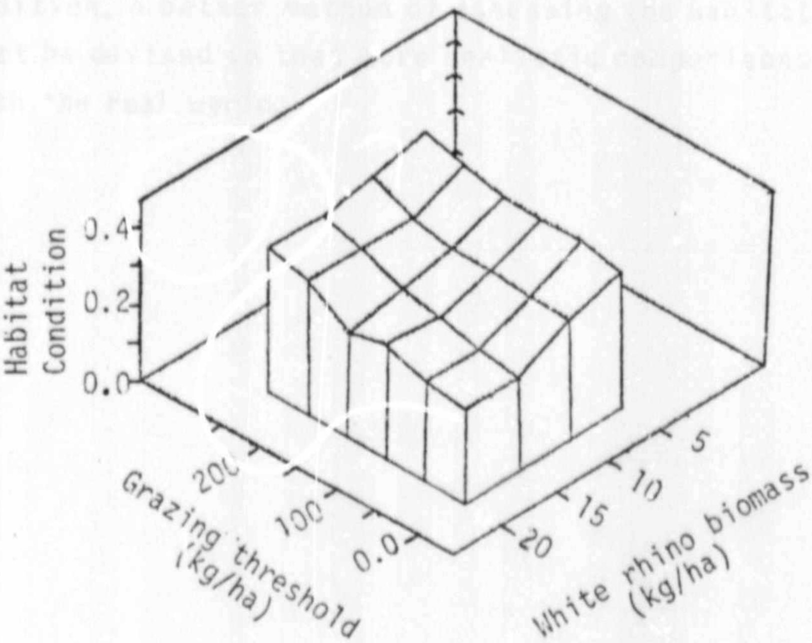


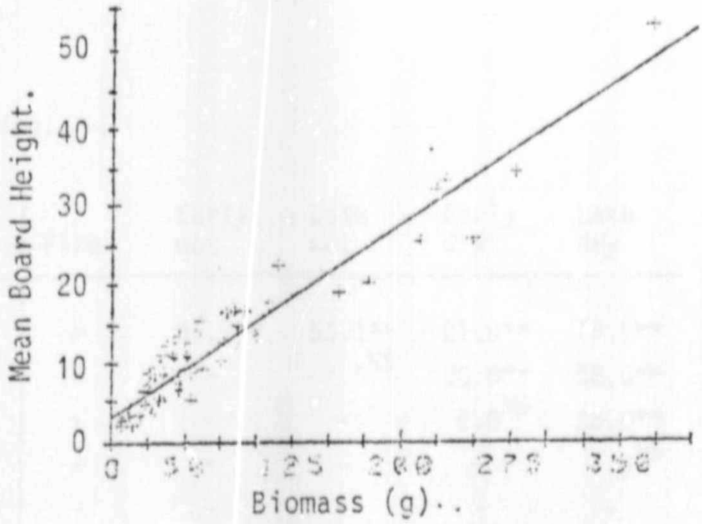
Figure 6.4 : A 3-dimensional graph depicting the relationships between white rhino biomass, the minimum grazing threshold and habitat condition.

altered. Hence, these species will play a major role in influencing the habitats carrying capacity.

The model was simple in its approach so as to highlight the important aspects requiring further research. The next step therefore should be to create a more sophisticated model which would reflect the plant-herbivore systems more accurately. In addition, a better method of assessing the habitat's condition must be devised so that more realistic comparisons can be made with the real world.

Linear Calibration Curves Fitted to the Dry Weight of Grass and Board for the Two Major Seasons.

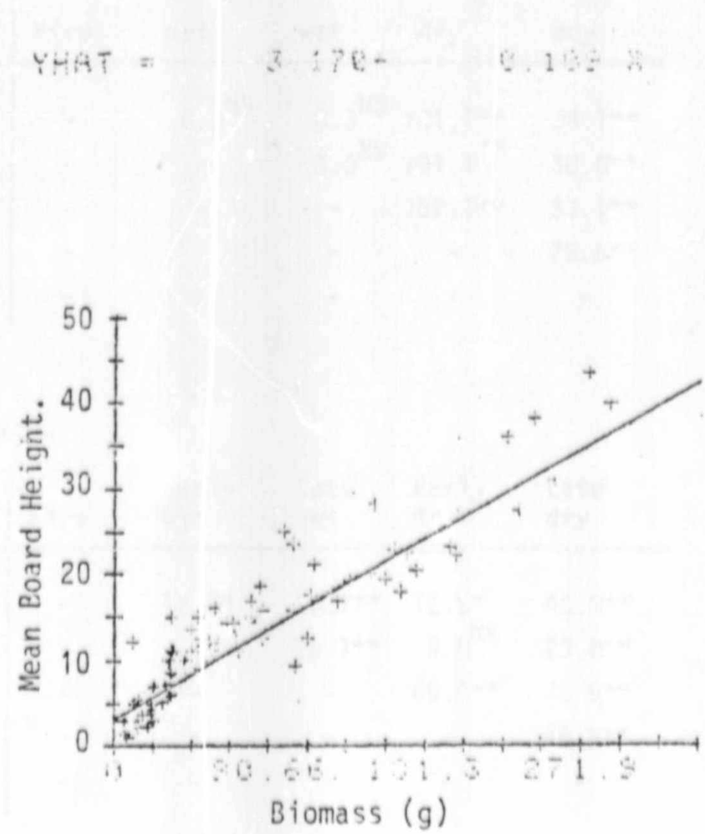
(a) Wet Season.




```
      LINEAR REG:CODE 1
SOURCE/DF      SS       MS       F
TOTAL 85    4720.8
REG    1    4305.8   4305.8 871.5
RESID 84     415.0      4.9
R SQUARE =          0.912

YHAT =      3.170+       0.102 X
```

(b) Dry Season.




```
   AOV: LINEAR REG:CODE 1
SOURCE/DF      SS       MS       F
TOTAL115    6416.6
REG    1    5322.2   5322.2 554.4
RESID114    1094.4      9.6
R SQUARE =         0.829

YHAT =      2.605 +       0.092 X
```

APPENDIX B

Results of Chi-square tests comparing seasonal differences in the habitat selection of all grazers. (* = Significant at the 5% level, ** = Significant at the 1% level and NS = No significance).

(i) [illegible]

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	56.1**	55.1**	21.5**	[illegible]5.0**
Early wet	-	-	7.5^{NS}	20.8**	58.0**
Late wet	-	-	-	5.8^{NS}	28.0**
Early dry	-	-	-	-	7.0^{NS}
Late dry	-	-	-	-	-

(ii) Hartebeest.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	0.0^{NS}	8.3^{NS}	101.1**	38.1**
Early wet	-	-	0.0^{NS}	101.1**	30.0**
Late wet	-	-	-	387.1**	33.1**
Early dry	-	-	-	-	75.6**
Late dry	-	-	-	-	-

(iii) Wildebeest.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	12.0*	26.7**	12.5*	40.9**
Early wet		-	26.7**	5.0^{NS}	23.8**
Late wet	-	-	-	45.0**	75.9**
Early dry	-	-	-	-	45.9**
Late dry	-	-	-	-	-

APPENDIX B (cont.)

(iv) Zebra.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	40.8**	52.4**	66.0**	3524.8**
Early wet	-	-	0.0^{NS}	40.6**	25.5**
Late wet	-	-	-	64.8**	55.4**
Early dry	-	-	-	-	202.7**
Late dry	-	-	-	-	-

(v) Impala.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	0.0^{NS}	25.6**	44.8**	99.0**
Early wet	-	-	21.3**	36.8**	22.3**
Late wet	-	-	-	89.1**	57.8**
Early dry	-	-	-	-	31.4**
Late dry	-	-	-	-	-

APPENDIX C.

Results of Chi-square tests comparing seasonal differences in habitat selection between the white rhino and other grazers. (* = Significant at the 5% level, ** = Significant at the 1% level and NS = No significance).

(i) Fire.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	45.0**	18.3**	11.4**	25.3**
Hartebeest	-	-	5.8^{NS}	122.8**	121.3**
Wildebeest	-	-	-	62.9**	65.3**
Zebra	-	-	-	-	21.3**
Impala	-	-	-	-	-

(ii) Early wet.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	23.5**	42.3**	35.8**	197.3**
Hartebeest	-	-	21.3**	5.8^{NS}	121.3**
Wildebeest	-	-	-	7.5^{NS}	53.3**
Zebra	-	-	-	-	65.3**
Impala	-	-	-	-	-

(iii) Late wet.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	83.9**	87.6**	101.8**	189.0**
Hartebeest	-	-	13.3**	12.5*	68.0**
Wildebeest	-	-	-	47.5**	48.0**
Zebra	-	-	-	-	85.3**
Impala	-	-	-	-	-

(iv) Early dry.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	396.4**	28.5**	80.8**	166.4**
Hartebeest	-	-	94.1**	183.1**	289.0**
Wildebeest	-	-	-	104.8**	214.4**
Zebra	-	-	-	-	143.0**
Impala	-	-	-	-	-

(v) Late dry.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	53.9**	13.8**	204.0**	39.8**
Hartebeest	-	-	117.9**	1577.7**	43.3**
Wildebeest	-	-	-	267.7**	71.7**
Zebra	-	-	-	-	284.7**
Impala	-	-	-	-	-

APPENDIX D.

Results for Student's t-test comparing seasonal differences in the forage type selection by white rhino. (* = Significant at the 5% level, ** = Significant at the 1% level and NS = No significance).

(i) Palatable species.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	1.6^{NS}			
Early wet	-	-	1.2^{NS}		
Late wet	-	-	-	1.8*	
Early dry	-	-	-	-	1.0^{NS}
Late dry	-	-	-	-	-

(ii) Intermediate species.

	Fire	Early wet	Late wet	Early dry	Late dry
Fire	-	1.8*			
Early wet	-	-	0.4^{NS}		
Late wet	-	-	-	1.4*	
Early dry	-	-	-	-	1.0^{NS}
Late dry	-	-	-	-	-

Results for Student's t-tests comparing differences in forage type selection between the white rhino and other grazers during the dry season. (** = Significant at the 1% level, * = Significant at the 5% level and NS = No significance).

(i) Palatable species.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	2.8**	1.8*	0.7^{NS}	0.1^{NS}

(ii) Intermediate species.

	White rhino	Hartebeest	Wildebeest	Zebra	Impala
White rhino	-	2.9**	1.9*	0.5^{NS}	0.2^{NS}

APPENDIX F

Key to the grass species utilized by the Pilanesberg grazers

Mnemonic	Species
CYDA	Cynodon dactylon
RHRE	Rhynchyletrum repens
HECO	Heteropogon contortus
THTR	Themeda triandra
ERCU	Eragrostis curvula
ERSU	E. superba
ERRI	E. rigidior
ERGU	E. gummiflua
HYHI	Hyparrhenia hirta
BOIN	Bothriochloa insculpta
BRSE	Brachiaria serrata
URMO	Urochloa mosambicensis
LOFL	Loudetia flavida
DIER	Digitaria eriantha
PADE	Panicum deustum
PACO	P. coloratum
SPPY	Sporobolus pyrimedalis
UNPA	Unpalatable species, eg. Elyonuris argenteus, and Cymbopogon species

APPENDIX C

SEASON	HABITAT	CYDA PC	CYDA PI	RHRE PC	RHRE PI	HECO PC	HECO PI	THTR PC	THTR PI	ERCU PC	ERCU PI	ERSU PC	ERSU PI	ERRI PC	ERRI PI	ERGU PC	ERGU PI	HYHI PC	HYHI PI	BOIN PC	BOIN PI
Fire	VALSAV	43.1	7.0	0.0	0.0	[illegible]	1.4	1.9	0.4	1.9	0.8	10.4	4.3	5.6	2.7	0.0	0.0	6.3	1.3	0.0	0.0
	SECGLD	0.5	0.1	2.6	0.3	20.9	1.4	0.6	0.2	6.7	8.6	14.5	1.5	1.1	[illegible]	[illegible]	8.6	31.8	4.0	0.0	0.0
Early wet	VALSAV	0.0	0.0	0.0	0.0	24.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]	0.0	36.5	7.4	0.0	0.0
	SECGLD	0.4	0.1	6.6	0.7	10.6	0.7	0.9	0.2	5.0	1.2	23.5	2.5	[illegible]	[illegible]	[illegible]	0.0	14.9	1.9	0.0	0.0
Late wet	VALSAV	5.4	0.9	0.4	0.1	34.7	2.2	2.7	0.6	5.4	6.4	6.9	2.9	5.4	[illegible]	[illegible]	0.0	5.4	1.1	0.0	0.0
	CYPAT	6.8	9.7	1.0	0.4	4.7	0.5	1.2	2.0	6.4	0.9	2.6	0.3	6.2	[illegible]	[illegible]	0.0	0.5	0.3	2.7	1.4
Early dry	VALSAV	1.1	0.2	1.7	0.5	34.3	2.2	14.3	2.9	1.5	0.6	0.7	0.3	4.0	1.9	0.0	0.0	7.1	1.4	1.8	2.3
	SECGLD	0.7	0.1	6.4	0.7	31.5	2.1	2.7	0.7	0.0	0.0	1.4	0.1	2.0	0.3	0.0	0.0	0.7	0.1	0.0	0.0
	CYPAT	0.0	0.0	9.0	3.2	32.6	3.7	1.4	2.3	4.8	0.7	10.7	1.3	6.7	0.7	0.0	0.0	3.7	2.5	0.0	0.0
	THICKET	2.9	0.2	7.0	35.0	4.9	0.9	0.0	0.0	10.4	2.4	0.0	0.0	5.2	2.7	0.0	0.0	0.0	0.0	0.0	0.0
Late dry	VALSAV	0.8	0.1	0.0	0.0	27.4	1.7	4.6	0.9	6.3	2.6	0.0	0.0	1.3	0.6	1.3	3.3	15.7	3.2	0.0	0.0
	SECGLD	3.2	0.3	18.3	1.9	12.5	0.8	0.9	0.0	0.0	0.0	30.8	3.3	9.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0

Appendix : Percentage Contribution in the diet (PC) and Preference Indices (PI) for grasses eaten by white rhinos, by habitat and season. A key to the grass species is given in Table 4.1

(PAL, INT and UNP [illegible] the proportions of palatable, intermediate and unpalatable grass species, respectively).

SECGLD = Secondary grasslands.
VALSAV = Valley savannas
THICKET = Acacia and riverine thickets
CYPAT = Cynodon dactylon "lawns"

n = Number of transects.

SEASON	HABITAT	BRSE PC	BRSE PI	URMO PC	URMO PI	LOFL PC	LOFL PI	DIER PC	DIER PI	PADE PC	PADE PI	PACO PC	PACO PI	SPPY PC	SPPY PI	UNPA PC	UNPA PI	PAL	INT	UNP	n
Fire	VALSAV	0.0	0.0	0.0	0.0	0.0	0.0	2.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.2	33.9	59.4	6.7	6
	SECGLD	0.5	0.5	2.6	0.6	0.0	0.0	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	11.4	2.1	39.1	48.5	11.7	9
Early wet	VALSAV	0.0	0.0	0.0	0.0	0.0	0.0	4.2	2.6	0.0	0.0	0.0	0.0	4.2	10.5	30.7	0.9	24.5	44.8	30.7	4
	SECGLD	7.4	6.7	12.0	2.3	0.0	0.0	0.0	0.0	1.7	8.5	0.0	0.0	8.2	2.4	6.6	1.2	56.1	37.3	6.6	9
Late wet	VALSAV	0.0	0.0	15.1	8.9	0.0	0.0	0.4	0.3	3.1	3.4	0.0	0.0	5.0	12.4	0.0	0.0	62.0	38.0	0.0	6
	CYPAT	1.0	5.0	36.5	2.1	0.0	0.0	6.8	9.7	18.3	18.3	4.7	1.6	0.4	0.4	5.4	2.3	69.0	25.6	5.4	10
Early dry	VALSAV	7.5	8.3	2.9	1.7	0.0	0.0	8.7	5.4	8.1	9.0	4.8	1.9	0.0	0.0	1.4	0.1	72.6	26.0	1.4	9
	SECGLD	25.8	23.5	10.2	2.1	0.0	0.0	11.5	4.6	10.8	10.8	0.0	0.0	0.0	0.0	2.0	0.4	82.4	15.6	2.0	4
	CYPAT	0.0	0.0	8.4	0.5	0.0	0.0	0.0	0.0	20.2	20.2	2.5	0.9	0.0	0.0	0.0	0.0	75.5	24.5	0.0	4
	THICKET	0.0	0.0	4.4	0.4	0.0	0.0	0.5	0.1	44.9	6.2	17.1	2.0	0.0	0.0	0.0	0.0	71.3	28.7	0.0	5
Late dry	VALSAV	0.0	0.0	2.0	1.2	0.0	0.0	9.1	5.7	16.0	16.0	14.5	5.8	0.0	0.0	1.0	0.1	64.5	24.5	1.0	5
	SECGLD	0.0	0.0	5.8	1.2	0.0	0.0	2.7	1.1	6.3	6.3	3.2	3.2	0.0	0.0	0.0	0.0	58.6	41.4	0.0	4

Appendix : (continued)

SEASON	HABITAT	CYDA		RHRE		HECO		THTR		ERCU		ERSU		ERRI		ERGU		HYHI		BOIN	
		PC	PI	PC	PI	PC	PI	PC	PI	PC	PI	PC	PI	PC	PI	PC	PI	PC	PI	PC	PI
Fire	VALSAV	43.1	7.0	0.0	0.0	21.6	1.4	1.9	0.4	1.9	0.8	10.4	4.3	5.6	2.7	0.0	0.0	6.3	1.3	0.0	0.0
	SECGLD	0.5	0.1	2.6	0.3	20.9	1.4	0.6	0.2	6.7	8.6	14.5	1.5	1.1	0.2	6.0	8.6	31.8	4.0	0.0	0.0
Early wet	VALSAV	0.0	0.0	0.0	0.0	24.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.5	7.4	0.0	0.0
	SECGLD	0.4	0.1	6.6	0.7	10.6	0.7	0.9	0.2	5.0	1.2	23.5	2.5	2.0	0.3	0.0	0.0	14.9	1.9	0.0	0.0
Late wet	VALSAV	5.4	0.9	0.4	0.1	34.7	2.2	2.7	0.6	5.4	6.4	6.9	2.9	5.4	2.6	0.0	0.0	5.4	1.1	0.0	0.0
	CYPAT	6.8	9.7	1.0	0.4	4.7	0.5	1.2	2.0	6.4	0.9	2.6	0.3	6.2	0.7	0.0	0.0	0.5	0.3	2.7	1.4
Early dry	VALSAV	1.1	0.2	1.7	0.5	34.3	2.2	14.3	2.9	1.5	0.6	0.7	0.3	4.0	1.9	0.0	0.0	7.1	1.4	1.8	2.3
	SECGLD	0.7	0.1	6.4	0.7	31.5	2.1	2.7	0.7	0.0	0.0	1.4	0.1	2.0	0.3	0.0	0.0	0.7	0.1	0.0	0.0
	CYPAT	0.0	0.0	9.0	3.2	32.6	3.7	1.4	2.3	4.8	0.7	10.7	1.3	6.7	0.7	0.0	0.0	3.7	2.5	0.0	0.0
	THICKET	2.9	0.2	7.0	35.0	4.9	0.9	0.0	0.0	10.4	2.4	0.0	0.0	5.2	2.7	0.0	0.0	0.0	0.0	0.0	0.0
Late dry	VALSAV	0.8	0.1	0.0	0.0	27.4	1.7	4.6	0.9	6.3	2.6	0.0	0.0	1.3	0.6	1.3	3.3	15.7	3.2	0.0	0.0
	SECGLD	3.2	0.3	18.3	1.9	12.5	0.8	0.0	0.0	0.0	0.0	30.8	3.3	9.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0

Appendix : Percentage Contribution in the diet (PC) and Preference Indices (PI) for grasses eaten by white rhinos, by habitat and season. A key to the grass species is given in Table 4.1

(PAL, INT and UNP are the proportions of palatable, intermediate and unpalatable grass species, respectively).

SECGLD = Secondary grasslands.
VALSAV = Valley savannas
THICKET = *Acacia* and riverine thickets
CYPAT = *Cynodon dactylon* "lawns"

n = Number of transects.

APPENDIX H

Seasonal changes in the Percentage Contribution in the diet, of the grass species for the other larger grazers. A key to the grass species is given in Appendix F.

Species	Hartebeest		Wildebeest		Zebra		Impala	
	Early PC PI	Late PC PI	Early PC PI	Late PC PI	Early PC PI	Late PC PI	Early PC PI	Late PC PI
CYDA	0.1(1.0)	1.0(0.3)	1.0(3.5)	3.4(0.8)	0.0(0.0)	0.0(0.0)	5.0(8.3)	11.5(4.1)
RHRE	31.1(24.2)	15.7(6.7)	14.6(17.0)	18.1(4.2)	0.6(0.9)	0.6(0.9)	0.0(0.0)	0.0(0.0)
HECO	13.1(13.7)	12.5(3.8)	30.6(25.9)	6.4(6.4)	29.1(28.3)	56.0(8.9)	0.5(5.1)	6.3(2.5)
THTR	8.4(17.0)	9.0(4.7)	0.0(0.0)	10.2(1.0)	2.3(2.2)	9.6(3.8)	11.1(14.2)	17.2(7.1)
ERCU	1.0(3.1)	2.7(0.8)	8.1(4.8)	4.7(1.2)	0.0(0.0)	0.0(0.0)	7.5(4.5)	10.9(2.2)
ERSU	5.5(8.7)	4.5(2.4)	9.4(10.1)	4.3(2.5)	32.0(19.1)	0.0(0.0)	0.0(0.0)	4.7(1.9)
ERRI	3.7(5.3)	1.4(1.4)	4.8(4.5)	3.8(1.1)	0.0(0.0)	0.0(0.0)	2.5(1.6)	2.8(0.8)
ERGU	3.4(9.8)	9.6(2.7)	0.2(10.7)	1.0(2.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
HYHI	8.3(11.3)	10.4(3.1)	0.7(9.3)	11.5(2.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	3.6(1.5)
BOIN	0.0(0.0)	0.0(0.0)	2.2(8.7)	0.4(2.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
BRSE	15.5(15.9)	1.6(5.5)	7.6(4.2)	7.2(1.0)	5.2(3.2)	13.0(5.0)	0.0(0.0)	0.0(0.0)
URMO	2.5(5.6)	4.5(1.5)	4.7(4.5)	9.4(1.1)	0.0(0.0)	0.0(0.0)	1.5(1.2)	1.0(0.6)
LOFL	0.0(0.0)	1.6(2.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	10.6(5.4)	0.0(0.0)	0.0(0.0)
DIER	2.8(11.1)	16.0(3.0)	7.0(9.0)	5.1(2.2)	13.4(7.5)	0.8(2.3)	0.0(0.0)	11.5(4.7)
PADE	0.0(0.0)	0.0(0.0)	3.0(4.7)	5.5(1.1)	0.0(0.0)	0.0(0.0)	74.9(80.7)	26.6(15.3)
PACO	1.0(7.2)	1.0(8.5)	5.7(2.5)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
SPPY	0.0(0.0)	1.6(0.5)	2.0(4.0)	3.3(1.0)	0.0(0.0)	8.8(2.8)	8.0(6.6)	4.2(3.3)
UNPA	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)

APPENDIX I

Summary of the 37 variables and their mnemonics used in the multivariate analysis.

No.	Mnemonic.	Variable.
1	COVER	Percentage aerial cover of herbaceous layer.
2	HEIGHT	Average height of herbaceous layer.
3	CYDA	% cover Cynodon dactylon.
4	ARCO	% cover Aristida congesta.
5	RHRE	% cover Rhychelytrum repens.
6	HECO	% cover Heteropogon contortus.
7	THTR	% cover Themeda triandra.
8	ERCU	% cover Eragrostis curvula.
9	ERSU	% cover E. superba.
10	ERRI	% cover E. rigidior.
11	ERRA	% cover E. racemosa.
12	ERPL	% cover E. plana.
13	ERGU	% cover E. gummiflua.
14	ELAR	% cover Elionuris argenteus.
15	CYEX	% cover Cymbopogon excavatus.
16	HYHI	% cover Hyparrhenia hirta.
17	TRGR	% cover Trichoneura grandeglumis.
18	BOIN	% cover Bothriochloa insculpta.
19	TRRE	% cover Tristachya rehmanii.
20	SEFL	% cover Setaria flabellata.
21	BRSE	% cover Brachiaria serrata.
22	BRNI	% cover B. nigropedata.
23	URMO	% cover Urochloa mosambicensis
24	LOFL	% cover Loudetia flavida.
25	DIER	% cover Digitaria eriantha.
26	DIAM	% cover Diheteropogon amplectans.
27	TRBE	% cover Tragus berteronianus.
28	PADE	% cover Panicum deustum
29	PACO	% cover P. coloratum.
30	POSQ	% cover Pogonarthria squarrosa.
31	SPPY	% cover Sporobolus pyramidalis.
32	CHVI	% cover Chloris virgata.
33	SENI	% cover Setaria nigrirostris
34	SPAF	% cover Sporobolus africanus
35	PEPA	% cover Perotus patens.
36	ERCR	% cover Eragrostis species
37	DISM	% cover Digitaria smutsii.

APPENDIX J

The univariate F ratios with percentage levels of probability for each of the 37 variables.

Variable	Wilks' Lambda	Univariate F ratio	Probability
COVER	0.91975	2.290	0.0645
HEIGHT	0.90303	2.819	0.0288
CYDA	0.89417	3.107	0.0185
ARCO	0.88196	3.513	0.0098
RHRE	0.79250	6.873	0.0001
HECO	0.82701	5.491	0.0005
THTR	0.94545	1.515	0.2032
ERCU	0.95965	1.104	0.3588
ERSU	0.96833	0.858	0.4915
ERRI	0.97159	0.767	0.5486
ERRA	0.99234	0.202	0.9364
ERPL	0.99634	0.096	0.9834
ERGU	0.87882	3.620	0.0083
ELAR	0.98265	0.463	0.7624
CYEX	0.96889	0.842	0.5011
HYHI	0.95076	1.359	0.2531
TRGR	0.95076	1.502	0.2069
BOIN	0.97824	0.583	0.6750
TRRE	0.81731	5.868	0.0003
SEFL	0.96116	1.061	0.3798
BRSE	0.87246	3.837	0.0060
BRNI	0.94796	1.441	0.2257
URMO	0.93515	1.790	0.1362
LOFL	0.94598	1.470	0.2167
DIER	0.97991	0.538	0.7081
TIAM	0.98958	0.276	0.8927
URBE	0.98911	0.289	0.8846
PADE	0.78292	7.278	0.0000
PACO	0.98196	0.482	0.7487
POSQ	0.96735	0.885	0.4752
SPPY	0.87654	3.697	0.0074
CHVI	0.95460	1.248	0.2951
SENI	0.98702	0.345	0.8469
SPAF	0.84465	4.828	0.0013
PEPA	0.98577	0.378	0.8233
ERCR	0.96716	0.891	0.4719
DISM	0.99005	0.263	0.9006

The standardized weights for 37 variables from a D.F.A. of 5 herbivore species.

Variable	DF1	DF2	DF3
% variance	49.61	26.45	13.94
COVER	0.091	0.308	-0.062
HEIGHT	0.565	-0.023	0.008
CYDA	-0.276	-0.470	-0.674
ARCO	0.132	-0.343	0.072
RHRE	0.249	-0.200	-0.055
HECO	-0.390	-0.119	-0.468
THTR	-0.283	-0.360	0.347
ERCU	-0.095	-0.367	-0.095
ERSU	-0.225	-0.278	-0.154
ERRI	-0.238	-0.306	-0.340
ERRA	-0.279	0.402	-0.259
ERPL	-0.408	0.265	0.426
ERGU	0.734	-0.001	0.289
ELAR	0.022	-0.167	-0.082
CYEX	-0.577	-0.152	-0.459
HYHI	0.282	-0.429	-0.183
TRGR	0.465	-0.269	0.077
BOIN	0.020	-0.069	-0.169
TRRE	-0.181	0.482	0.568
SEFL	0.015	0.046	0.017
BRSE	-0.349	0.028	-0.229
BRNI	-0.200	-0.010	0.030
URMO	-0.060	-0.226	-0.489
LOFL	0.254	-0.708	0.084
DIER	-0.141	-0.493	0.081
DIAM	-0.245	-0.138	-0.217
TRBE	-0.035	-0.164	-0.214
PADE	-0.727	-0.868	-0.019
PACO	0.161	-0.115	-0.235
POSQ	0.173	-0.105	0.226
SPPY	-0.142	-0.398	0.404
CHVI	0.265	0.098	0.483
SENI	0.036	-0.098	-0.063
SPAF	-0.199	0.283	0.388
PEPA	0.271	0.906	-0.139
ERCR	-0.328	-0.283	0.109
DISM	0.086	0.033	-0.174

Appendix L

(a) Secondary Grasslands:

	Late-wet	Late-dry
Late-wet	-	9.97**
Late-dry	-	-

(b) Pediment Grasslands:

	Late-wet	Late-dry
Late-wet	-	9.55**
Late-dry	-	-

(c) Valley Savannas:

	Late-wet	Late-dry
Late-wet	-	3.18*
Late-dry	-	-

(d) Thickets:

	Late-wet	Late-dry
Late-wet	-	7.83**
Late-dry	-	-

Table 3.3 : Results for Students' t-test comparing differences in above ground biomass for each season. (* = significant the 5% level; ** = significant at the 1% level).

APPENDIX M

```
PROGRAM STOCKDENS (INPUT, OUTPUT);
(*==============*)

CONST M=5; A=1; E=5; NUMDAYS=91;

TYPE PRODRANGE = 1..E;
     PRODINDEX = 0..E;
     PRODRECORD = RECORD
                   PAL : REAL;
                   INT : REAL;
                  END;

     PRODARRAY = ARRAY [PRODRANGE] OF PRODRECORD;

     ANINDEX = 0..M;
     ANRANGE = 1..M;
     ANARRAY = ARRAY [PRODRANGE, ANRANGE] OF REAL;

     INITANARRAY = ARRAY [ANRANGE] OF REAL;

     COEFRANGE = 1..4;
     COEFINDEX = 0..4;

     COEFARRAY = ARRAY [PRODRANGE, ANRANGE, COEFRANGE] OF REAL;

     RAINRANGE = 1..4;

     CHARSET = SET OF CHAR;

     CONCOEFARRAY = ARRAY [ANRANGE] OF REAL;
     MINPLARRAY = ARRAY [ANRANGE] OF REAL;
     DISTARRAY = ARRAY [ANRANGE] OF REAL;

VAR PRINTOUT : TEXT;

    VEG : PRODARRAY;

    HABITAT : PRODINDEX;

    ANBIOM : ANARRAY;

    INITANBIO : INITANARRAY;

    DISTFILE : TEXT;

    AREA : ARRAY [PRODRANGE] OF INTEGER;
    PALTOINT, MAXPLBI : ARRAY [PRODRANGE] OF REAL;
    PREFPAL, CONCOEF : CONCOEFARRAY;

    INIDISTCOEF : COEFARRAY;

    MINPLBI : MINPLARRAY;

    MINRAIN, MAXRAIN : ARRAY [RAINRANGE] OF INTEGER;

    SEED, PERIOD, YEAR : INTEGER;

    SEASON : COEFINDEX;

    RAINFALL, PLPROD, SUMCONPAL, SUMCONINT : REAL;

    MINDIST : DISTARRAY;
```

```
 CHFIRE, QPRINT : CHAR;
 FIRE, NEGPLBIO, PALBOOL : BOOLEAN;

PROCEDURE READDATA;
(*---------------*)

 VAR I : PRODRANGE;
     J : ANRANGE;

 BEGIN

  FOR J := 1 TO M DO
   BEGIN

    WRITE ('INIT ANIM BIOM OF SP',J, '='); READLN (INITANBIO[J]);
    WRITELN;

   END;

  FOR I := A TO E DO
   BEGIN

    WRITE ('INIT PAL STAND CROP FOR HABITAT',I, '='); READLN (VEG[I].PAL);
    WRITE ('INIT INT STAND CROP FOR HABITAT',I, '='); READLN (VEG[I].INT);
    WRITELN;

   END;

  WRITE ('FIRE : YES(Y) OR NO(N)?'); READLN (CHFIRE);
  WRITE ('RANDOM INTEGER NUMBER='); READLN (SEED);
  WRITE ('PERIOD='); READLN (PERIOD);

END; (*READDATA*)


PROCEDURE CONSTANTS;
(*----------------*)

  GIN

  AREA[1]:=3120; AREA[2]:=1630; AREA[3]:=7320; AREA[4]:=2336;
  PALTOINT[1]:=0.45; PALTOINT[2]:=0.3; PALTOINT[3]:=0.5; PALTOINT[4]:=0.6;
  PALTOINT[5]:=0.6; PREFPAL[1]:=0.65; PREFPAL[2]:=0.4; PREFPAL[3]:=0.6;
  PREFPAL[4]:=0.7; PREFPAL[5]:=0.8; CONCOEF[1]:=0.25; CONCOEF[2]:=0.2;
  CONCOEF[3]:=0.2; CONCOEF[4]:=0.2; CONCOEF[5]:=0.15; MAXPLBI[1]:=13.1;
  MAXPLBI[2]:=12.1; MAXPLBI[3]:=46.8; MAXPLBI[4]:=173;
  MAXPLBI[5]:=30; MINRAIN[1]:=100; MINRAIN[2]:=150; MINRAIN[3]:=0;
  MINRAIN[4]:=0; MAXRAIN[1]:=400; MAXRAIN[2]:=600; MAXRAIN[3]:=100;
  MAXRAIN[4]:=40; AREA[5]:=7535; MINPLBI[1]:=2.5; MINPLBI[2]:=0.002;
  MINPLBI[3]:=0.0025; MINPLBI[4]:=0.003; MINPLBI[5]:=0.0035;

 END; (*CONSTANTS*)


FUNCTION RANDOM (VAR SEED : INTEGER) : REAL;
(*-------------*)

CONST DIVISOR = 32767;

 BEGIN

  (* $R- *)
```

```
  SEED := (25173 * SEED + 13849) MOD DIVISOR;

 (* $R+ *)

  SEED := ABS (SEED);

  RANDOM := SEED / DIVISOR;

END; (*RANDOM*)


PROCEDURE READCOEF (VAR INIDISTCOEF : COEFARRAY);
(*---------------*)

VAR I : PRODRANGE;
    J : ANRANGE;
    SEASON : COEFRANGE;
BEGIN

 FOR I := A TO E DO
  FOR J := 1 TO M DO
   FOR SEASON := 1 TO 4 DO
    BEGIN
     READ (DISTFILE, INIDISTCOEF[I,J,SEASON]);
    END;

 END; (*READCOEF*)


 PROCEDURE READCH (MARKSET : CHARSET; VAR CH : CHAR);
 (*-------------*)

 BEGIN
  REPEAT
   READ (CH);

    IF (CH IN MARKSET) THEN WRITE (CH) ELSE
     WRITE (CHR(7));

  UNTIL (CH IN MARKSET);

 END; (*READCH*)


PROCEDURE SEASONLOOP (DISTCOEF : COEFARRAY);
(*-----------------*)

 VAR SPECIES : ANRANGE;
     NIGSPECIES : ANINDEX;
     CONPAL, CONINT : REAL;
     DISTLIMIT : ANRANGE;

PROCEDURE PLANTBIOM (RAINFALL : REAL; VAR VEG : PRODARRAY);
(*---------------*)

 VAR PROD : PRODARRAY;
     PLRAIN : REAL;
     I : PRODRANGE;


PROCEDURE PRODUCTION (PLRAIN, PALTOINT, VEGPAL, VEGINT, MAXPLEI : REAL;
 (*-----------------)  AREA : INTEGER; VAR PLPROD, PRODPAL,
                        PRODINT : REAL);
```

```
  BEGIN

   PLPROD := PLRAIN * AREA * (1 - ((VEGPAL + VEGINT) / MAXPLBI))
            (PWROFTEN(6));

   PRODPAL := PLPROD * PALTOINT;
   PRODINT := PLPROD - PRODPAL;

  END; (*PRODUCTION*)


 PROCEDURE VEGETATION (PRODPAL, PRODINT : REAL; VAR VEGPAL,
 (*----------------*)  VEGINT : REAL);

  BEGIN

   VEGPAL := VEGPAL + PRODPAL;
   VEGINT := VEGINT + PRODINT;

  END; (*VEGETATION*)


 BEGIN (*PLANTBIOM*)

  IF RAINFALL > 21 THEN
   PLRAIN := -113 + 5.48 * RAINFALL
  ELSE
   PLRAIN := 10;

   FOR I := A TO E DO
    BEGIN

    PRODUCTION (PLRAIN, PALTOINT[I], VEG[I].PAL, VEG[I].INT, MAXPLBI[I],
                AREA[I], PLPROD, PROD[I].PAL, PROD[I].INT);

    VEGETATION (PROD[I].PAL, PROD[I].INT, VEG[I].PAL, VEG[I].INT);

    END;

 END; (*PLANTBIOM*)


PROCEDURE ANIMCONS (ANBIOM, CONCOEF, PREFPAL : REAL;
(*--------------*)  VAR CONPAL, CONINT : REAL);

 VAR CONSUMP : REAL;

  BEGIN
   CONSUMP := ANBIOM * CONCOEF * NUMDAYS;

    CONPAL := CONSUMP * PREFPAL;
    CONINT := CONSUMP * (1 - PREFPAL);
  END; (*ANIMCONS*)


PROCEDURE VEGCONS (DISTCOEF : COEFARRAY; INITANBIO : INITANARRAY);
(*--------------*)

 VAR J : ANRANGE;
```

```
PROCEDURE HEADING;
(*----------------*)

 VAR I : ANRANGE;

  BEGIN

   WRITELN (PRINTOUT); WRITELN (PRINTOUT);
   WRITELN (PRINTOUT, ' ':4, 'YEAR = ',YEAR:1, ' ':10, 'SEASON = ',
             SEASON:1, ' ':10, 'RAINFALL = ', RAINFALL:7:1);
   WRITELN (PRINTOUT); WRITELN (PRINTOUT);
   WRITELN (PRINTOUT, ' ':30, 'ANIMAL BIOMASS:');
   WRITELN (PRINTOUT, ' ':30, '==============');
   WRITELN (PRINTOUT);
   WRITE (PRINTOUT, ' ':14);
    FOR I := 1 TO M DO
     WRITE (PRINTOUT, ' SPECIES ',I:1, ' ':2);
   WRITELN (PRINTOUT);

  END; (*HEADING*)


  PROCEDURE ANIMTABLE (HABITAT : PRODINDEX; ANBIOM : ANARRAY);

  VAR I : PRODRANGE;
      J : ANRANGE;

  BEGIN

   FOR I := A TO E DO
    BEGIN
     WRITE (PRINTOUT, 'HABITAT',I : 1);
     FOR J := 1 TO M DO
      BEGIN
       WRITE (PRINTOUT, ANBIOM[I,J]:10:4,' ':4);
      END;

     WRITELN (PRINTOUT);

    END;
  END;


PROCEDURE PLANTTABLE (VEG : PRODARRAY);
(*----------------*)

 VAR I : PRODRANGE;

  BEGIN

   WRITELN (PRINTOUT);
   WRITELN (PRINTOUT, ' ':30, 'PLANT BIOMASS:');
   WRITELN (PRINTOUT, ' ':30, '=============');
   WRITELN (PRINTOUT);
   WRITE (PRINTOUT, ' ':14);
    FOR I := A TO E DO
     WRITE (PRINTOUT, ' HABITAT ',I:1,' ':2);
     WRITELN (PRINTOUT);

   WRITE (PRINTOUT, ' PALATABLE    ');
    FOR I := A TO E DO
     WRITE (PRINTOUT, VEG[I].PAL:10:4, ' ':2);
   WRITELN (PRINTOUT);
   WRITE (PRINTOUT, ' INTERMEDIATE ');
    FOR I := A TO E DO
     WRITE (PRINTOUT, VEG[I].INT:10:4, ' ':2);
```

```
   WRITELN (PRINTOUT);

 END; (*PLANTTABLE*)


BEGIN (*VEGCONS*)
 HEADING;

  HABITAT := 0;
   REPEAT
    HABITAT := HABITAT + 1;

    SUMCONPAL := 0; SUMCONINT := 0;
   FOR J := 1 TO M DO
    BEGIN
     WRITELN (PRINTOUT, 'DISTCOEF=', DISTCOEF[HABITAT,J,SEASON]);

     ANBIOM[HABITAT,J] := INITANBIO[J] * DISTCOEF[HABITAT,J,SEASON];

   ANIMCONS (ANBIOM[HABITAT,J], CONCOEF[J], PREFPAL[J],
             CONPAL, CONINT);

    SUMCONPAL := SUMCONPAL + CONPAL;
    SUMCONINT := SUMCONINT + CONINT;

   END;

    VEG[HABITAT].PAL := VEG[HABITAT].PAL - SUMCONPAL;
    VEG[HABITAT].INT := VEG[HABITAT].INT - SUMCONINT;

     WRITELN (PRINTOUT, 'SUMCONPAL=',SUMCONPAL,'SUMCONINT=',SUMCONINT);

    NEGSPECIES := 0;
     REPEAT
     NEGSPECIES := NEGSPECIES + 1;
      NEGPLBIO := (VEG[HABITAT].PAL < (MINPLBI[NEGSPECIES] *
                  PREFPAL[NEGSPECIES])) OR
                  (VEG[HABITAT].INT < (MINPLBI[NEGSPECIES] * (1 -
                  PREFPAL[NEGSPECIES])));
     UNTIL (NEGSPECIES >= M) OR NEGPLBIO;

   UNTIL (HABITAT >= E) OR NEGPLBIO;

  IF NOT NEGPLBIO THEN
   BEGIN
    ANIMTABLE (HABITAT,ANBIOM);
    PLANTTABLE (VEG);
   END
   ELSE
    BEGIN
    VEG[HABITAT].PAL := VEG[HA[illegible] + SUMCONPAL;
    VEG[HABITAT].INT := VE[illegible] + SUMCONINT;
    END;

 END; (*VEGCONS*)


PROCEDURE MODMINDIST (VEG : PRODARRAY; MINPLBI : MINPLARRAY;
(*-----------------*)  INITANBIO : INITANARRAY; PLPROD : REAL;
                      VAR MINDIST : DISTARRAY);

 VAR PLBITEMP, PLBION, PLBIOFF, TEMPPLBION, CONPAL, CONINT : REAL;
     HERB : ANINDEX;
```

```
FUNCTION SUMINIT (INIDISTCOEF : COEFARRAY) : REAL;

 VAR J : ANRANGE;
     SUM : REAL;

 BEGIN
  FOR J := 1 TO M DO
   IF J <> NEGSPECIES THEN
    SUM := SUM + INIDISTCOEF[HABITAT,J,SEASON];
    SUMINIT := SUM
 END; (*SUMINIT*)


BEGIN (*MODMINDIST*)


ANIMCONS (ANBIOM[HABITAT,NEGSPECIES], CONCOEF[NEGSPECIES],
          PREFPAL[NEGSPECIES], CONPAL, CONINT);


PALBOOL := FALSE;

IF  (VEG[HABITAT].PAL-SUMCONPAL) < (MINPLBI[NEGSPECIES] *
   PREFPAL[NEGSPECIES]) THEN
   BEGIN
    PALBOOL := TRUE;
    PLBITEMP := VEG[HABITAT].PAL - SUMCONPAL;
   END
 ELSE
IF (VEG[HABITAT].INT-SUMCONINT) < (MINPLBI[NEGSPECIES] *
       (1 - PREFPAL[NEGSPECIES])) THEN
   PLBITEMP := VEG[HABITAT].INT - SUMCONINT;

IF PLBITEMP < 0 THEN
 PLBIOFF := ABS(PLBITEMP) + MINPLBI[NEGSPECIES]
ELSE
 PLBIOFF := MINPLBI[NEGSPECIES] - PLBITEMP;

IF (PLBIOFF > CONPAL) OR (PLBIOFF > CONINT) THEN
 BEGIN
  DISTLIMIT := M;
  MINDIST[NEGSPECIES] := 0;

   IF PALBOOL = TRUE THEN
    TEMPPLBION := VEG[HABITAT].PAL - (MINPLBI[NEGSPECIES] *
                  PREFPAL[NEGSPECIES]) ELSE
    TEMPPLBION := VEG[HABITAT].INT - (MINPLBI[NEGSPECIES] *
                  (1 - PREFPAL[NEGSPECIES]));

   HERB:= 0;
  REPEAT
   HERB:= HERB + 1;
   IF NOT (HERB = NEGSPECIES) THEN

   MINDIST[HERB] := ((TEMPPLBION * (INIDISTCOEF[HABITAT,HERB,
                                                  SEASON] /
                         SUMINIT(INIDISTCOEF))) / (CONCOEF[HERB] * P1)) /
                         INITANBIO[HERB];
   WRITELN (PRINTOUT, 'MINDIST=',MINDIST[HERB]);
  UNTIL HERB >= M;
 END
 ELSE BEGIN
  IF PALBOOL = TRUE THEN
   PLBION := CONPAL - PLBIOFF
  ELSE BEGIN
   PLBION := CONINT - PLBIOFF;
   MINDIST[NEGSPECIES] := ((PLBION / CONCOEF[NEGSPECIES]) * P1) /
                          INITANBIO[NEGSPECIES];
```

```
    DISTLIMIT := 1;
    WRITELN (PRINTOUT, 'MINDIST=',MINDIST[NEGSPECIES]);
   END;
  END;

 END; (*MODMINDIST*)


PROCEDURE MODDIST (MINDIST : DISTARRAY; INIDISTCOEF : COEFARRAY;
(*-------------*)  VAR DISTCOEF : COEFARRAY);

 VAR HAB : PRODINDEX;
     TEMPCOEF, DIFFDIST : REAL;
     TEMPSPECIES : ANRANGE;


 PROCEDURE UPDATEDIST (MINDIST : DISTARRAY; INIDISTCOEF : COEFARRAY;
 (*----------------*) VAR DISTCOEF : COEFARRAY;
                      VAR DIFFDIST : REAL);

  VAR SPECIES : ANRANGE;

  BEGIN

      DIFFDIST := INIDISTCOEF[HABITAT,TEMPSPECIES,SEASON] -
                  MINDIST[TEMPSPECIES];
      DISTCOEF[HABITAT,TEMPSPECIES,SEASON] := MINDIST[TEMPSPECIES];
  WRITELN (PRINTOUT, 'MODDIST1=',DISTCOEF[HABITAT,TEMPSPECIES,SEASON]);

  END; (*UPDATEDIST*)


FUNCTION SUMHAB (HABITAT : PRODINDEX; SPECIES : ANINDEX) : REAL;
(*-----------*)

 VAR I : PRODRANGE;
     SUM : REAL;

 BEGIN

  SUM := 0;

  FOR I := 1 TO E DO
   IF I <> HABITAT THEN
    SUM := SUM + INIDISTCOEF[I,SPECIES,SEASON];
    SUMHAB := SUM;

 END; (*SUMHAB*)


 BEGIN (*MODDIST*)

 FOR SPECIES := 1 TO DISTLIMIT DO
 BEGIN
  IF DISTLIMIT = 1 THEN TEMPSPECIES := NEGSPECIES
  ELSE TEMPSPECIES := SPECIES;

  UPDATEDIST (MINDIST, INIDISTCOEF, DISTCOEF, DIFFDIST);

   HAB := 0;

   REPEAT
```

```
 HAB := HAB + 1;
  IF NOT (HAB = HABITAT) THEN
   BEGIN

    TEMPCOEF := (INIDISTCOEF[HAB,TEMPSPECIES,SEASON] *
                                          DIFFDIST) /
                                          SUMHAB(HABITAT,TEMPSPECIES);

    DISTCOEF[HAB,TEMPSPECIES,SEASON] := TEMPCOEF + INIDISTCOEF[HAB,
                                          TEMPSPECIES,SEASON];
    WRITELN (PRINTOUT, 'MODDIST2=',DISTCOEF[HAB,TEMPSPECIES,SEASON]);

   END;
  UNTIL HAB = E;
 END;
END; (*MODDIST*)

BEGIN (*SEASONLOOP*)

 SEASON := 0;

 NEGPLBIO := FALSE;

 REPEAT

  SEASON := SEASON + 1;

   IF NOT NEGPLBIO THEN

   RAINFALL := MINRAIN[SEASON] + (MAXRAIN[SEASON] - MINRAIN[SEASON])
               * RANDOM(SEED);

  PLANTBIOM (RAINFALL, VEG);
  VEGCONS (DISTCOEF, INITANBIO);

   IF NEGPLBIO THEN BEGIN
    MODMINDIST (VEG, MINPLBI, INITANBIO, PLPROD, MINDIST);
    MODDIST (MINDIST, INIDISTCOEF, DISTCOEF);

    SEASON := SEASON - 1;
   END;

 UNTIL SEASON >= 4;

END; (*SEASONLOOP*)



(*MAIN PROGRAM FOLLOWS*)


BEGIN


 WRITE (' PRINTED COPY ? (Y/N) '); READLN (QPRINT);

  IF QPRINT = 'Y' THEN
   REWRITE (PRINTOUT, 'PRINTER:')
    ELSE
   REWRITE (PRINTOUT, 'CONSOLE:');

 WRITELN (PRINTOUT);
```

```
WRITELN (' INSERT DISK WITH DISTDATA FILE(S) THEN TYPE SPACE: ');
READCH(I' 'I,QPRINT);
RESET (DISTFILE, 'DISTDATA.DATA');

READDATA;
CONSTANTS;
READCOEF (INIDISTCOEF);

 YEAR := 0;

 REPEAT

  YEAR := YEAR + 1;

  SEASONLOOP (INIDISTCOEF);

 UNTIL YEAR >= PERIOD;

CLOSE (DISTFILE, LOCK);

END. (*MAIN PROGRAM*)
```