Animal Energy Balance and Populations

Animal conditions and populations are modeled through their energy balances in Savanna. Energy intake for each of the groups is determined by their intake rate, forage density, and forage quality.



The energy intake is reduced by energy expenditures from activity such as movements or lactation, and by stressors such as temperature. The result is the energy balance, reflected in the body weights of the population and their condition indices.

In Savanna, animal populations are modeled with each year an age class, and animals move through each age class as years pass (or they die). However, results are summaries and reported based upon five age/sex groups, 1) first-year animals, 2) juvenile females, 3) juvenile males, 4) adult fe-



males, and 5) adult males. During each time step, the population in each age class will change due to births and mortality.



Notes: Although Savanna reports results for five age/sex classes for animals, the mathematical tools used to model the populations operate upon each year's cohort for males and females separately.

Using switches in SIMCON.PRM, animal population modeling may be turned-on or turned-off. In NCA-Savanna, population modeling for migratory animals is always turned-off, for example. We do this because only a portion of the migratory animal's habitat has been included in the study area.

Animal Energy Use in Savanna

Diets are determined by values set in DIET.PRM and CONSUME.PRM (as well as available forage, for example), but the energy available to the animal is described in ENBUDGT.PRM.

Enbudgt.prm sample

17	//nsp	- Number of different
1	//** CATTL **	- Number of herds of
1	//	- Indices of consume
1	//irqop	— Flag for Metaboliz
2	//igestop	— Flag for simulatio
2	//imlkop	- Flag to Simulate E
0	//itrvop	- Flag for Travel En
0	//isnwop	— Flag for Travel Co
0.90,1.15	//bwtmn,bwtmx	- Ratio of Minimum B
59.,150.,150.,250.,340.	//bodsiz	- Body Weight by Age
0.70	//cond	- Initial Condition
-0.22,0.20	//wtlrmx,wtgrmx	- Maximum Rate of We
.84	//emetab	- Metabololizability
2	//ienrequnit	- Flag indicating wh
.19,.24	//enusemn,enuse	mx — Min and max ener
.2,.05,.5,.1,1.,1.	//enuseinrat	- Ratio of energy us
7,5	//mgestf,mgestl	- First and last mon
12*0.	//gestcost	- Gestation cost as
.67	//pregnrt	 Pregnancy rate of
12*0.	//emilk	- Milk energy conten
0.5	//lactcost	- Lactation cost as
2,7	//mlactf,mlactl	- First and last mon
0,0	//trvcsh,trvcsv	- Travel Cost of Hor
2	//ientrvunit	 Flag indicating if
0,0,0,0,0,0,0,0,0,0,0,0,0	//dstrvm	— Mean Distance Trav
0	//perslp	- Mean Steepness of
0.,7.,25.,40.	//tvdswt	- Distance Traveled
/5,0.0	//briskh,snwtrv -	- Brisket Height(cm)

As for other animal parameter files, ENBUDGT.PRM is made-up of a set of values repeated for each of the animal groups in the model. For each animal group, there are several switches that turn-off or turn-on modeling an energy cost explicitly - usually when turned-off, the cost in question is included in a grand total. After the switches, information used to calculate condition indices (de-



scribed in detail later) is given, followed by general energy costs and detailed costs associated with gestation, lactation, travel costs, and even the cost of pushing through deep snow.

Exercise: Look at the ENBUDGT.PRM file in the "parms" directory.

Method: Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Note that everything to the right of "//" on a line is ignored by Savanna.

Notes: The switches in ENBUDGT.PRM may be turned-on to model energy costs explicitly, presumably yielding more reliable estimates of animal energy use and condition, but with increased complexity. In general, because these energy costs may be included in the basal costs, the extra detail may not be needed. These options may be enabled if important in management decisions. In NCA-Savanna, for example, gestation and lactation costs for livestock are modeled explicitly, but not for wildlife.

Animal Populations in Savanna

Basic population levels are set in Savanna in a file whose name can be changed, but is generally DENS.DAT, which follows:

Dens.dat	17	//nhrd - Number
1	.16,.13,.06,.53,.12	//** CATTL ** -
sample	.15,.05,.05,.40,.35	//** MWILD ** -
	.15,.05,.05,.40,.35	//** RWILD ** -
DENS DAT first pro-	.15,.12,.08,.48,.17	//** MZEB ** -
	.15,.12,.08,.48,.17	//** RZEB ** -
vides Savanna with	.15,.12,.08,.48,.17	//** ABUFF ** -
the initial age/sex	.15,.12,.08,.48,.17	//** CBUFF ** -
the mitial age/sex	.30,.10,.10,.40,.10	//** MGANT ** -
distributions, <i>but</i> that	.30,.10,.10,.40,.10	//** RGANT ** -
option is not used in	.30,.10,.10,.40,.10	//** GOAT ** -
option is not used in	.30,.10,.10,.40,.10	//** SHEEP ** -
NCA-Savanna. Initial	.30,.10,.10,.40,.10	//** ABANT ** -
aga/agy distributions	.30,.10,.10,.40,.10	//** CBANT ** -
age/sex distributions	.16,.13,.06,.53,.12	//** ELEPH ** -
in NCA-Savanna are	.16,.13,.06,.53,.12	//** GIDIE **
the DOD* DDM	.10,.13,.00,.53,.12	//** GIRAF ** -
in the POP*.PRM	.30,.10,.10,.40,.10	//** WHOG *** =
files described shortly.		//ipopin - Flag
	3000	// 11140115 1 149
Next there are settings	105468 450000 9000 62	959 7187 500
that control when		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
population values are	// CATTL, MWILD, RWILD,	MZEB, RZEB, ABUFF,
used		

- Lastly, initial population sizes for the animal groups are given. If population modeling is not turned-on, the value listed will be constant throughout the simulation.
- If culling of populations is enabled, and populations reach some upper limit set in CULL.PRM, the excess animals will be culled. Enough animals will be removed from the population to reach a lower culling limit, also set in CULL.PRM. The animals removed are accumulated and reported.





Cull nrm	&cullprm	
Cun.prm	icull=0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0	!/0-no cull
	cullrule=2,2,2,2,2,2,2,2,2	!/Cull rule
	tarmalep=0,0,0,0,0,0,0,0	!/Target ma
	cullstartyr=17*1963	!/First yea
	cullendyr=17*3000	!/Last year
	cullfile=' `	!/For icull
	moncull=17*6	!/Month of
	culltrig=125000,8*0,105000,105000,6*0	!/Populatio
	cullresult=120000,8*0,100000,100000,6*0	!/Resulting
	icullyng=17*1	!/1-Include
	hefrrepl=17*.25	!/ For cull
	bullrepl=17*.05	!/ For cull
	ŵ	

Exercise: Look at the DENS.DAT and CULL.PRM files in the "parms" directory.

Method: Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Note that everything to the right of "//" on a line is ignored by Savanna.

Animal Rates of Change in Savanna

Just as vegetation POP*.PRM provided rates of change for plants, a suite of POP*.PRM files provide rates of change for animal populations. In addition, these files are used to initialize the age/sex distribution for each animal group.

Popcattl.prm	2			//ipo	pinit	- ** CATTLE **
1	2			//ide	mostoc	- 1- Use demog
sample	2			//mon	birth	- Month of bir
-	0.,	.6,1.,	.93	//ef	fcbrth	— Birth rate
	.0,	.4,.4,	.1,.7,	.0 //d	thcond	- Death rate
	.5			//pma	lebirth	- Proportion o
	25			//nag	emx	- Maximum age
	1	650	600	0.650	0.600	0.00
	2	531	448	0.817	0.700	0.00
	3	478	360	0.900	0.750	0.35
	4	430	290	0.900	0.750	0.65
	5	387	210	0.900	0.750	0.65
	6	348	170	0.900	0.750	0.65
	7	313	140	0.900	0.750	0.65
	8	282	108	0.900	0.750	0.65
	9	254	90	0.900	0.800	0.65
	10	229	82	0.900	0.800	0.65
	11	206	65	0.900	0.800	0.65
	12	185	52	0.900	0.800	0.65
	13	167	42	0.900	0.800	0.65
	14	137	31	0.825	0.733	0.65
	15	103	20	0.750	0.667	0.60
	16	70	12	0.675	0.600	0.49
	17	42	7	0.600	0.533	0.43
	18	22	3	0.525	0.467	0.38
	19	10	1	0.450	0.400	0.32
	20	4	0	0.375	0.333	0.27
	21	1	0	0.300	0.267	0.22
	22	0	0	0.225	0.200	0.16
	23	0	0	0.150	0.133	0.11
	24	0	0	0.075	0.067	0.05
	25	0	0	0.000	0.000	0.00

After some switches are set, the month when births occur is set, then the relationship between the birth rate and the condition index is set, as is the relationship between the death rate and condition index. The proportion of births that are male is set, then the maximum age of individuals in the wild is given.



Following these initial values, rows of values are given, with one row per year of the animal's age. On each row, the year is given, followed by an initial population size for females and males. That is followed by average survival for female and male animals in that age class. Finally, the birth rate for females in the age class is given.

Exercise: Look at and contrast the POPCATTL.PRM and POPELEPH.PRM files in the "parms" directory. That is, compare the cattle and elephant POP*.PRM files.

Method: Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown.

Notes: The second and third columns in POP*.PRM might be misleading. In practice, in NCA-Savanna, the columns represent how many animals survive to the end of each time period, given that we begin with 1,000 females and 1,000 males.

Animal Migration in Savanna

Savanna is able to model the movements of animals into and out of the study area being modeled. These movements are simply represented by a fraction of the total animal group population that is not on the site. As you might predict, these values are stored in the file MIGRATE.PRM, shown below.

Migrate.prm

3 //nsp - Number of functional groups 2 // ** MWILD ** - MIGRATORY WILDEBEEST .65 //condimm - Condition index of animal c 75.,.8,400.,1.4 //ppt3cnd - Effect of three-month runni 550.,.95,1100.,1.6 //ppt12cnd - Effect of twelve-month run .6,.4,.4,.0,.6,1.,1.,1.,1.,1.,95,.8 //rmigrate - Fractio 4 // ** MZEB ** - MIGRATORY ZEBRA .65 //condimm - Condition index of animal c //ppt3cnd - Effect of three-month runni 75.,.8,400.,1.2 550.,.9,1100.,1.7 //ppt12cnd - Effect of twelve-month runn .6,.3,0.,.4,.75,.8385,1.,1.,1.,1.,1.,92 //rmigrate - Fractio // ** MGANT ** - MIGRATORY GRAZING ANTEL 8 .65 //condimm - Condition index of animal c 75.,.8,400.,1.4 //ppt3cnd - Effect of three-month runni 550.,.9,1100.,1.7 //ppt12cnd - Effect of twelve-month runn .6, .5, .2, 0., .4, .75, 1., 1., 1., 1., 1., 0.95 //rmigrate - Fractio

- In the file shown you see that three animal groups (wildebeest, zebra, and grazing antelope) are migratory. We do not know what the condition of forage outside the study area may be, so when animals return to the study site, they are assigned a condition index (.65 in the file above). We can infer, however, their condition somewhat based upon mean short and long-term rainfall, and so the returning index is adjusted based upon values provided on the next two lines.
- Lastly, the migratory pattern of the animal is given. A value is listed for each of the 12 months, with a number between 0.0 and 1.0 assigned. If 0.0, all the animals are on the study site. If a value of 1.0 is given, the entire population has migrated off the site.

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Integrated Management and Assessment System. These materials are from April 2000 and pertain to Savanna 4E.2. A newer model and volume may be available. See the 'About' boxes in SavView for contacts.

Exercise: Look at the MIGRATE.PRM file in the "parms" directory.

Method: Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown.

Notes: Because only some of the habitat used annually by migratory animals is included in the NCA-Savanna model (that is, the remainder of the Greater Serengeti Ecosystem is not modeled), condition indices of migrants are not as variable as they are for resident animal groups. Given that population changes are closely associated with condition indices, population changes would be biased. We therefore maintain constant migratory populations.

Animal Diets in Savanna

Animal diets in Savanna are affected by settings in Savanna's parameter files, but two files primarily control diet: DIET.PRM and CONSUME.PRM.

DIET.PRM describes, for each animal, how likely the animal is to forage upon each plant functional group. The file also includes the relative amount an animal may eat of each plant type, and the parts of the plants the animal favors.

Diet.prm sample

- 17 //nsp - Number 200.,20.,10.,15.,5.,5.,30. //** CATTL ** - prfs .99,.10,.10,.05,.03,.05,.10 //prefmax - Maximum 100.,20.,12.,0. //prfgr,prfst,prfdl,p 200., 7.,10.,5.,.1,.1, 0.1 //** MWILD ** - prfs .90,.01,.05,.03,.03,.01,.01 //prefmax - Maximum 100.,20.,50.,0. //prfgr,prfst,prfdl,p 200., 7.,10.,15.,.1,.1, 0.1 //** RWILD ** - prfs .90,.01,.05,.03,.03,.01,.01 //prefmax - Maximum 100.,20.,50.,0. //prfgr,prfst,prfdl,p . . .
- Notice that for DIET.PRM and for many of the file describing animal parameters to Savanna, blocks of the same types of values are repeated, one per animal group. This is true for CONSUME.PRM as well, which follows.

CONSUME.PRM outlines how much of each plant type an animal may eat, how intake rate may decline if plant biomass declines, the effect of digestibility upon intake rates, wasted or unavailable graze, and how tall the animal can reach. In Savanna, animals can only graze upon plants within their reach. In NCA-Savanna, the 17 sets of values each end with two parameters describing how snow reduces foraging, which were not used.



Consume.prm	 1	// **CATTL** - nherd
sample	⊥ .040,.050,.030,.040,.030,.0)35,.040 // crmx -
	0.,0.,20.,.75,50.,1. 3. .3,.75,.6,1. 0.1 1.5	<pre>// fresp - Intake // ungzg - Ungraz // edintk - Effect // waste - Forage // reachht - Maximu // converter - Effect</pre>
	0.0	// fcrst - Reduct // **MWILD** - nherd

Exercise: Look at the DIET.PRM and CONSUME.PRM files in the "parms" directory.

Notes: As you would guess, DIET.PRM controls the diets of herbivores, at least in-part. CONSUME.PRM tells Savanna how much of each plant functional group an animal might consume. Note that in CONSUME.PRM (and elsewhere) the files speak of both animal groups *and* animal herds. Although not used in NCA-Savanna, animal groups may have more than one animal herd, if groups of animals are distinct.

Animal Habitat Suitability and Distribution

- To judge the value of the habitat at each grid cell, for each time step Savanna calculates a Habitat Suitability Index (HSI). HSIs are mathematical formulas relating habitat information such as elevation, cover, and forage density to a score from 0.0 to 1.0.
- In Savanna, animal populations are placed upon the landscape at each time step, based upon the HSI scores. Animal densities may be constrained using minimum and maximum values.



Distrib.prm	1 7	//ncn _ Numbor
sample	17	//lisp – Nulliber
sample DISTRIB.PRM tells Savanna how ungulates should be dis- tributed on the landscape.	<pre> 1 1 0.,.01,50.,1.,100.,1. 0.,1.,.5,1. 25. 1 0.,1.,10000.,.4,30000.,.05 .0,.8,1.,15,1.,1.,0. 1.,1.,5.,1.,7.,1. 0.,1.,1500.,1.,2000.,1.,4000., 0,0 0 0 500. 0,0,0,0 0.,.2,10.,1. 0 5 10 1</pre>	<pre>//** CATTL ** - nhe // ind //pforage - Index //emetintk - Effect //watreq - Water R //rqmnrl - Flag fo //pdisw - Distanc //pshcv - Habitat //pthcv - Habitat //pthcv - Habitat 1. //pelev - Habitat //prfgmn - Critica //prefam - Preferr //hdenmx - Maximum //psnow - Effect //pgreenhb - Effect //pdeadhb - Effect</pre>
	3.,.01,15.,1.,30.,1.,40.,.1	//ptemper - Effect
60	-999	//end of file mark
00		



Integrated Management and Assessment System. These materials are from April 2000 and pertain to Savanna 4E.2. A newer model and volume may be available. See the 'About' boxes in SavView for contacts.

Exercise: Look at the DISTRIB.PRM parameter file in the "parms" directory.

Method: Use Windows Explorer to move to the \savanna\sites\nca\parms directory, double-click upon the files, and select the Notepad to view the file, if not already shown. Note that like many parameter files dealing with animals, DISTRIB.PRM is a set of values (18 lines) repeated for each animal.

Notes: For the DISTRIB.PRM file, as well as ENBUDGT.PRM, the effect of several of the values may be turned on or off. For example, the effect of snow depth upon travel costs may be incorporated, but is not of interest in Ngorongoro Conservation Area, and so is turned-off using the switches at the top of the file.