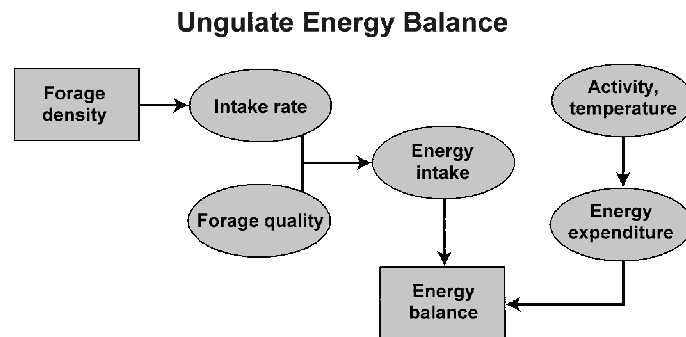


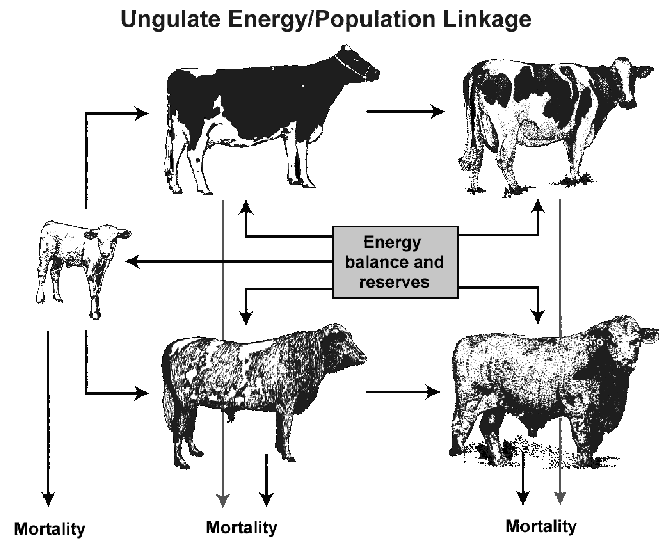
## Animal Energy Balance and Populations

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





## 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 //** CATTLE ** - 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,enusemx - 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 //dstrvm - Mean Distance Trav
0 //perslp - Mean Steepness of
0.,7.,25.,40. //tvdswt - Distance Traveled
75,0.0 //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-





## 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 sample

DENS.DAT first provides Savanna with the initial age/sex distributions, *but* that option is not used in NCA-Savanna. Initial age/sex distributions in NCA-Savanna are in the POP\*.PRM files described shortly. Next there are settings that control when population values are used.

```

17 //nhrd - Number
.16,.13,.06,.53,.12 //** CATTL ** -
.15,.05,.05,.40,.35 //** MWILD ** -
.15,.05,.05,.40,.35 //** RWILD ** -
.15,.12,.08,.48,.17 //** MZEB ** -
.15,.12,.08,.48,.17 //** RZEB ** -
.15,.12,.08,.48,.17 //** ABUFF ** -
.15,.12,.08,.48,.17 //** CBUFF ** -
.30,.10,.10,.40,.10 //** MGANT ** -
.30,.10,.10,.40,.10 //** RGANT ** -
.30,.10,.10,.40,.10 //** GOAT ** -
.30,.10,.10,.40,.10 //** SHEEP ** -
.30,.10,.10,.40,.10 //** ABANT ** -
.30,.10,.10,.40,.10 //** CBANT ** -
.16,.13,.06,.53,.12 //** ELEPH ** -
.16,.13,.06,.53,.12 //** RHINO ** -
.16,.13,.06,.53,.12 //** GIRAF ** -
.30,.10,.10,.40,.10 //** WHOG ** -
0 //ipopin - Flag
0 //ihdens - Flag
3000
105468.,450000.,9000.,62959.,7187.,500.,

// CATTL, MWILD, RWILD, MZEB, RZEB, ABUFF,
    
```

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.





## 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 sample

2				//ipopinit	- ** CATTLE **
2				//idemostoc	- 1- Use demog
2				//monbirth	- Month of bir
0...	6,1...			//effcbrth	- Birth rate
.0,..	.4,..	.1,..	.7,..	//dthcond	- Death rate
.5				//pmalebirth	- Proportion o
25				//nagemx	- 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.







## 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.,.95,.8 //rmigrate - Fractio
4 // ** MZEB ** - MIGRATORY ZEBRA
.65 //condimm - Condition index of animal c
75.,.8,400.,1.2 //ppt3cnd - Effect of three-month runni
550.,.9,1100.,1.7 //ppt12cnd - Effect of twelve-month runn
.6,.3,0.,.4,.75,.8385,1.,1.,1.,1.,.92 //rmigrate - Fractio
8 // ** MGANT ** - MIGRATORY GRAZING ANTEL
.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.,.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.





## 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. /** CATTLE ** - 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.

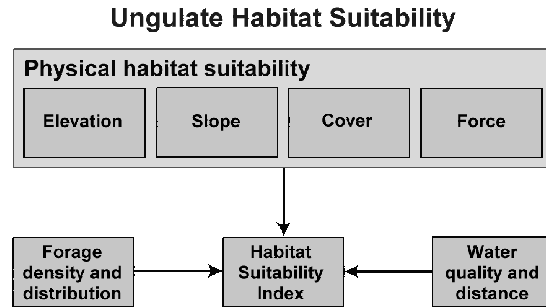
CONSUME.PRM outlines how much of each plant type an animal may eat, how intake rate may decline if plant biomass declines, the effect of digestibility upon intake rates, wasted or unavailable graze, and how tall the animal can reach. In Savanna, animals can only graze upon plants within their reach.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



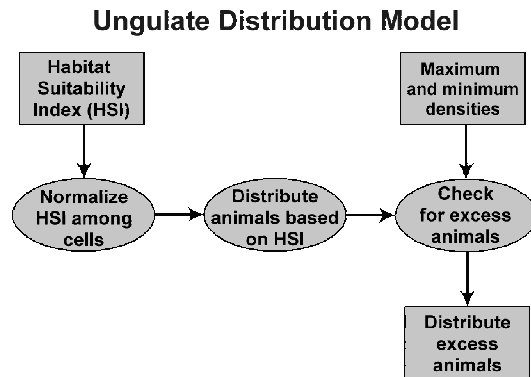


# Animal Habitat Suitability and Distribution

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 sample

**DISTRIB.PRM** tells Savanna how ungulates should be distributed on the landscape.

```

17 //nsp - Number
...
1 //** CATTLE ** - nhe
1 // ind
0.,.01,50.,1.,100.,1. //pforage - Index
0.,1.,.5,1. //emetintk - Effect
25. //watreq - Water R
1 //rqmnr1 - Flag fo
0.,1.,10000.,.4,30000.,.05 //pdisw - Distanc
.0,.8,1.,1. //pshcv - Habitat
.5,1.,1.,0. //pthcv - Habitat
1.,1.,5.,1.,7.,1. //pslope - Habitat
0.,1.,1500.,1.,2000.,1.,4000.,1. //pelev - Habit
0,0 //prfgmn - Critica
0 0 //prefam - Preferr
500. //hdenmx - Maximum
0,0,0,0 //psnow - Effect
0.,.2,10.,1. //pgreenhb - Effect
0.,.5,10.,1. //pdeadhb - Effect
3.,.01,15.,1.,30.,1.,40.,.1 //ptemper - Effect
...
-999 //end of file mark
    
```



