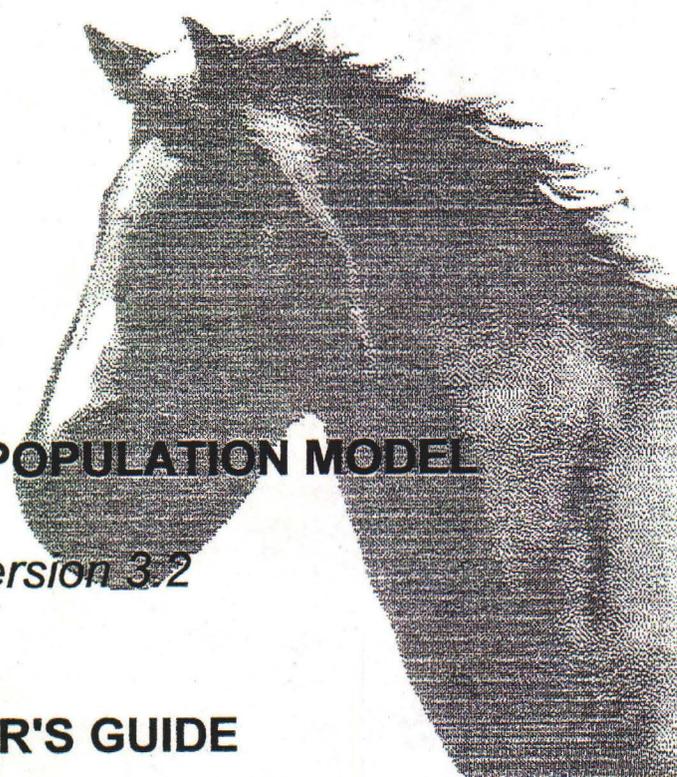


9/29/96



**WILD HORSE POPULATION MODEL**

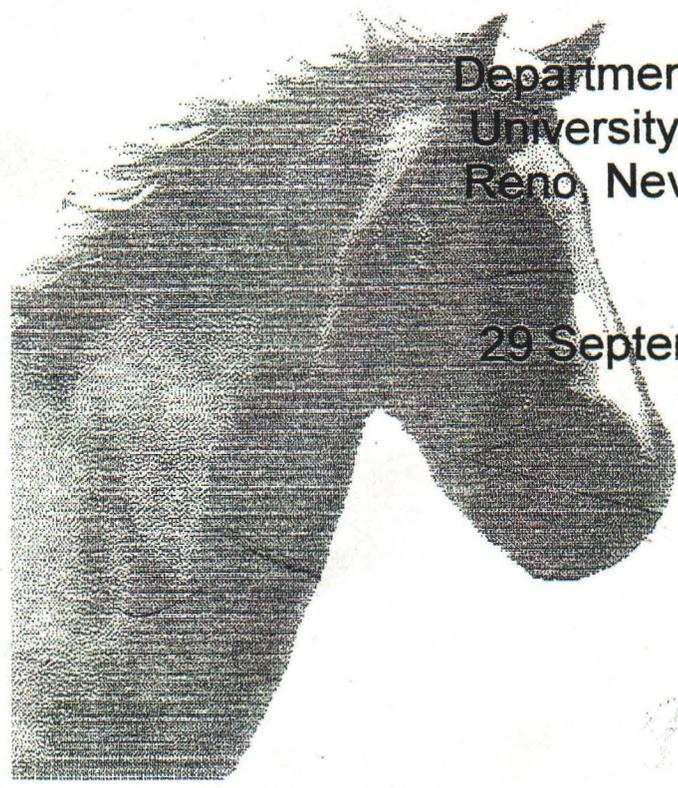
*Version 3.2*

**USER'S GUIDE**

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## USER'S GUIDE FOR WILD HORSE POPULATION MODEL, version 3.2

### ERRATA, 4 November 1996

- (1) p. 2: The last paragraph describes .pic (this should read “.pif”) and .ico files on the distribution diskette to facilitate running the program under Windows. I am not including the .pif file because different versions of it may be needed for Windows 3.1 and Windows 95. The simplest way to run the program is to follow the instructions in the first sentence of this paragraph. If you want to set it up to run directly from Windows, you will need to make your own .pif file.
- (2) p. 3: The title screen should read “WILD HORSE POPULATION MODEL v 3.2”.
- (3) p. 15: The second paragraph on this page describes two horizontal blue lines running across the “spaghetti graph” that represents the basic graphical output of the model. One of these is the threshold population size for gather and removal; the other is the target population size following removal. The target population size may coincide with the x-axis, and so may not appear as a separate horizontal line, although the numerical values for both threshold and target population sizes should appear beside the y-axis on the right side of the graph.

If the calculations for a simulation are taking too long, you may interrupt them by hitting the “s” key while waiting for the spaghetti graph to be drawn.

- (4) p. 32: Additional acknowledgments go to R. Duncan and C. Reed for constructive comments on the program.

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## INTRODUCTION

This is a population model for wild horses, designed to help evaluate various management plans that might be considered for a particular area. The model uses data on survival and reproductive rates of horses to project population growth for up to 50 years. The model uses a random process to account for unpredictable future variation in these demographic parameters. This random process reflects the fact that future environmental conditions that may affect horse populations can't be known in advance. Therefore each trial with the model will give a different pattern of population growth -- some trials may include mostly "good" years, others may include a series of several "bad" years in succession. This **stochastic** approach to modeling population growth uses repeated trials to project a range of possible population sizes after a given number of years, which is more realistic than predicting a single, specific population size.

The model can be used to compare many different strategies of removal and fertility treatment. One important aspect of population dynamics that is **not** included in the present model is density-dependent mortality and reproduction in horses. There is some evidence that these processes are density-dependent, but there are insufficient data at this time to use in a model.

## USE AND ABUSE OF POPULATION MODELING

Population modeling is widely used in ecology and conservation biology, but has several pitfalls that must be discussed. The most important of these is that results may be taken too seriously as **predictions** of what will happen to a particular population in the future. Caswell (1989) makes an important distinction between **forecasting** and **projection** as potential uses of a population model: "A forecast is an attempt to predict what *will* happen. A projection is an attempt to describe what *would* happen, given certain hypotheses" (Caswell 1989: 20). What you are really doing when you use the *Equus* model to project population growth is saying: **If** a set of assumptions about survival, reproduction, environmental variability, and management actions hold true, **then** we expect the population to grow at a certain rate determined by the model. In other words, the results of this model, like those of any model, depend on its assumptions, and the user must always keep those assumptions in mind when interpreting the results. Too often, once output is produced from a model, the assumptions tied to that output are forgotten in the user's enthusiasm for the apparent specificity and concreteness of the results.

Given this danger of taking results of the program too literally as forecasts of future population growth, what is the best use of the model? I think the most appropriate and effective way to use the model is for **comparison** of population growth under various conditions. The model is specifically designed for comparing fertility control and removal as management strategies. It can also be used to compare effects of different levels of environmental variability on population growth. I urge users to adopt an exploratory attitude when running the program. If you don't have all the necessary data for your population, make up some numbers and see what happens! The most important objective of the program is to help you learn more about population dynamics of wild horses, not to use it as a crutch to make management decisions for you.

## INSTALLATION

Before installing the program on your hard disk, it would be wise to make a working copy of the installation diskette. To do so, format a blank diskette, then place the installation diskette in your 3½" disk drive and type the following at the DOS prompt:

```
diskcopy a: a:
```

or

```
diskcopy b: b:
```

depending on whether your 3½" drive is identified as *a:* or *b:* by your system. Follow the instructions to swap disks that appear on the screen. Label the working diskette, store the original installation diskette in a safe place, and use the working diskette to run the program or install it on your hard disk.

To install the files needed to run the program on your hard disk, first make a new directory on the hard disk to contain these files. You may want to call it **eqdir**. You may do this using a file-management program (e.g., the Windows File Manager), or by going to the root directory in DOS (so that the DOS prompt is C:\>) and typing

```
mkdir eqdir
```

Then change into this directory:

```
cd c:\eqdir
```

Then copy all files from the working diskette into this directory:

```
copy a:\*.*
```

(or copy b:\\*.\* if you are using disk drive *b*).

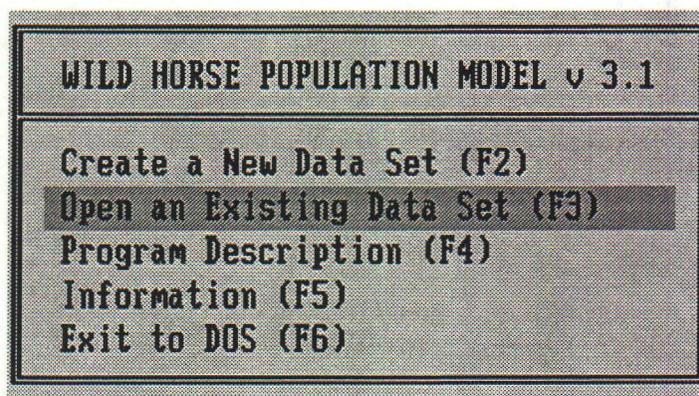
Again, you may be able to perform these steps more easily using a file-management program. It is important that all the files on the distribution diskette get copied into the **eqdir** directory on the hard disk; otherwise the program won't run properly. View the **readme** file for additional details.

To run the program, change into the **eqdir** directory in DOS, then type **equus**. If you wish to set up the program to run as a DOS application in Windows, there are **.pic** and **.ico** files on the distribution diskette that may help you to do so.

## TUTORIAL

All of your interaction with the program is through a series of menus in which you enter data or make choices about various options for management, form of output, etc. On-line help is available for each menu. Therefore, it should be relatively easy to learn how the program works just by running it. If you feel more comfortable going through this tutorial before you start playing with the program on your own, do so; otherwise use this tutorial only if you get stuck on a particular part of the program.

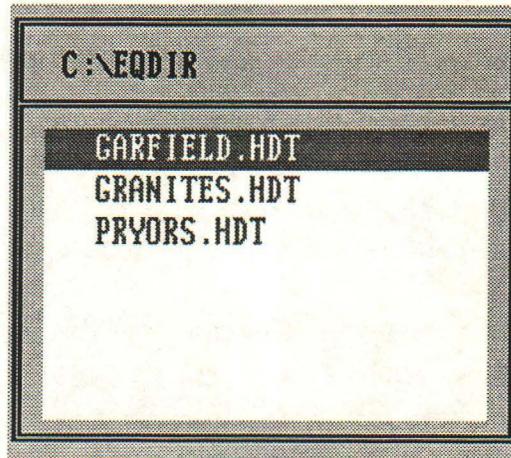
If you've installed the program successfully and started it running as described above, you will soon see a title screen. After about 3 seconds, this introductory menu will appear:



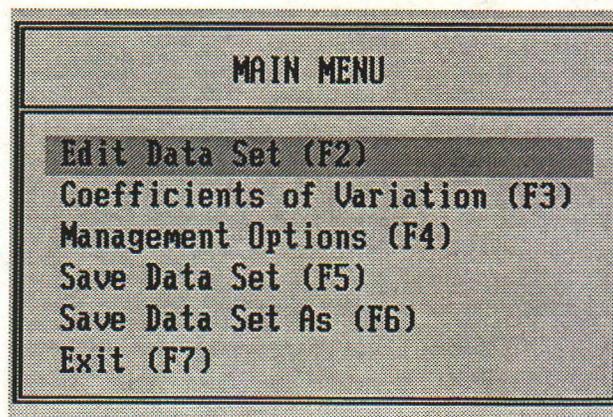
F1 = Help | Esc = Exit | Use arrows, then hit Enter, to select an item

Notice the line at the bottom of the screen. This describes how to make choices from the menu and states what two important keys do. Function key F1 at the top or left hand side of your keyboard displays a context-sensitive help screen. The Escape key takes you back to the previous menu (in this case, because there is no previous menu, the Esc key stops the program and returns you to DOS).

To choose an item from the menu, hit the function key (in parentheses), or use the arrow keys to move the pointer up or down and hit **Enter** when you are ready. Let's begin by typing **F3** to *Open an Existing Data Set*. You should now see a file selection menu:



This box lists all of the data files supplied with the program, as well as new data files you may have created and stored in the C:\EQDIR directory. Use the ↓ key to move the pointer to the file named **PRYOR.HDT**, and hit **Enter** to select this file. Now you will see the Main Menu, as reproduced below:



Press **F2** to select *Edit Data Set*.

EDIT DATA SET
General Information (F2)
Survival Probabilities (F3)
Foaling Rates (F4)
Sex Ratio at Birth (F5)
Exit (F6)

Now press **F2** to see *General Information* about this data set.

GENERAL INFORMATION
Default directory C:\EQDIR
Filename PRYORS .hdt
Description: Pryor Mountain data
Notes 1: Long-term data from Pryor Mountain, MT
Notes 2: (1976-1986; Garrott, R. A. and L. Taylor, 1990,
Notes 3: Dynamics of a feral horse population in Montana
Notes 4: Journal of Wildlife Management 54:603-612.)

This screen shows that the Pryor Mountain data come from a long-term study of wild horses at Pryor Mountain, Montana, reported by Garrott and Taylor in 1990. These are the best demographic data available for wild horses in the western U.S. It's unfortunate that intensive

monitoring of wild horses at Pryor Mountain ended in 1986; the 11 years of data collected prior to that time could have been the basis for a unique long-term record of year-to-year variability in survival and reproduction for a large mammal.

Hit **Esc** to go back to the previous menu, then press **F3** to see *Survival Probabilities* for Pryor Mountain:

SURVIVAL PROBABILITIES					
Age	Females	Males	Age	Females	Males
0	0.948	0.921	13	0.986	0.957
1	0.994	0.965	14	0.981	0.952
2	0.994	0.965	15	0.975	0.946
3	0.994	0.965	16	0.965	0.936
4	0.994	0.965	17	0.949	0.922
5	0.994	0.965	18	0.927	0.900
6	0.993	0.964	19	0.894	0.866
7	0.993	0.964	20	0.845	0.821
8	0.993	0.964	21	0.777	0.754
9	0.992	0.963	22	0.683	0.663
10	0.991	0.962	23	0.560	0.543
11	0.990	0.961	24	0.414	0.402
12	0.988	0.959	25	0.000	0.000

This table shows **average** survival probabilities for males and females from each age to the next older age class. Note that these values are very high -- greater than 90% through age 18. Average survival probabilities are also greater for females than for males of each age class and are a little bit less for foals than for 1-year-olds but decrease with age thereafter. The chance of a horse living from birth to a given age can be computed by multiplying the successive probabilities from age 0 up to that age. For example, the chance that a female at Pryor Mountain would live to be 25 years old is

$$(0.948)(0.994)(0.994) \dots (0.414) = 0.064.$$

This program doesn't permit horses to live beyond 25 years old; the fact that such a small proportion reach age 25 indicates that this is not as serious a limitation as it might appear to be.

We won't change any of these data at this time, but try using the arrow keys to move around the screen and hitting **F1** to read the help screen for *Survival Probabilities*. When you are ready, hit **Esc** to go back to the *Edit Data Set* menu. Now press **F4** to see the *Foaling Rates* for Pryor Mountain.

PROPORTION OF MARES FOALING AT EACH AGE			
Age	Foaling Rate	Age	Foaling Rate
0	0.000	13	0.470
1	0.000	14	0.470
2	0.000	15	0.470
3	0.410	16	0.470
4	0.410	17	0.470
5	0.410	18	0.470
6	0.550	19	0.470
7	0.550	20	0.470
8	0.550	21	0.470
9	0.550	22	0.470
10	0.550	23	0.470
11	0.470	24	0.470
12	0.470	25	0.470

These are average proportions of females of each age that have foals. Note that females at Pryor Mountain produce their first foal at age 3. For some populations, first reproduction occurs at age 2, which would be reflected in a nonzero value adjacent to age 2 in the table. Don't change any data, but hit **Esc** to go back to the previous menu. Now hit **F5** to see the *Sex Ratio at Birth*:

SEX RATIO AT BIRTH	
Proportion males	0.400
Proportion females	0.600

The cursor should be adjacent to the number 0.400, indicating that 40% of foals born at Pryor

Mountain were males. Note that the proportion of females among foals born was 0.600. Let's change the sex ratio to 50% males by typing 0.500 and hitting the ↓ key. When the proportion of males is changed from 0.400 to 0.500, the proportion of females automatically changes from 0.600 to 0.500, because the total must equal 1.0 (in horses, unlike some organisms, there are only two sexes). To activate your change for this run of the program, hit **Enter**.

You have now changed a parameter of this data set. Now hit **Esc** to return to the *Edit Data Set* menu. Let's back up one more level (**F6**) to the Main Menu.

MAIN MENU	
Edit Data Set (F2)	
Coefficients of Variation (F3)	
Management Options (F4)	
Save Data Set (F5)	
Save Data Set As (F6)	
Exit (F7)	

If at this point you hit **F5**, for *Save Data Set*, you would overwrite the original Pryor Mountain data set with one that had the same survival probabilities and foaling rates, but a different sex ratio at birth. Unless you want to subvert someone else in your office who is using the same version of the program, you don't really want to do this. If you try it, the program gives you one chance to change your mind before overwriting PRYOR.HDT. Instead, press **F6**, for *Save Data Set As*. You'll see the following screen:

SAVE DATA	
Default Directory	C:\EQDIR
File Name	.hdt

Type any legitimate DOS file name (i.e., fewer than 8 characters); for example, PRYORMOD, and your altered data will be saved under that name with HDT added as an extension (e.g., PRYORMOD.HDT). The data are saved in ASCII (plain text) format, so can be examined using a text editor or word-processing program. I advise you not to make changes in these data outside this horse simulation program, however, because if you inadvertently change the format of the data file (e.g., by removing a blank line or inserting an extra blank line), the data may not be usable by the horse program. A better way to modify a set of demographic data is to load it into this program, edit it, and then save it with a new name.

Before continuing, let me make one comment about entering a completely new data set. One of the choices on the introductory menu (don't go there now, but look back at the first graphic in this tutorial) is F2 for *Create a New Data Set*. This choice would lead you down the same path we just followed, except that the data entry screens would be filled with 0's instead of the data from Pryor Mountain. You would have to enter your own values for general information, survival probabilities, foaling rates, and sex ratio at birth, then save the data set. If you wanted to experiment with a common set of survival probabilities but several different sets of foaling rates, you would enter all the data and save a file, then edit the foaling rates and save a new file with a different name, etc.

Before this digression, we were looking at the Main Menu. When you have returned to this menu, type F3, to select *Coefficients of Variation*:

Coefficients of Variation	
Foal Mortality	2.000
Adult Mortality	1.700
Foaling Rate	0.200

These numbers are indices of year-to-year variation in foal mortality, adult mortality, and foaling rate for the Pryor Mountain population. Read the rather lengthy help file associated with this screen to see what these indices mean, how they are estimated, and how they are used by the program to mimic environmental stochasticity. When you've viewed all four pages of this help file, return to the Main Menu and select F4 for *Management Options*. You should see the following screen:

MANAGEMENT OPTIONS
Initial Population (F2)
General Specifications (F3)
Removal Parameters (F4)
Contraception Parameters (F5)
Run Simulation (F6)
Output Results (F7)
Exit (F8)

We're finally getting to the heart of the program! The first item in the *Management Options* menu is *Initial Population (F2)*:

INITIAL CONDITIONS
<p>As for most population models, this one requires an initial age/sex distribution in order to run; i.e., number of horses of each sex and age class at the beginning of an experiment. If you DON'T have such data, you may enter an estimate of the total population size at the beginning of a run, and the program will calculate an initial age/sex distribution for use in that run. This calculation assumes that survival probabilities and foaling rates have been constant for several years and that the age structure hasn't been altered by a recent, age-selective removal. Therefore the results of the model will be more accurate if you can enter the actual initial age/sex distribution, rather than just the initial population size. But the former data may not be available in many cases.</p>
<p>Enter or change age/sex distribution (dist) or population size (size) or load distribution from disk (load)? <span style="float: right;">size</span></p>

Suppose you don't know the age distribution of your population this year, because horses haven't been gathered and aged, but that you have an estimate of total population size and are willing to assume that the age distribution is stable.<sup>1</sup> "Size" (in red at the lower right) is the default option that allows you to pick a starting population level. Hit **Enter** and type **150** in the box that appears on the next screen:

Initial population size = 150

Hit **Enter** to accept this value, and examine the new *Initial Age Distribution*. When you are satisfied, hit **Enter**. At this point you will be given the opportunity to save this initial age distribution as a file for future use. If you decide to do so, you will be asked to enter some descriptive information for the file, and then a file name, on the next two screens (not shown here). For now, accept the default choice of "No" and return to the Management Options Menu. Then hit **F3** to set General Management Specifications (see next page).

INITIAL AGE DISTRIBUTION (computed by program)					
Age	Females	Males	Age	Females	Males
0	12	12	13	2	1
1	10	10	14	1	1
2	8	8	15	1	1
3	7	7	16	1	1
4	6	6	17	1	1
5	5	5	18	1	1
6	5	4	19	1	0
7	4	3	20	0	0
8	4	3	21	0	0
9	3	2	22	0	0
10	3	2	23	0	0
11	2	2	24	0	0
12	2	1	25	0	0
<b>TOTAL</b>	<b>79 ♀♀</b>	<b>+ 71 ♂♂</b>	<b>=</b>	<b>150 horses</b>	

<sup>1</sup>A **stable age distribution** is an age distribution that remains the same from year-to-year; i.e., proportions of animals in each age class stay the same, even though total numbers may be increasing at a steady rate. For long-lived animals like wild horses, a stable age distribution may be realized after 20 to 40 years of growth in a constant environment with no management and no density-dependence in mortality or reproduction.

GENERAL MANAGEMENT SPECIFICATIONS	
Gather when population exceeds	250 horses
Reduce population to	100 horses
Are foals included in AML?	yes
Percent of population that can be gathered:	80
Continue gather after reduction to treat ???	yes
Duration of fertility control:	0 years
Percent effectiveness of fertility control	100
Minimum interval between gathers:	1 years

This form allows you to set the general conditions of the simulation. Your first option (flashing cursor) lets you set a threshold population size, above which a gather is done. Type in 250 then hit the ↓ to move to the next field (you can use both ↑ and ↓ to move around this menu). This next field is where you set the target population level (the AML or some proportion of it). Type 100 for this simulation, then hit the Tab key to move to the next field. This option allows you to include or exclude foals from the AML. To change the default, backspace over "yes" and type in "no". Because in most cases not all of the horses in a population can be successfully gathered, you can set the expected percentage of the population that is appropriate for your HMA in the next field. The default is 80%. If you are using fertility control and leave the default value of the next option at "yes", then you will simulate treating all of the females that can be gathered. If you change this value to "no", then each gather will end when the population has been reduced to the target value. This means that less money will have been spent on the gather, but some females may not have been captured and treated. Fertility-control agents that last for >1 year are being tested. By changing the default value of the duration of fertility control from 0 to 1 to 5 years, you include fertility control in the simulation. Set this parameter at "1" for this tutorial. Because chemical fertility control is not perfect, some animals will remain fertile after treatment. The next option allows you to set the efficacy of the contraceptive. Let's make it 80% (backspace over the 100 and type 80) for this tutorial. The final option allows you to space gathers at some minimum interval. For example, it might be unrealistic to gather a population every year, but more feasible to gather it every 3rd year or later if it hadn't yet surpassed the size specified in the first field of this form. Change this minimum interval to 3. Now hit enter to accept the values you have set for the simulation and return to the *Management Options* menu. (Note: To model growth without management, set the first two fields of the General Management Specifications menu to 0).

Now that the general management conditions of the simulation have been set, you can hit **F4** to examine or change *Removal Parameters*. This screen shows the percentage of each age-sex class to be removed. To change any of the default values, move the cursor to the desired age and sex class with the arrow keys, backspace over the old value, and type in the new value. When you are done with your changes hit **Enter** to accept the changes or **Esc** to reset the default values, and return to the *Management Options* menu.

PERCENTAGE OF HORSES TO BE REMOVED					
Age	Females	Males	Age	Females	Males
0	100	100	13	0	0
1	100	100	14	0	0
2	100	100	15	0	0
3	100	100	16	0	0
4	100	100	17	0	0
5	100	100	18	0	0
6	0	0	19	0	0
7	0	0	20	0	0
8	0	0	21	0	0
9	0	0	22	0	0
10	0	0	23	0	0
11	0	0	24	0	0
12	0	0	25	0	0

The final option to be examined before running the simulation is *Contraception Parameters* (F5). This form shows the percentages of each age class that are to be treated with contraceptives. Of course, if duration of fertility control had been set to 0 years on the *General Management Specifications* screen, then these values would be meaningless. Let's leave the default values in place for now and return to the *Management Options* menu by hitting Esc.

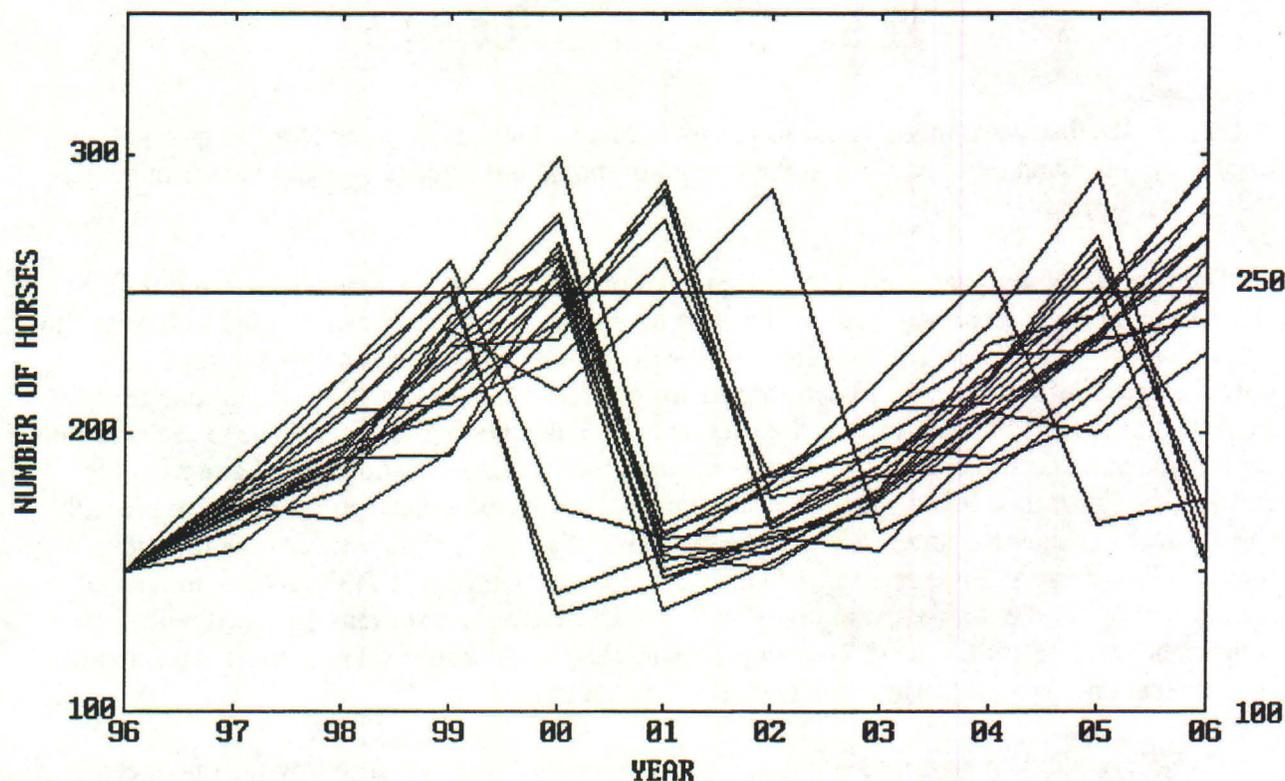
PERCENTAGE OF RELEASED MARES TO BE TREATED			
Age	Percentage	Age	Percentage
0	100	13	100
1	100	14	100
2	100	15	100
3	100	16	100
4	100	17	100
5	100	18	100
6	100	19	100
7	100	20	100
8	100	21	100
9	100	22	100
10	100	23	100
11	100	24	100
12	100	25	100

Now hit F6 for the last step before running the simulation:

RUN PARAMETERS	
Number of trials:	30
Initial calendar year:	1996
Number of years:	10

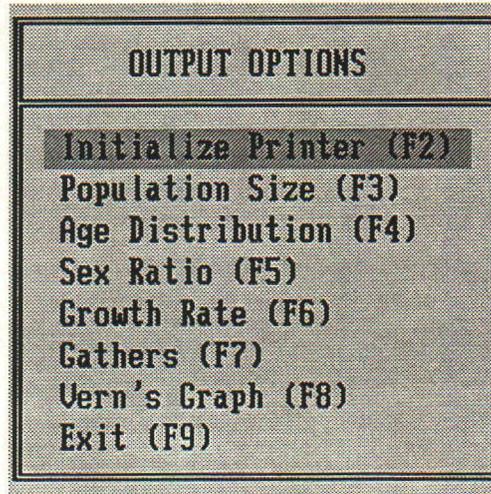
Because this is a stochastic model, each trial will give different results, as survival probabilities and foaling rates are adjusted upward or downward from their average values in successive years to simulate unpredictable variation in environmental conditions from year-to-year. The maximum number of trials is 50. For this tutorial, change the number of trials to 20 so the program will run a bit faster. You can set the initial year to one other than the current one by moving the cursor, backspacing over the default value, and entering the new initial year. You can also change the number of *Years* simulated in each trial. The maximum number of years is 50. Leave the default value at 10 years for now and hit **Enter** to run the simulation.

After a brief delay for calculations to be made, a graph like the one below of population size vs. time will appear on the screen. The actual results of your run will differ from those shown here because this is a stochastic model with mortality and foaling rates selected at random each year. Each red line in this "spaghetti graph" represents a different trial; the output illustrates the range of possible outcomes of population growth taking year-to-year variation in environmental conditions into account. Note the two horizontal blue lines running across the graph. These represent the threshold population size for gather and removal (upper line) and the target population size following removal (lower line). When all the trials are done, the graph is rescaled to show maximum and minimum population sizes for the whole set of trials. At this time you can use the mouse to point to a particular simulation line, click on it (notice the color change), and see which trial it represents. Highlight a few of the trials and make a note of the interesting trial number(s) for later use.



USE MOUSE TO IDENTIFY TRIALS FOR LATER ANALYSIS; ANY KEY TO CONTINUE

When you have finished viewing this output, hit any key to return to the *Management Options* menu. At this menu, type **F7** to *Output Results*, and you will see the following screen:



All results are displayed in graphical form on the screen, but can be saved to a file or sent to a printer by following the directions at the bottom of the output screens or using the on-line help for more information.

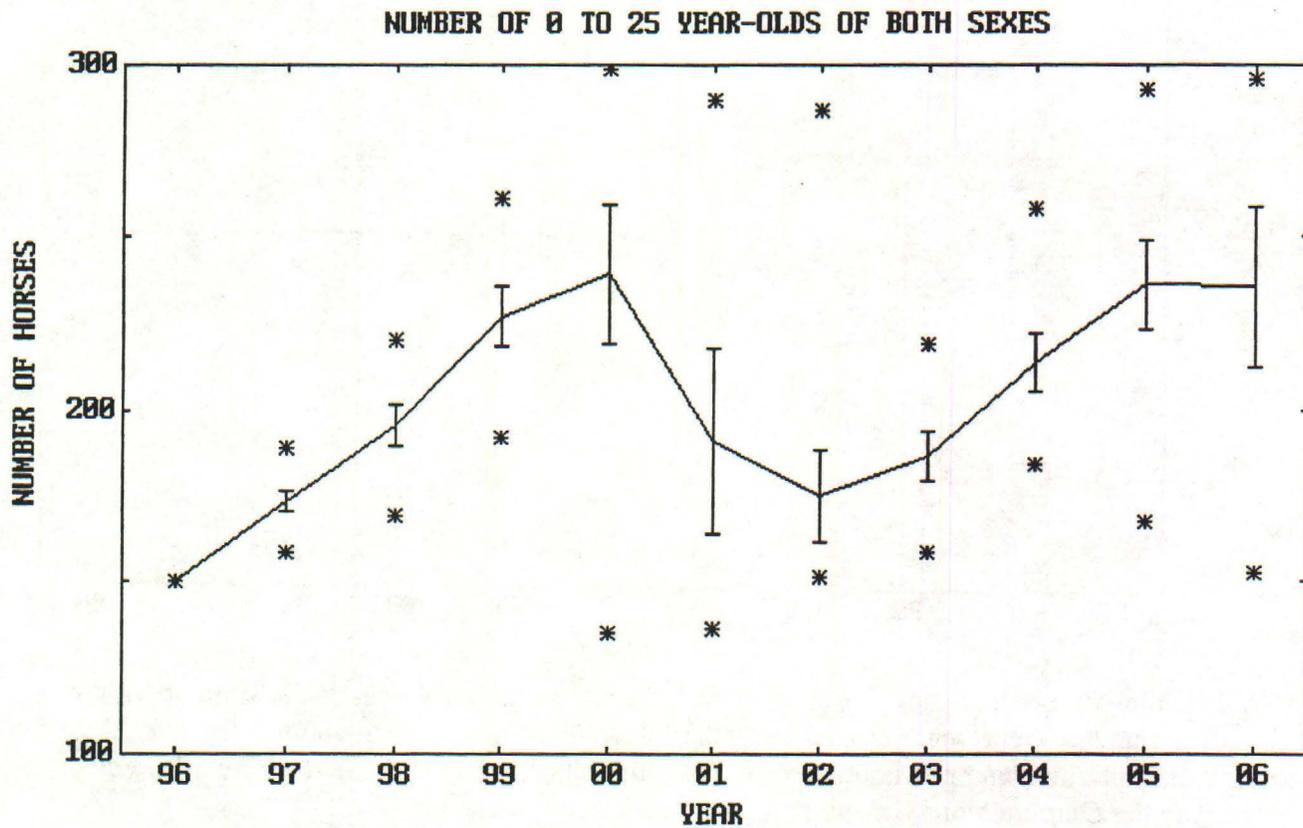
The *Output Options* menu lists the six types of output that can be displayed. *Population Size* (F3) shows changes in average population size over time. This option can be used to look at the entire population or subsets of age and sex classes. *Age Distribution* (F4) allows you to see how the age distribution changed across time for a specific trial or how it varied among trials at a specific time (e.g., the last year of the simulation). This option also allows you to see how the abundance of a specific age class as a proportion of the whole population varied among trials and years. *Sex Ratio* (F5) displays the average sex ratio across time and can be viewed for all age classes or a subset of interest. *Growth Rate* (F6) displays growth rates for the individual trials as well as the average rate for the entire set of trials. *Gathers* (F7) shows the number of animals gathered, the number of animals removed, and the number of mares treated with contraceptives. *Vern's Graph* (F8) depicts the initial age distribution and the most typical and least typical ending age distributions from the simulation.

Before viewing any of the output, hit **F2** (*Initialize Printer*) and follow the on-screen instructions to set up the program to print graphs and tables as desired.

Type F3 to see a graph of *Population Size*. This brings up yet another menu screen:

Do you wish to see data for
<b>both sexes (F2)</b>
females (F3)
males (F4)

As you can see, you can choose to view a graph of the total population (all ages and both sexes, the default), or a graph of a particular age/sex class. Choose both sexes and the default age range (0-25) by hitting **Enter** twice.



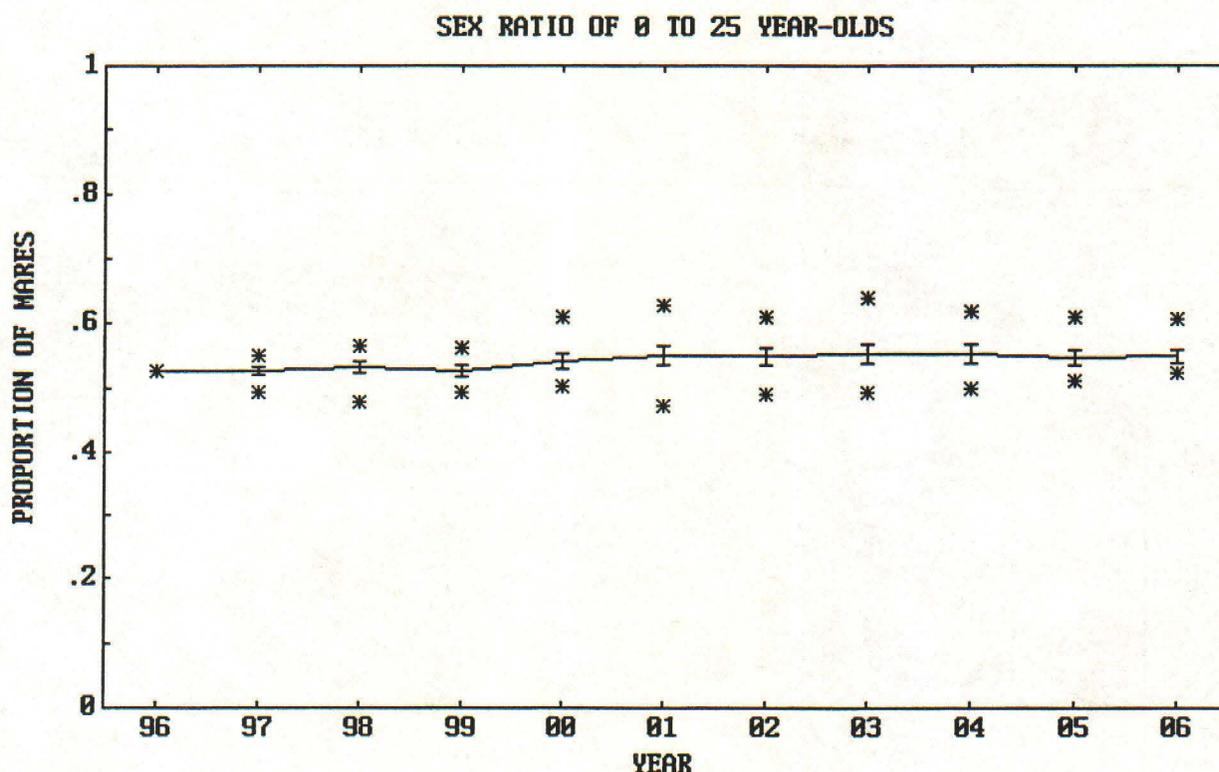
F1 = HELP	t = SHOW TABLE	s = SAVE RESULTS	p = PRINT GRAPH	esc = EXIT
-----------	----------------	------------------	-----------------	------------

In this graph, the broken blue line shows average population size for each year of the simulation, the vertical blue lines represent means  $\pm 1$  standard deviation for each year, and the red asterisks represent minimum and maximum population sizes for the set of trials that were run.

When you are finished looking at this graph, hit **Esc** to return to the *Output Options* menu. If you wish, hit **F3**, then change the sex or age classes to see the dynamics of a subset of the total population. When you are done experimenting, hit **Esc** to return to the *Output Options* menu.

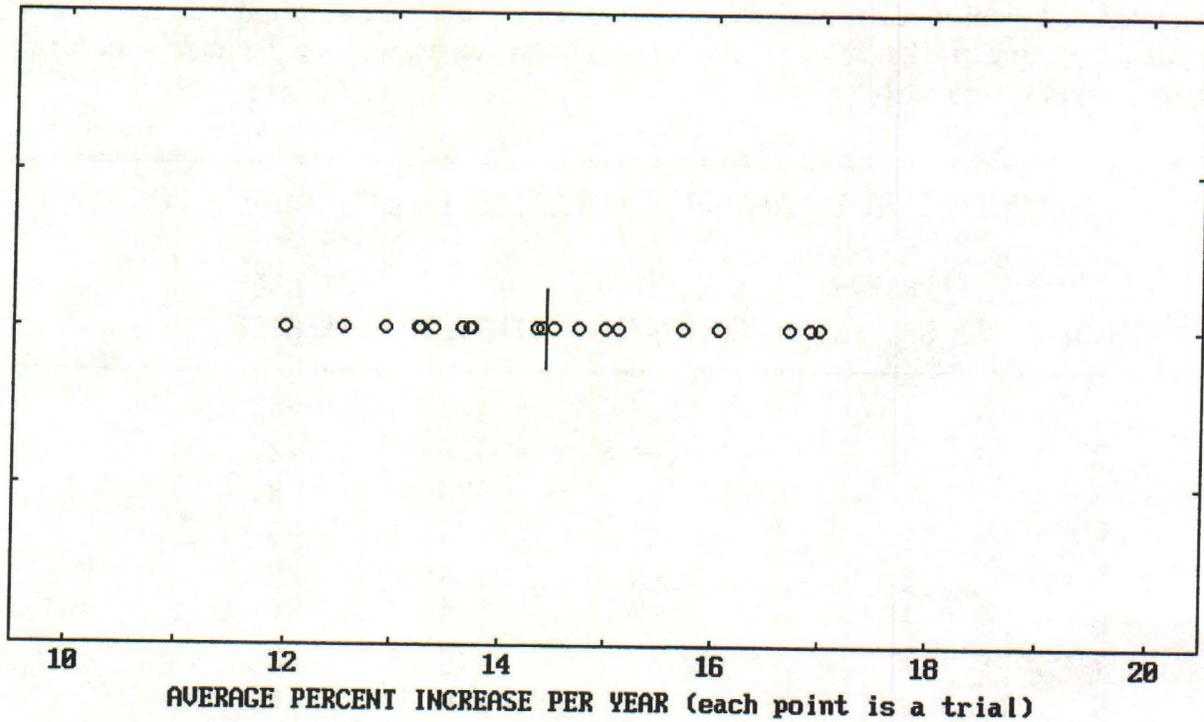
The next thing we'll look at is *Age Distribution* -- hit **F4** to do this, then from the next menu (not shown here), select **F2** for a specific year, **F3** for a particular trial, or **F4** to select a range of ages. Choose a particular trial by hitting **F3** and then entering the number of one of the trials you highlighted earlier. The resulting graph is not shown in this User's Guide because it depends on color to be interpreted, and the colors can't be reproduced here.

Return to the *Output Options* menu and let's examine Sex Ratio (**F5**). You have the option to view all or a subset of age classes. Hit enter to accept the defaults. You will see the following screen:



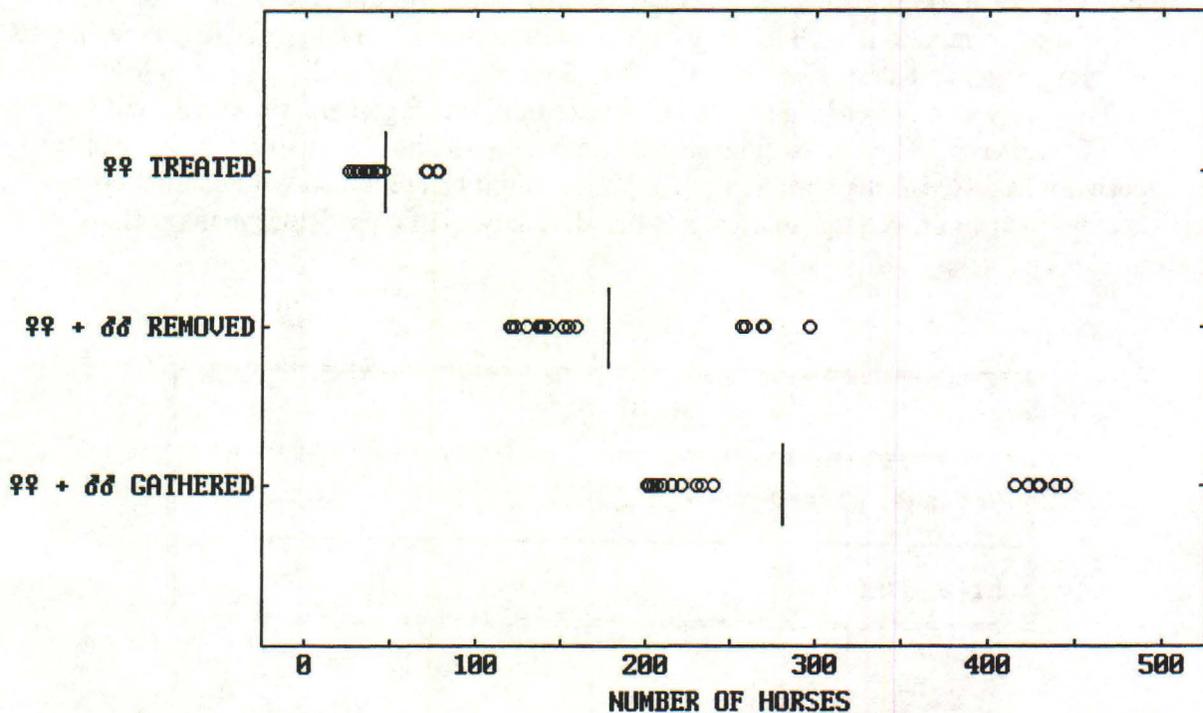
In this graph, the broken blue line shows average sex ratio for each year of the simulation, the vertical blue lines represent means  $\pm 1$  standard deviation for each year, and the red asterisks represent minimum and maximum sex ratios for the set of trials that were run. Now hit **Esc** to return to the *Output Options* menu and hit **F6** for *Growth Rate*.

POPULATION GROWTH RATES IN ALL TRIALS (| = mean)



Notice that there is substantial variation in growth rate among the trials. This is due to the stochasticity built into the model. Now hit **Esc** to return to the *Output Options* menu and hit **F7** for *Gathers*. Here you have the option of viewing results for both sexes and all ages or subsets of the data. Hit **Enter** twice to accept the defaults and see the following graph:

NUMBER OF 0 TO 25 YEAR-OLDS PROCESSED IN EACH TRIAL (| = mean)



Note that there are three sets of data displayed: number of horses gathered, number of horses removed, and number of females treated. The circles represent the values of individual trials while the red lines mark the means. Having seen a few graphs, we should look at some tabular output. Type **t** to select *Table*.

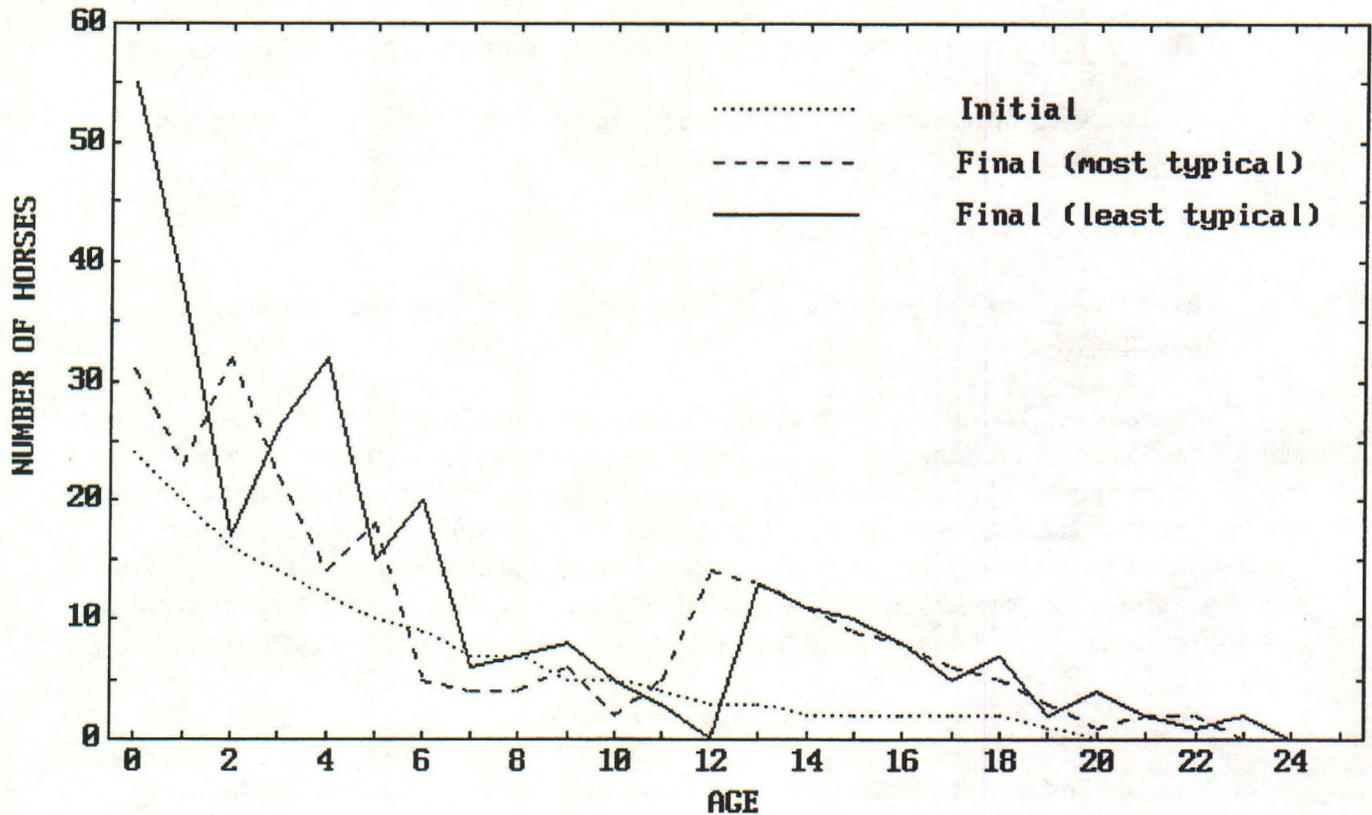
NUMBER OF 0 TO 25 YEAR-OLDS PROCESSED IN EACH TRIAL				
TRIAL	NUMBER OF GATHERS	HORSES GATHERED	HORSES REMOVED	FEMALES TREATED
1	1	230	143	43
2	1	204	136	29
3	1	202	120	31
4	1	221	139	37
5	1	206	136	27
6	1	204	123	36
7	1	215	140	31
8	2	438	268	76
9	1	233	138	42
10	1	210	121	45
11	1	240	158	36
12	2	428	268	69
13	2	415	258	70

This table gives the actual number of horses gathered, number of animals removed, and number of females treated for each trial, as well as means and other summary statistics (you may have to scroll down to see these statistics). You could use this table to compare the cost and effectiveness of simulations with fertility control only, removal only, and fertility control plus removal as management strategies. If you hit **s** to Save Results, you will see the following screen. This allows you to enter a file name to store the data on gathers, removals, and fertility treatment for this run. The data will be stored as a comma-delimited text file, which can easily be imported into a spreadsheet program, where they might be combined with data on costs of various management procedures to do a cost-benefit analysis of a particular management strategy.

SAVE DATA	
Default Directory	C:\EQDIR
File Name	.dat

After saving these results, hit **Esc** to return to the *Output Options* menu, then **F8** for *Vern's Graph*. This graph depicts the initial age distribution together with the most typical and least typical ending age distributions from among all the trials. It aptly illustrates the divergence of population structures due to the stochastic nature of the model.

### INITIAL vs. FINAL AGE DISTRIBUTIONS



This is the end of the tutorial. Hit **Esc** several times in succession to quit the program. I hope you enjoy using the program.

## DATA REQUIREMENTS

This program requires five sets of data about a population in order to do a simulation:

- (1) the initial age distribution, or number of horses in each age/sex class at the start of a simulation.
- (2) survival probabilities for males and females from each age to the next older age.
- (3) age-specific foaling rates; i.e., proportions of females of each age class that produce foals.
- (4) sex-ratio of foals at birth.
- (5) coefficients of year-to-year variation for foal mortality, adult mortality, and foaling rate.

You may not have all these pieces of information for your population, in which case you will have to use values for another population and assume yours is similar or try to make reasonable guesses to fill in the holes in your data. This is a perfectly reasonable procedure as long as you don't assume that the output of the model is exactly what will happen in your population. A good strategy for using the program would be to explore the sensitivity of the results to variation in parameters for which you don't have solid data, and focus future efforts at data collection on those parameters that have the greatest effect on population growth.

### *Initial Age Distribution*

It should be fairly straightforward to get an accurate initial age distribution for your population, if most of the population is gathered and individuals are sexed and aged at the beginning of a study. Although precise aging of animals greater than 10 years old is problematic (Garrott 1991), this shouldn't unduly influence population projections unless age estimates are systematically biased upward or downward.

Here is an example of how to use census and gather data to estimate the initial age distribution for a population. Suppose an aerial census yielded a count of 200 animals. One-hundred and sixty were then gathered, with 100 removed and 60 released. Of the 160 gathered, 8 were 2-year-old females (5%). If the proportion of each age-sex class among horses not gathered is the same as that among those gathered, then we can estimate that 5% of the 40 horses not gathered were 2-year-old females, or 2 of this age-sex class. To this we should add the known number of 2-year-old females that were gathered and released (which may = 0 if all gathered horses  $\leq$  5-years-old were removed). This should be repeated for all age-sex classes, with suitable approximation to obtain whole numbers of horses in each age-sex class (many of these values, especially for older horses, will = 0).

You may only have data on total population size at the beginning of a study, if no gathers have been done recently. The program includes the option of calculating an age/sex distribution based on a total population size entered by the user. If you select this option, the stable-age distribution based on survival probabilities, foaling rates, and sex ratio at birth for your

population is used together with the total population size you enter to compute an initial age distribution for simulating population growth for your population. In the Pryor Mountain stable age distribution, for example, there would be 11% female foals, so if your total population were 200, approximately 22 animals would be classified as female foals. Use of the stable-age distribution depends on the assumption that the population has been growing at a constant rate for 20 to 40 years. See the information screen that appears when you select this option in the program, as well as the associated Help file, for more discussion of the validity of this approach.

### *Survival Probabilities*

Of the fundamental demographic parameters of a population, survival probabilities are often the most difficult to get, especially for long-lived animals such as wild horses. There is a tradition in wildlife biology of converting age ratios collected at one point in time (e.g., from hunter-check stations for deer or roundups of horses) into survival probabilities (Caughley 1974, 1977, Eberhardt 1988, Jenkins 1989). However, if a population is increasing or decreasing in size, this procedure systematically underestimates or overestimates survival probabilities, respectively. Only if a population is constant in size and has remained so for a fairly long time (30-40 years for horses), will the ratios of animals in successive age classes equal survival probabilities. Because the purpose of estimating survival probabilities is usually to build a model to predict potential growth rate of a population, assuming growth rate = 0 in order to calculate survival probabilities is a serious problem!

Here is an example to illustrate why survival probabilities can't be estimated from a standing age distribution without also knowing the population growth rate. Suppose there are 100 one-year-olds and 80 two-year-olds at a census of the population in 1993. If the population is not growing and has been constant long enough to achieve a stable age distribution, then there would have been 100 one-year-olds in 1992, and so the survival probability from age 1 to age 2 =  $80/100 = 0.80$ . But if the population is growing at 12% per year, then there would have been only 89 one-year-olds in 1992 ( $1.12 \times 89 = 100$ ), and the survival probability from age 1 to age 2 would be  $80/89 = 0.90$ . Conversely, if the population is decreasing at 12% per year, there would have been 114 one-year-olds in 1992 ( $0.88 \times 114 = 100$ ), and survival probability of one-year-olds would be  $80/114 = 0.70$ . This shows that a ratio of number of two-year-olds to number of one-year-olds of 0.80 at a given point in time is consistent with survival probabilities for one-year-olds ranging from 0.70 to 0.90 (if we assumed higher or lower growth rates, the range of survival probabilities would be even greater). Thus, although age distribution data are relatively easy to obtain (for example, Garrott [1991] presents age distributions for three sets of horses totaling more than 60,000 animals), these data cannot be translated into survival probabilities as wildlife biologists are often tempted to do.

To get accurate estimates of survival probabilities for wild horses requires keeping track of known individuals over time, to see how long they live. This could be done by gathering a population, aging and marking all individuals, and then following the fates of those individuals over several years, either by intensive field observations or subsequent gathers. If this population model stimulates just one BLM district to set up such a long-term monitoring program, I will consider it a success.

### *Foaling Rates*

Foaling rates are in principal much easier to estimate than survival rates, because they don't necessarily require long-term monitoring of a population. You should bear in mind, however, that foaling rates used by the program are proportions of females of each age class that actually give birth. Therefore pregnancy rates assessed by visual observation, palpation, or hormonal assays (Wolfe et al. 1989, Garrott et al. 1991, Kirkpatrick and Turner 1989) may underestimate foaling rates if done too early in the "reproductive year", before all females have mated, or may overestimate foaling rates if done in the middle of the gestation period because they don't account for fetal losses prior to birth.

### *Sex Ratio*

The program also needs to know sex ratio at birth. This can be estimated by determining sexes of a sample of foals in a population at or shortly after birth. Lacking this information, a sex ratio of 50% male: 50% female could be assumed (although the sex ratio among foals at Pryor Mountain was 40% male: 60% female).

### *Coefficients of Variation*

You may be discouraged by all the data needed to use a population model such as this, but there is one more feature of the model for which it is even more difficult to obtain appropriate data. In discussing survival probabilities and foaling rates above, I have considered variation with age, but not variation from year to year. Yet a realistic model should account for the fact that bad weather in some years may depress survival and foaling rates below average values whereas favorable conditions in other years may increase these rates. This program incorporates such unpredictable variation in environmental conditions by modeling population growth as a stochastic process. It uses coefficients of variation in foal mortality rate, adult mortality rate, and foaling rate to calculate different survival probabilities and foaling rates for each year of a simulation. To estimate these coefficients of variation requires long-term studies such as those at Pryor Mountain, Montana (11 years; Garrott and Taylor 1990), the Granite Range, Nevada (6 years; Berger 1986), and Assateague Island, Maryland and Virginia (8 years; Keiper and Houpt 1984).

If you have long-term demographic data for a population, then the coefficient of variation (CV) for a parameter is the standard deviation divided by the mean value of that parameter. Note that the program uses mortality rates instead of survival probabilities in these computations (mortality rate = 1 - survival probability). For example, if adult survival probabilities (all age classes combined) in five years are 0.95, 0.90, 0.75, 0.95, and 0.85, then corresponding mortality rates are 0.05, 0.10, 0.25, 0.05, and 0.15. Mean mortality rate is 0.12 and the standard deviation of mortality rate is 0.08, so the coefficient of variation =  $0.08/0.12 = 0.67$ .

Lacking long-term demographic data, you may use coefficients of variation for Pryor Mountain, which are the defaults for the program. These CV's are quite large (greater than 1 for both foal and adult mortality rate), reflecting the fact that there was one very bad winter at Pryor Mountain when mortality rate increased from less than 10% to about 50%. Alternatively, you may set CV's at 0, to run a simulation without environmental stochasticity. An interesting

experiment is to see how population growth (with no management) responds to variation in coefficients of variation. With high CV's, the range of ending population sizes will clearly be greater. How do high CV's influence average ending population sizes? Which has the strongest influence: a high coefficient of variation in adult mortality, foal mortality, or foaling rate? In making these comparisons, keep in mind that the maximum possible value of foaling rate CV is less than maxima for foal and adult mortality rates, because the mean is greater for the former and CV's depend on both the mean and standard deviation of a parameter. The maximum for foaling rate is probably about 0.5, whereas maxima for mortality rates are in the range of 2 to 3.

It may be worth re-emphasizing that the program is essentially simulating year-to-year variation in weather and other environmental factors by incorporating year-to-year variation in mortality and foaling rates. If we knew how winter snowfall, for example, influenced mortality rate and how winter snowfall varied from year-to-year, then we could take a more direct approach to modeling the effects of environmental stochasticity on horses. But we don't have good concrete data on the relationships between particular environmental factors and feral horse demography, so the program simply uses year-to-year variation in mortality and reproduction to model environmental stochasticity, and thus bypasses the need to know the mechanisms by which the environment affects horses. If we could write an equation relating, for example, mortality rate to winter snowfall, then we might have a more robust model because there are longer records of winter snowfall than of feral horse demography. But it seems probable that the relationship of feral horse survival and reproduction to environmental factors is quite complex, unlikely to be captured in a simple equation.

## MANAGEMENT OPTIONS

With one important exception, the program is quite flexible in the range of management options that can be specified by the user. The program implements management by simulating gathers when the population exceeds a target level. At each gather, horses of one or both sexes are removed from the population and females to be released back are treated with a contraceptive, assuming you set conditions for removal and fertility treatment.

Before running a simulation, you specify the minimum interval in years between gathers, the target population size which will trigger a gather, the size to which the population will be reduced, and various other management options. You don't have the option of varying the gathering schedule or conditions for fertility treatment and removal in the middle of a simulation. There are two reasons for this limitation: (1) to do otherwise would have made the program much more complex, and (2) because this is a stochastic model, an unexpectedly low (or high) population size in a particular year may result from random environmental variation rather than an ill-timed gather. The best use of the program is not to let it determine optimal management decisions for you but to use it for experiments to learn how various management choices interact with demographic characteristics of a population and stochastic environmental variation to influence population growth.

### *Fertility Control*

Pilot studies are underway to determine the effectiveness in the field of an immunocontraceptive developed by Turner, Kirkpatrick, and colleagues (Liu et al. 1989, Kirkpatrick et al. 1990, Turner and Kirkpatrick 1991). In captive animals, this contraceptive

prevents pregnancy for about one year. This is represented in the program by specifying the percent effectiveness of fertility control in the *General Specifications* form. If you thought all females could be treated successfully, this percentage would be 100%; more realistic would be a value less than 100% to account for females for whom the treatment doesn't work.

You will soon discover from running the program that a one-year contraceptive doesn't contribute much to stabilizing population size. Therefore you have the option of simulating the effects of longer-lasting contraceptives on population growth. If current research designed to lengthen the lifespan of immunocontraceptives is successful, or if BLM reconsiders the use of hormonal implants which can prevent pregnancy for several years (Eagle et al. 1992, Garrott et al. 1992, Plotka et al. 1992), then simulations with longer-lasting contraceptives will reflect viable management options.

When experimenting with fertility control, bear in mind that the percentages of released mares to be treated in the *Contraception Parameters* form are only relevant if the duration of fertility control (in *General Management Specifications*) is  $> 0$  years. If the duration of fertility control is left at its default value of 0 years, then there is no fertility control, regardless of any values  $> 0\%$  in the *Contraception Parameters* form.

### *Removal*

The program enables you to reduce the population to a target value (carrying capacity or AML) at each gather. Reducing the population to a target value is similar to actual management practice, because such target values are calculated for each Herd Management Area based on forage availability and other factors.

Removing horses to a target value is a form of adaptive management. The number of horses to be removed is calculated at each gather based on the population size at that time and the target value. If the population is below the target value, no horses will be removed. If the population is above the target value and the age range for removal is set at 0 to 25, then the number of horses removed = population size - target value. If a more limited age range for removal is specified, then the population won't be decreased to the target value at each gather unless there are enough horses in this age range to do so.

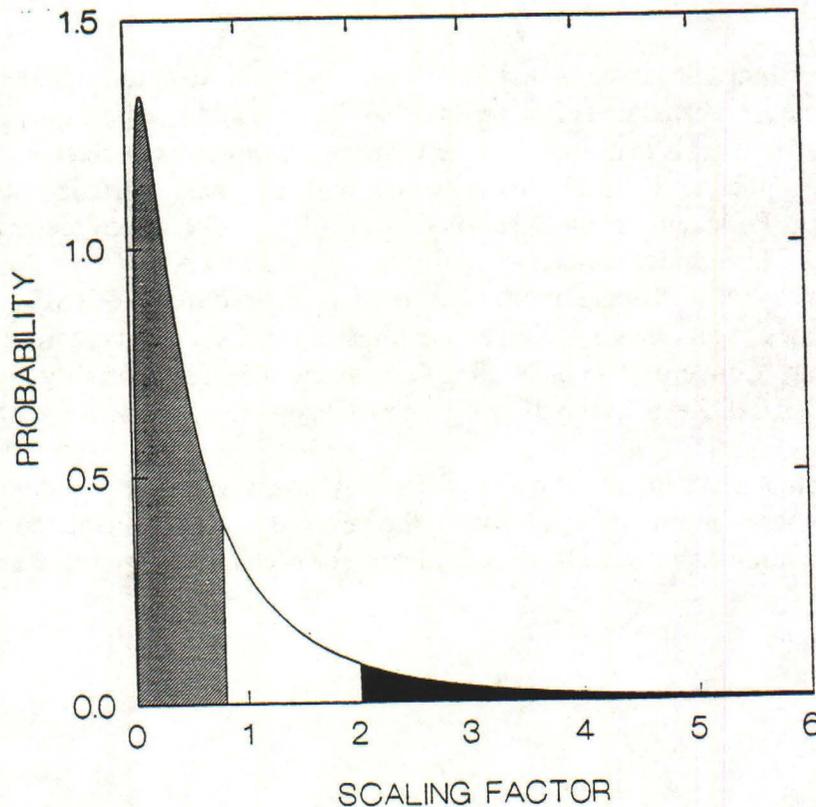
## HOW THE PROGRAM WORKS

Any computer program uses three fundamental process to do its job: **sequential** operations, **repetitive** operations, and **branching** based on values of decision variables. I'll describe how this program works in terms of these three processes.

The steps described below are repeated for each year of a trial, and then for each trial of a simulation run. Results are different for each trial because random numbers are used to simulate environmental and demographic stochasticity (these concepts are described more fully below). The population is censused in summer, immediately after the foaling season, and so for purposes of the model each year goes from mid-summer to mid-summer, say July 1st to the following June 30th. Here are the steps that are performed in sequence for each year:

(1) If this is a gathering year, then individuals are gathered and processed one-by-one, in random sequence by age and sex. If a horse is in an age-sex group to be gathered (based on the *Removal Parameters* form), then a decision is made to remove it or not based on keeping the percentage of that age-sex class removed as close as possible to the specified value. For example, if 50% of 3-year-old males are to be removed, then every other 3-year-old male gathered is removed. This process is continued until the target population size (the second field of the *General Management Specifications* form) is achieved or the gathering limit is reached (for example, if the total population size at the time of a gather = 300 and the percentage of the population that can be gathered = 80% [the default], then the gathering limit = 240). Treatment of individual females for fertility control is handled similarly. If the option to "continue gather after reduction to treat ♀♀" on the *General Management Specifications* form is set at "yes", then the gather continues until the gathering limit is reached; otherwise, the gather stops when the population has been reduced to the target size.

(2) Next, a scaling factor is calculated which will be multiplied by the mean mortality rate of each age class to simulate environmental stochasticity. This scaling factor is selected at random from a lognormal distribution with a mean of 1 and a standard deviation (SD) equal to the coefficient of variation (CV) of adult mortality rate supplied by the user (since  $CV = SD/\text{mean}$ ,  $SD = CV$  when the mean = 1). A lognormal distribution is one in which the logarithms of a set of numbers are normally distributed, i.e., exhibit a bell-shaped curve. If the numbers themselves, rather than their logs, are plotted on the x-axis, the distribution will have an extended right tail compared to a normal distribution which is symmetrical around the mean. The reason for using a lognormal distribution to simulate environmental stochasticity is that such a distribution fits the Pryor Mountain data fairly well, and there are no other records of mortality rates for wild horses as long as the 11 years of data for Pryor Mountain. A lognormal distribution with mean = 1.0 and SD = 1.7 (reflecting year-to-year variation in adult mortality rate at Pryor Mountain) looks like this:



The probability of picking a scaling factor less than 0.8 is the hatched area under the curve to the left of 0.8 on the x-axis; this probability = 0.656. The probability of picking a scaling factor greater than 2.0 is the shaded area under the curve to the right of 2.0 on the x-axis: 0.116. The probability of picking a scaling factor between 0.8 and 2.0 is the area under the curve between 0.8 and 2.0 on the x-axis: 0.228. Other probabilities can be determined similarly. An example of a random sequence of 19 scaling factors selected from this distribution is 0.86, 4.81, 6.24, 0.15, 3.72, 0.56, 0.32, 0.43, 2.04, 0.16, 0.14, 0.48, 0.18, 0.10, 0.57, 0.35, 0.08, 1.57, and 0.59. These scaling factors would be applied to mean mortality rates in 19 successive years of a simulation trial.

(3) I assume that a bad year for adult survival is also a bad year for foal survival, and vice versa. This makes sense if the major cause of year-to-year variation is the same for both foals and adults, e.g., winter weather conditions. This assumption is implemented by making the scaling factor for foal mortality perfectly correlated with that for adult mortality. The following formula is used to compute the value for foals:

$$f_{foal} = 1 + \frac{CV_{foal}}{CV_{ad}} (f_{ad} - 1)$$

where  $CV_{foal}$  and  $CV_{ad}$  are coefficients of variation of foal and adult mortality, respectively, and  $f_{foal}$  and  $f_{ad}$  are scaling factors for foal and adult mortality. This formula says that if the scaling factor for adults is, for example, 2 standard deviations above the mean, then it will be 2 standard deviations above the mean for foals also. For Pryor Mountain, a scaling factor for adult mortality of 4.4 would be 2 standard deviations above the mean scaling factor of 1.0, since SD for adults = 1.7 and  $1.0 + 2 \times 1.7 = 4.4$ . This would translate to a scaling factor of 5.0 for foals, since their SD = 2.0 and  $1 + (2.0/1.7) \times (4.4 - 1) = 5.0$ .

(4) Next, mortality is simulated for 24-year-old males to determine the number of 25-year-old males at the next census. This is repeated for 24-year-old females, then 23-year-olds, etc., all the way down to foals that survive to be yearlings. For each age class, the scaling factor described above is applied to the mean mortality rate to get an actual mortality rate for a given year of a given trial. For example, mean survival probability of 3-year-old males at Pryor Mountain is 0.965. This implies a mean mortality rate =  $1 - 0.965 = 0.035$ . If the scaling factor for the current year is 4.4, then actual mortality rate of 3-year-old males this year =  $4.4 \times 0.035 = 0.154$ . Mortality rates of all other age classes are adjusted similarly. This represents a moderately bad year. Conversely, if the scaling factor were 0.7, then mortality rate of 3-year-old males would be  $0.7 \times 0.035 = 0.024$ , indicating a better-than-average year for survival.

Once the actual mortality rate for an age/sex class in a given year of a given trial is calculated, the number of animals that survive to the next older age class is determined as follows. A random number between 0 and 1 is picked for each animal, and that animal dies if

the random number is less than the actual mortality rate for its age class and lives otherwise.<sup>2</sup>

To continue the example from the previous paragraph, if the mortality rate of 3-year-old males in a given year of a given trial is 0.154 and there are 40 3-year-old males in the population, then the expected number of survivors to the next year is  $(1-0.154) \times 40 = 33.84$ . However, the actual number of survivors obviously has to be an integer -- it may be possible to have 0.84 of a horse, but unlikely that this partial horse would be alive! What the 0.154 mortality rate really means is that each horse has a probability = 0.154 of dying before the next census; the most realistic way to simulate this process is to have each individual horse either live or die according to probabilities of 0.846 and 0.154, respectively. This is called demographic stochasticity, in contrast with the unpredictable year-to-year variation in mortality rates, or environmental stochasticity, discussed above.

(5) Now surviving animals are one year older and we've progressed to the foaling season just before next year's census. Each individual female has an expected foaling probability based on its age, or a foaling probability of 0 if it was successfully treated with a fertility-control drug 2 years ago (for a drug lasting one year) or  $\geq 2$  years ago (for a longer-lasting drug).<sup>3</sup> The foaling probability is further adjusted for year-to-year variation (environmental stochasticity) in the same manner as mortality rates were adjusted, but using the coefficient of variation of foaling rate instead of the CV for adult mortality or juvenile mortality. This means that year-to-year variation in foaling rate is uncorrelated with year-to-year variation in mortality. This reflects the situation at Pryor Mountain, although in other habitats a severe winter which caused increased mortality might also contribute to a reduced foaling rate the next summer.

For each female in each age class, a random number between 0 and 1 is selected; if that number is less than the probability of having a foal, she does so. The sex of that foal is determined similarly, based on the proportion of males among foals at birth. Finally, the number of male and female foals produced by mothers of all ages are added up to give the total number of male and female foals produced in each year of each trial.

This completes one year of one trial, and these steps are now repeated for all years of every trial, with results saved for later visualization in various forms. One thing that may be puzzling as you watch the population grow and decline is that it may rarely reach the target population size, or AML, even immediately after a gather. The reason for this is that there is a foaling season between each gather and the next census, so even if the population was reduced to the target value by the gather, it may not be reduced much further by overwinter mortality and rebound to a level above the target value by the next census.

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<sup>2</sup>To visualize this process, imagine a ruler 1 meter long. Divide the ruler into two segments with lengths determined by probabilities of living or dying. For example, if mortality rate is 0.1, then the portion of the ruler from 0 to 0.1 m would represent death and the proportion from 0.1 to 1.0 m would represent remaining alive. Picking a random number from 0 to 1 is equivalent to placing a mark at a random location on the ruler. If the mark is to the left of 0.1 (i.e., the random number is less than 0.1), the individual dies; otherwise it lives.

<sup>3</sup>If an immunocontraceptive is given to a pregnant female, it won't cause her to abort that offspring, but prevent her from becoming pregnant in the next breeding season, and so prevent her from having a foal two years hence.

## ADDITIONAL COMMENTS

### *Population Trajectories*

When you select **Run Simulation** from the Management Options menu, you will see how the population grows over time in each trial. The variation among trials results from both environmental and demographic stochasticity. If you set all coefficients of variation equal to zero, the variation seen on this graph will reflect only demographic stochasticity.

When viewing this graph, you may notice abrupt declines in population size at periodic intervals. These result from removal of animals at each gather.

I purposely designed the program so that this is the only output you are required to look at (all other output is optional), because this graph is a vivid demonstration of how random variation influences population growth. I think it's essential that wildlife managers become comfortable with the idea that precise, specific predictions of population trajectories are unrealistic.

### *Saving Results*

In addition to viewing and printing output, you can save results as disk files. Tables are saved as comma-delimited text files. Although these are somewhat difficult to read if viewed using a text editor or word-processing program, a major benefit of saving files of results in this format is that they can be imported directly into a spreadsheet program, using the commas to separate the fields in the spreadsheet. If you do this, you will see that numerical results are lined up in columns, with appropriate labels. These output files typically have more details than do results shown on the screen, either as graphs or tables. They also all contain a section near the bottom showing all of the demographic data and management specifications used for the run that produced the output. Once you have imported the results into a spreadsheet, you can do further numerical manipulations with these results; e.g., a cost analyses of gathers, removals, and fertility treatment. See Appendix 1 for an example of an output file produced by the program, and Appendix 2 for an example of this file after it has been imported into a spreadsheet.

### *Format of Files Containing Demographic and Age-Distribution Data*

Although I urge you to use the program to create the files containing basic demographic data (survival probabilities, foaling rates, sex ratio at birth) and initial age distributions, these can be examined and modified using an ASCII (plain text) editor. As an example of a demographic file, here is how the demographic data for the Pryor Mountains appear in *pryors.hdt*. The important things about the structure of this file are: (1) There are exactly 8 lines of text before the numerical data (the 7th of these is blank). (2) There are 25 lines of numerical data, each with 4 values: age, male survival probability from that age to the next, female survival probability from that age to the next, and foaling rate of females of that age. (3) These numerical data are followed by a blank line, then the final line of the file which has some explanatory text followed by the proportion of males at birth. (4) The first line of the file contains the file name, the next line contains the description from the General Information screen, and the next 4 lines contain the notes from the General Information screen. (5) The age classes must be arranged in order from 0 to 25. Survival probability of 25-year-old males and

females must = 0.

pryors.hdt

Pryor Mountain data

Long-term data from Pryor Mountain, MT

(1976-1986; Garrott, R. A. and L. Taylor, 1990,  
Dynamics of a feral horse population in Montana  
Journal of Wildlife Management 54:603-612.)

age	male surv	fem surv	foal rate
0	.921	.948	.000
1	.965	.994	.000
2	.965	.994	.000
3	.965	.994	.410
4	.965	.994	.410
5	.965	.994	.410
6	.964	.993	.550
7	.964	.993	.550
8	.964	.993	.550
9	.963	.992	.550
10	.962	.991	.550
11	.961	.990	.470
12	.959	.988	.470
13	.957	.986	.470
14	.952	.981	.470
15	.946	.975	.470
16	.936	.965	.470
17	.922	.949	.470
18	.900	.927	.470
19	.866	.894	.470
20	.821	.845	.470
21	.754	.777	.470
22	.663	.683	.470
23	.543	.560	.470
24	.402	.414	.470
25	.000	.000	.470

Proportion males at birth = .400

Here is an example of a file containing an initial age distribution, for a different population. It is called *garfield.adt*. The first line is the file name. The next line is the description from the General Information screen. The next 4 lines are the notes from the General Information screen. In this case, the user didn't supply any notes in the first 3 of these, so these lines are blank. The 4th line in this section is supplied by the program and tells the source of the initial age distribution. The 3 choices for this line of text are "Initial age distribution supplied by user", "Initial age distribution computed by program", and "Initial age distribution computed; modified". The next line contains a code for the source of the initial age distribution. A code of "01" means "supplied by user", "10" means "computed by program", and "11" means "computed; modified". The file must contain all 7 of these lines, followed by a blank line, followed by another text line which is a header for the numerical data. Following the header line that reads "age males females", there are 25 lines of data, each with 3 numbers representing age, number of males in the initial age distribution, and number of females in the initial age distribution. Ages must be listed from 0 to 25 in order.

garfield.adt  
Garfield Flat age distribution, 1996.

Initial age distribution supplied by user.  
code: 01

age	males	females
0	38	23
1	35	31
2	25	22
3	8	20
4	10	15
5	8	7
6	6	11
7	7	9
8	1	3
9	3	3
10	3	5
11	6	0
12	1	0
13	5	3
14	0	0
15	8	1
16	0	0
17	0	0
18	4	2
19	0	0
20	0	0
21	2	1
22	0	0
23	2	1
24	0	0
25	2	0

Do you agree that it will be easier to let the program create these files for you, instead of trying to make sure you get them formatted correctly?

#### ACKNOWLEDGMENTS

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## APPENDIX 1

This is a sample of a comma-delimited text file of gather results produced by the program. These data came from a different run than illustrated in the tutorial portion of this user's guide, so won't correspond to the snapshots of screens shown earlier in the guide.

RESULTS (see below for simulation parameters)

### NUMBER OF 0 TO 25 YEAR-OLDS PROCESSED IN EACH TRIAL

,Total,Horses,Horses, Females

Trial,# Gathers,Gathered,Removed,Treated

1, 2, 457, 283, 75  
2, 1, 240, 151, 36  
3, 2, 428, 250, 72  
4, 1, 236, 144, 48  
5, 2, 428, 276, 66  
6, 1, 220, 144, 32  
7, 1, 207, 137, 35  
8, 2, 443, 272, 84  
9, 2, 448, 276, 72  
10, 1, 232, 143, 38  
11, 1, 201, 122, 33  
12, 1, 203, 136, 31  
13, 2, 404, 257, 69  
14, 2, 418, 252, 81  
15, 1, 213, 134, 33  
16, 1, 220, 143, 34  
17, 1, 221, 132, 38  
18, 1, 205, 136, 32  
19, 2, 434, 265, 74  
20, 1, 209, 138, 31

MEANS, 1.4, 303, 190, 51

MINIMA, 1, 201, 122, 31

MAXIMA, 2, 457, 283, 84

LO LIMIT,, 252, 159, 41, (95% confidence limit)

HI LIMIT,, 354, 220, 60,(95% confidence limit)

### GATHERS BY TRIAL AND YEAR FOR AGE/SEX CLASSES SHOWN ABOVE

Trial, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006

1, 0, 0, 0, 0, 240, 0, 0, 0, 0, 217, 0  
2, 0, 0, 0, 0, 0, 240, 0, 0, 0, 0, 0  
3, 0, 0, 0, 0, 221, 0, 0, 0, 0, 207, 0  
4, 0, 0, 0, 0, 0, 0, 236, 0, 0, 0, 0  
5, 0, 0, 0, 0, 204, 0, 0, 0, 0, 224, 0  
6, 0, 0, 0, 0, 220, 0, 0, 0, 0, 0, 0

7, 0, 0, 0, 0, 207, 0, 0, 0, 0, 0, 0  
 8, 0, 0, 0, 0, 222, 0, 0, 0, 0, 221, 0  
 9, 0, 0, 0, 0, 220, 0, 0, 0, 0, 228, 0  
 10, 0, 0, 0, 0, 0, 232, 0, 0, 0, 0, 0  
 11, 0, 0, 0, 0, 201, 0, 0, 0, 0, 0, 0  
 12, 0, 0, 0, 0, 203, 0, 0, 0, 0, 0, 0  
 13, 0, 0, 0, 0, 201, 0, 0, 0, 0, 0, 203, 0  
 14, 0, 0, 0, 0, 0, 217, 0, 0, 0, 0, 201, 0  
 15, 0, 0, 0, 0, 213, 0, 0, 0, 0, 0, 0  
 16, 0, 0, 0, 0, 220, 0, 0, 0, 0, 0, 0  
 17, 0, 0, 0, 0, 0, 221, 0, 0, 0, 0, 0  
 18, 0, 0, 0, 0, 205, 0, 0, 0, 0, 0, 0  
 19, 0, 0, 0, 0, 217, 0, 0, 0, 0, 0, 217, 0  
 20, 0, 0, 0, 0, 0, 209, 0, 0, 0, 0, 0, 0

**REMOVALS BY TRIAL AND YEAR FOR AGE/SEX CLASSES SHOWN ABOVE**

Trial, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006

1, 0, 0, 0, 0, 152, 0, 0, 0, 0, 131, 0  
 2, 0, 0, 0, 0, 0, 151, 0, 0, 0, 0, 0  
 3, 0, 0, 0, 0, 137, 0, 0, 0, 0, 113, 0  
 4, 0, 0, 0, 0, 0, 144, 0, 0, 0, 0, 0  
 5, 0, 0, 0, 0, 128, 0, 0, 0, 0, 148, 0  
 6, 0, 0, 0, 0, 144, 0, 0, 0, 0, 0, 0  
 7, 0, 0, 0, 0, 137, 0, 0, 0, 0, 0, 0  
 8, 0, 0, 0, 0, 144, 0, 0, 0, 0, 128, 0  
 9, 0, 0, 0, 0, 139, 0, 0, 0, 0, 137, 0  
 10, 0, 0, 0, 0, 0, 143, 0, 0, 0, 0, 0  
 11, 0, 0, 0, 0, 122, 0, 0, 0, 0, 0, 0  
 12, 0, 0, 0, 0, 136, 0, 0, 0, 0, 0, 0  
 13, 0, 0, 0, 0, 129, 0, 0, 0, 0, 0, 128, 0  
 14, 0, 0, 0, 0, 0, 142, 0, 0, 0, 0, 110, 0  
 15, 0, 0, 0, 0, 134, 0, 0, 0, 0, 0, 0  
 16, 0, 0, 0, 0, 143, 0, 0, 0, 0, 0, 0  
 17, 0, 0, 0, 0, 0, 132, 0, 0, 0, 0, 0  
 18, 0, 0, 0, 0, 136, 0, 0, 0, 0, 0, 0  
 19, 0, 0, 0, 0, 136, 0, 0, 0, 0, 129, 0  
 20, 0, 0, 0, 0, 0, 138, 0, 0, 0, 0, 0, 0

**FEMALES TREATED BY TRIAL AND YEAR FOR AGE CLASSES SHOWN ABOVE**

Trial, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006

1, 0, 0, 0, 0, 39, 0, 0, 0, 0, 36, 0  
 2, 0, 0, 0, 0, 0, 36, 0, 0, 0, 0, 0  
 3, 0, 0, 0, 0, 36, 0, 0, 0, 0, 36, 0  
 4, 0, 0, 0, 0, 0, 48, 0, 0, 0, 0, 0  
 5, 0, 0, 0, 0, 30, 0, 0, 0, 0, 36, 0  
 6, 0, 0, 0, 0, 32, 0, 0, 0, 0, 0, 0  
 7, 0, 0, 0, 0, 35, 0, 0, 0, 0, 0, 0

8, 0, 0, 0, 0, 37, 0, 0, 0, 0, 47, 0  
 9, 0, 0, 0, 0, 37, 0, 0, 0, 0, 35, 0  
 10, 0, 0, 0, 0, 0, 38, 0, 0, 0, 0, 0  
 11, 0, 0, 0, 0, 33, 0, 0, 0, 0, 0, 0  
 12, 0, 0, 0, 0, 31, 0, 0, 0, 0, 0, 0  
 13, 0, 0, 0, 33, 0, 0, 0, 0, 0, 36, 0  
 14, 0, 0, 0, 0, 0, 38, 0, 0, 0, 43, 0  
 15, 0, 0, 0, 0, 33, 0, 0, 0, 0, 0, 0  
 16, 0, 0, 0, 0, 34, 0, 0, 0, 0, 0, 0  
 17, 0, 0, 0, 0, 0, 38, 0, 0, 0, 0, 0  
 18, 0, 0, 0, 32, 0, 0, 0, 0, 0, 0, 0  
 19, 0, 0, 0, 0, 35, 0, 0, 0, 0, 39, 0  
 20, 0, 0, 0, 0, 31, 0, 0, 0, 0, 0, 0

gather when pop. exceeds:,,, 250  
 pop. size after gather:,,, 100  
 foals included in AML?,,, YES  
 percent to gather:,,, 80  
 continue for fert treat?,,, YES  
 duration fertility control:,,, 1  
 % efficacy fert. control:,,, 80  
 trials:,,, 20  
 years:,,, 10  
 initial calendar year:,,, 1996  
 coeff. var. foal mortality:,,, 2  
 coeff. var. adult mortality:,,, 1.7  
 coeff. var. foaling rate:,,, .2  
 source of age distribution:,,, computed by program  
 prop. male @ birth,,, .5  
 , init. age dist.,, surv. prob.,, foal. rate, % to take,, % to treat  
 age, female, male, female, male,, female, male,  
 0, 12, 12, .948, .921, 0, 100, 100, 100  
 1, 10, 10, .994, .965, 0, 100, 100, 100  
 2, 8, 8, .994, .965, 0, 100, 100, 100  
 3, 7, 7, .994, .965, .41, 100, 100, 100  
 4, 6, 6, .994, .965, .41, 100, 100, 100  
 5, 5, 5, .994, .965, .41, 100, 100, 100  
 6, 5, 4, .993, .964, .55, 0, 0, 100  
 7, 4, 3, .993, .964, .55, 0, 0, 100  
 8, 4, 3, .993, .964, .55, 0, 0, 100  
 9, 3, 2, .992, .963, .55, 0, 0, 100  
 10, 3, 2, .991, .962, .55, 0, 0, 100  
 11, 2, 2, .99, .961, .47, 0, 0, 100  
 12, 2, 1, .988, .959, .47, 0, 0, 100  
 13, 2, 1, .986, .957, .47, 0, 0, 100  
 14, 1, 1, .981, .952, .47, 0, 0, 100  
 15, 1, 1, .975, .946, .47, 0, 0, 100

16, 1, 1, .965, .936, .47, 0, 0, 100  
17, 1, 1, .949, .922, .47, 0, 0, 100  
18, 1, 1, .927, .9, .47, 0, 0, 100  
19, 1, 0, .894, .866, .47, 0, 0, 100  
20, 0, 0, .845, .821, .47, 0, 0, 100  
21, 0, 0, .777, .754, .47, 0, 0, 100  
22, 0, 0, .683, .663, .47, 0, 0, 100  
23, 0, 0, .56, .543, .47, 0, 0, 100  
24, 0, 0, .414, .402, .47, 0, 0, 100  
25, 0, 0, 0, 0, .47, 0, 0, 100

## APPENDIX 2

These are the data of Appendix 1 after being imported into a spreadsheet. I used Quattro Pro and imported the text file using the "only commas" format, but you could accomplish the same thing with Lotus, Excel, or another spreadsheet program. Once you have the data in a spreadsheet, you could create formulae to calculate expected costs of gathers, removals, and fertility treatment.

RESULTS (see below for simulation parameters)												
NUMBER OF 0 TO 25 YEAR-OLDS PROCESSED IN EACH TRIAL												
Trial	Total # Gathers	Horses Gathered	Horses Removed	Females Treated								
1	2	457	283	75								
2	1	240	151	36								
3	2	428	250	72								
4	1	236	144	48								
5	2	428	276	66								
6	1	220	144	32								
7	1	207	137	35								
8	2	443	272	84								
9	2	448	276	72								
10	1	232	143	38								
11	1	201	122	33								
12	1	203	136	31								
13	2	404	257	69								
14	2	418	252	81								
15	1	213	134	33								
16	1	220	143	34								
17	1	221	132	38								
18	1	205	136	32								
19	2	434	265	74								
20	1	209	138	31								
MEANS	1.4	303	190	51								
MINIMA	1	201	122	31								
MAXIMA	2	457	283	84								
LO LIMIT		252	159	41	(95% confidence limit)							
HI LIMIT		354	220	60	(95% confidence limit)							
GATHERS BY TRIAL AND YEAR FOR AGE/SEX CLASSES SHOWN ABOVE												
Trial	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
1	0	0	0	0	240	0	0	0	0	217	0	
2	0	0	0	0	0	240	0	0	0	0	0	
3	0	0	0	0	221	0	0	0	0	207	0	
4	0	0	0	0	0	0	236	0	0	0	0	
5	0	0	0	0	204	0	0	0	0	224	0	
6	0	0	0	0	220	0	0	0	0	0	0	
7	0	0	0	0	207	0	0	0	0	0	0	
8	0	0	0	0	222	0	0	0	0	221	0	
9	0	0	0	0	220	0	0	0	0	228	0	
10	0	0	0	0	0	232	0	0	0	0	0	
11	0	0	0	0	201	0	0	0	0	0	0	
12	0	0	0	0	203	0	0	0	0	0	0	
13	0	0	0	201	0	0	0	0	0	203	0	
14	0	0	0	0	0	217	0	0	0	201	0	

15	0	0	0	0	213	0	0	0	0	0	0
16	0	0	0	0	220	0	0	0	0	0	0
17	0	0	0	0	0	221	0	0	0	0	0
18	0	0	0	205	0	0	0	0	0	0	0
19	0	0	0	0	217	0	0	0	0	217	0
20	0	0	0	0	209	0	0	0	0	0	0

REMOVALS BY TRIAL AND YEAR FOR AGE/SEX CLASSES SHOWN ABOVE

Trial	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	0	0	0	0	152	0	0	0	0	131	0
2	0	0	0	0	0	151	0	0	0	0	0
3	0	0	0	0	137	0	0	0	0	113	0
4	0	0	0	0	0	0	144	0	0	0	0
5	0	0	0	0	128	0	0	0	0	148	0
6	0	0	0	0	144	0	0	0	0	0	0
7	0	0	0	0	137	0	0	0	0	0	0
8	0	0	0	0	144	0	0	0	0	128	0
9	0	0	0	0	139	0	0	0	0	137	0
10	0	0	0	0	0	143	0	0	0	0	0
11	0	0	0	0	122	0	0	0	0	0	0
12	0	0	0	0	136	0	0	0	0	0	0
13	0	0	0	129	0	0	0	0	0	128	0
14	0	0	0	0	0	142	0	0	0	110	0
15	0	0	0	0	134	0	0	0	0	0	0
16	0	0	0	0	143	0	0	0	0	0	0
17	0	0	0	0	0	132	0	0	0	0	0
18	0	0	0	136	0	0	0	0	0	0	0
19	0	0	0	0	136	0	0	0	0	129	0
20	0	0	0	0	138	0	0	0	0	0	0

FEMALES TREATED BY TRIAL AND YEAR FOR AGE CLASSES SHOWN ABOVE

Trial	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	0	0	0	0	39	0	0	0	0	36	0
2	0	0	0	0	0	36	0	0	0	0	0
3	0	0	0	0	36	0	0	0	0	36	0
4	0	0	0	0	0	0	48	0	0	0	0
5	0	0	0	0	30	0	0	0	0	36	0
6	0	0	0	0	32	0	0	0	0	0	0
7	0	0	0	0	35	0	0	0	0	0	0
8	0	0	0	0	37	0	0	0	0	47	0
9	0	0	0	0	37	0	0	0	0	35	0
10	0	0	0	0	0	38	0	0	0	0	0
11	0	0	0	0	33	0	0	0	0	0	0
12	0	0	0	0	31	0	0	0	0	0	0
13	0	0	0	33	0	0	0	0	0	36	0
14	0	0	0	0	0	38	0	0	0	43	0
15	0	0	0	0	33	0	0	0	0	0	0
16	0	0	0	0	34	0	0	0	0	0	0
17	0	0	0	0	0	38	0	0	0	0	0

18	0	0	0	32	0	0	0	0	0	0	0
19	0	0	0	0	35	0	0	0	0	39	0
20	0	0	0	0	31	0	0	0	0	0	0
gather when pop. exceeds:		250									
pop. size after gather:		100									
foals included in AML?		YES									
percent to gather:		80									
continue for fert treat?		YES									
duration fertility control:		1									
% efficacy fert. control:		80									
trials:		20									
years:		10									
initial calendar year:		1996									
coeff. var. foal mortality:		2									
coeff. var. adult mortality:		1.7									
coeff. var. foaling rate:		0.2									
source of age distribution:		computed by program									
prop. male @ birth		0.5									
init. age dist.		surv. prob.		foal. rate		% to take		% to treat			
age	female	male	female	male		female	male				
0	12	12	0.948	0.921	0	100	100	100			
1	10	10	0.994	0.965	0	100	100	100			
2	8	8	0.994	0.965	0	100	100	100			
3	7	7	0.994	0.965	0.41	100	100	100			
4	6	6	0.994	0.965	0.41	100	100	100			
5	5	5	0.994	0.965	0.41	100	100	100			
6	5	4	0.993	0.964	0.55	0	0	100			
7	4	3	0.993	0.964	0.55	0	0	100			
8	4	3	0.993	0.964	0.55	0	0	100			
9	3	2	0.992	0.963	0.55	0	0	100			
10	3	2	0.991	0.962	0.55	0	0	100			
11	2	2	0.99	0.961	0.47	0	0	100			
12	2	1	0.988	0.959	0.47	0	0	100			
13	2	1	0.986	0.957	0.47	0	0	100			
14	1	1	0.981	0.952	0.47	0	0	100			
15	1	1	0.975	0.946	0.47	0	0	100			
16	1	1	0.965	0.936	0.47	0	0	100			
17	1	1	0.949	0.922	0.47	0	0	100			
18	1	1	0.927	0.9	0.47	0	0	100			
19	1	0	0.894	0.866	0.47	0	0	100			
20	0	0	0.845	0.821	0.47	0	0	100			
21	0	0	0.777	0.754	0.47	0	0	100			
22	0	0	0.683	0.663	0.47	0	0	100			
23	0	0	0.56	0.543	0.47	0	0	100			
24	0	0	0.414	0.402	0.47	0	0	100			
25	0	0	0	0	0.47	0	0	100			