Appendix C - Population Modeling

Population Model Overview

WinEquus is a program to simulate the population dynamics and management of wild horses created by Stephen H. Jenkins of the Department of Biology, University of Nevada at Reno. For further information about this model, you may contact Stephen H. Jenkins at the Department of Biology/314, University of Nevada, Reno, NV 89557.

The following data was summarized from the information provided within the WinEquus program, and will provide background about the use of the model, the management options that may be used, and the types of output that may be generated.

The population model for wild horses was designed to help wild horse and burro specialists evaluate various management strategies that might be considered for a particular area. The model uses data on average survival probabilities and foaling rates of horses to project population growth for up to 20 years. The model accounts for year-to-year variation in these demographic parameters by using a randomization process to select survival probabilities and foaling rates for each age class from a distribution of values based on these averages. This aspect of population dynamics is called environmental stochasticity, and reflects the fact that future environmental conditions that may affect wild horse population's demographics can't be established in advance. Therefore each trial with the model will give a different pattern of population growth. Some trials may include mostly "good" years, when the population grows rapidly; other trials may include a series of several "bad" years in succession. The stochastic approach to population modeling uses repeated trials to project a range of possible population trajectories over a period of years, which is more realistic than predicting a single specific trajectory.

The model incorporates both selective removal and fertility treatment as management strategies. A simulation may include no management, selective removal, fertility treatment, or both removal and fertility treatment. Wild horse and burro specialists can specify many different options for these management strategies such as the schedule of gathers for removal or fertility treatment, the threshold population size which triggers a gather, the target population size following a removal, the ages and sexes of horses to be removed, and the effectiveness of fertility treatment.

To run the program, one must supply an initial age distribution (or have the program calculate one), annual survival probabilities for each age-sex class of horses, foaling rates for each age class of females, and the sex ratio at birth. Sample data are available for all of these parameters. Basic management options must also be specified.

Descriptions/Definitions of terms used in the Population Model

Population Data: Age-Sex Distribution

An important point about the initial age-sex distribution is that it is NOT necessarily the starting population for each of the trials in a simulation. This is because the program assumes that the initial age-sex distribution supplied on this form or calculated from a population size that the user enters is not an exact and complete count of the population. For example, if the user enters an initial population size of 100 based on an aerial survey, this is really an estimate of the population, not a census. Furthermore, it is likely to be an underestimate, because some horses will be missed in the survey. Therefore, the program uses an average sighting probability of approximately 90% (Garrott et al. 1991) to "scale-up" the initial population estimate to a starting population size for use in each trial. This is done by a random process, so the starting population sizes are different for all trials. An option does exist to consider the initial population size to be exact and bypass this scaling-up process.

Population Data: Survival Probabilities

A fundamental requirement for a population model such as this is data on annual survival probabilities of each age class. The program contains files of existing sets of survival, or it is possible to enter a new set of data in the table.

In most cases, Wild Horse and Burro Specialists don't have information on survival probabilities for their populations, so the sample data files provided with WinEquus are used and assume that average survival probabilities in the populations are similar. These data are more difficult to get than is often assumed, because they require keeping track of known individuals over time. A "snapshot" of a population, providing information on the age distribution at a single gather, can NOT be used to estimate survival probabilities without assuming a particular growth rate for the population (Jenkins1989). More data from long-term studies of marked horses are needed to develop estimates of survival in various habitats.

Population Data: Foaling Rates

Foaling rates are the proportions of females in each age class that produce a foal at that age. Files are available within the program that contains existing sets of foaling rates, or the user may enter a new set of data in the table. The user may also enter the sex ratio at birth, another necessary parameter for population simulation.

Environmental Stochasticity

For any natural population, mortality and reproduction vary from year to year due to unpredictable variation in weather and other environmental factors. This model mimics such environmental stochasticity by using a random process to increase or decrease survival probabilities and foaling rates from average values for each year of a simulation trial. Each trial uses a different sequence of random values, to give different results for population growth. Looking at the range of final population sizes in many such trials will give the user an indication of the range of possible outcomes of population growth in an uncertain environment.

How variable are annual survival probabilities and foaling rates for wild horses? The longest study reporting such data was done at Pryor Mountain, Montana by Garrott and Taylor (1990). Based on 11 years of data at this site, survival probability of foals and adults combined was greater than 98% in 6 years, between 90 and 98% in 3 years, 87% in 1 year, and only 49% in 1 year of severe winter weather. These values clearly aren't normally distributed, but can be approximated by a logistic distribution. This pattern of low mortality in most years but markedly higher mortality in occasional years of bad weather was also reported by Berger (1986) for a site in northwestern Nevada. Therefore, environmental stochasticity in this model is simulated by drawing random values from logistic distributions. If desired, different values can be entered to change the scaling factors for environmental stochasticity.

Because year-to-year variation in weather is likely to affect foals and adults similarly, this model makes foal and adult survival perfectly correlated. This means that when survival probability of foals is high, so is survival probability of adults, and vice versa. By contrast, the correlation between survival probabilities and foaling rates can be adjusted to any value between -1 and +1. The default correlation is 0 based on the Pryor Mountain data and the assumption that most mortality occurs in winter and winter weather is not highly correlated with foaling-season weather.

The model includes another form of random variation, called demographic stochasticity. This means that mortality and reproduction are random processes even in a constant environment; i.e., a foaling rate of 40% means that each female has a 40% chance of having a foal. Because of demographic stochasticity, even if scaling factors for both survival probabilities and foaling rates were set equal to 0, different runs of the simulation would produce different results. However, variation in population growth due to demographic stochasticity will be small except at low population sizes.

Gathering Schedule

There are three choices for the gather schedule: gather at a regular interval, gather at a minimum interval (the default), or gather in specific years. Gathering at a minimum interval means that gathers will be conducted no more frequently than a prescribed interval (e.g., 3 years), but will not be conducted if the time interval has passed unless the population is above a threshold size that triggers a gather.

Gather interval

This is the number of years between gathers.

Gather for fertility treatment regardless of population size?

If this option is selected (the default), then gathers occur according to the gathering schedule specified regardless of whether or not the population exceeds a threshold population size. One effect of this is that a minimum-interval schedule really functions as a regular interval.

Continue gather after reduction to treat females?

Continuing a gather after a reduction to treat females (with fertility control management options) means that, if a gather for a removal has been triggered because the population has exceeded a threshold population size, then horses will continue to be processed even after enough have been removed to reduce the population to the target population size. As additional horses are processed, females, to be released back, will be treated with an immunocontraceptive according to the information specified in the Contraceptive Parameters form.

Threshold for gather

The threshold population size for triggering a gather is the actual population size in a particular year estimated by the program. This is NOT the same as the number of horses counted in an aerial census, but closer to an estimate of population size taking into account the fact that an aerial census typically underestimates population size.

Target population size

This is the goal for the population size following a gather and removal. Horses will be removed until this target is reached, although it may not be possible to achieve this goal, depending on the removal parameters (percentages of each age-sex class to be removed) and gathering efficiency.

Are foals included in AML?

In most districts, foals are counted as part of the appropriate management level (AML).

Gathering efficiency

Typically, some horses will successfully resist being gathered, either by hiding in habitats where they can't be seen or moved by a helicopter, or following escape routes that make it dangerous or uneconomical for them to be herded from the air. These horses aren't available for removals or fertility treatment. The default gathering efficiency is 80%, meaning that the program assumes that 20% of the population will successfully resist being gathered. This value may be changed.

Note that the program assumes that horses of all age-sex classes are equally likely to be able to be gathered. This is an unrealistic assumption because bachelor males, for example, may be more likely to successfully avoid being gathered than females or foals or band stallions.

Sanctuary-bound horses

Age-selective removals typically target younger age classes such as 0 to 5-year-olds or 0 to 9-year-olds because these horses are more easily adopted. However, it may not be possible to reduce the population to a target size by restricting removals to these younger age classes, especially if age-selective removals have been conducted in the past. In this case, an option is available to remove older animals as well, who may be destined for permanent residence in a long term holding facility rather than for adoption. The minimum age of these long term holding facility horses is specified for this element. When older age classes as well as younger age classes are identified for removal on the Removal Parameters form, horses of these older age classes are selected along with younger age class horses as the population is reduced to the target value. If a minimum age for long term holding facility horses is specified, then older animals are only removed if the population can't be reduced to the target population size by removing the younger ones.

Percent Effectiveness of fertility control

These percentages represent the percentage of treated females that are in fact sterile for one year, two years, etc. (i.e., the efficacy or effectiveness of fertility treatment). The default values are 90% efficacy for one year. However, the user may specify the effectiveness year by year, for up to five years.

Removal Parameters

This allows the user to determine the percentages of horses in each sex and age class to be removed during a gather. The program uses these percentages to determine the probabilities of removing each horse that is processed during a gather. If the percentage for an age-sex class is 100%, then all horses of that age-sex class that are processed will be removed until the target population size is reached. If the percentage for an age-sex class is 0%, then all horses of that age-sex class will be released. If the percentage for an age-sex class is greater than 0% but less than 100%, then the proportion of horses of that age-sex class removed will be approximately equal to the specified percentage.

Contraception Parameters

This allows the user to specify the percentage of released females of each age class that will be treated with an immunocontraceptive. The default values are 100% of each age class, but any or all of these may be changed.

Most Typical Trial

This is the trial that is most similar to each of the other trials in a simulation

Population Size Table

The default is both sexes and all age classes, but summary results may also be chosen for a subset of the population. The table identifies some key numbers such as the lowest minimum in all trials, the median minimum, and the highest minimum. Thinking about the distribution of minima for example, half of the trials have a minimum less than the median of the minima and half have a minimum greater than the median of the minima. If the user was concerned about applying a management strategy that kept the population above some level, because the population might be at risk of losing genetic diversity if it were below this level, then one might look at the 10th percentile of the minima, and argue that there was only a 10% probability that the population would fall below this size in x years, given the assumptions about population data, environmental stochasticity, and management that were used in the simulation.

Gather Table

The default is both sexes and all age classes, but summary results may be for a subset of the population. The table shows key values from the distribution of the minimum total number of horses gathered, removed, and (if one elected to display data for both sexes or just for females) treated with a contraceptive across all trials. This output is probably the most important representation of the results of the program in terms of assessing the effects of your management strategy because it shows not only expected average results but also extreme results that might be possible. For example, only 10% of the trials would have entailed gathering fewer animals than shown in the row of the table labeled "10th percentile", while 10% of the trials would have entailed gathering more than shown in the row labeled "90th percentile". In other words, 80% of the time one could expect to gather a number of horses between these 2 values, given the assumptions about survival probabilities, foaling rates, initial age-sex distribution, and management options made for a particular simulation

Growth Rate

This table shows the distribution of the average population growth rate. The direct effects of removals are not counted in computing average annual growth rates, although a selective removal may change the average foaling rate or survival rate of individuals in the population (e.g., because the age structure of the population includes a higher percentage of older animals), which may indirectly affect the population growth rate. Fertility control clearly should be reflected in a reduction of population growth rate.

Population Modeling – Fifteenmile HMA

To complete the population modeling for the Fifteenmile HMA, version 1.40 of the WinEquus program was utilized.

Objectives of Population Modeling

Review of the data output for each of the simulations provided many useful comparisons of the possible outcomes for each alternative. Some of the questions that need to be answered through the modeling include:

- Do any of the Alternatives "crash" the population?
- What effect does fertility control have on population growth rate?
- What effects do the different alternatives have on the average population size?
- What effects do the different alternatives have on the genetic health of the herd?

Population Data, Criteria, and Parameters utilized for Population Modeling

Initial age structure for the current herd was developed from age structure data collected during the 2000 Fifteenmile HMA wild horse gather. Following the 2000 gather, approximately 64 horses remained in the HMA that were not captured. A total of 72 captured horses were released back into the HMA. The age and sex of the released horses was known. The age and sex of the horses not captured was estimated based on the population structure of all horses captured during the removal effort.

The wild horse population model was used to scale the population upward to 186 horses, which is the number of horses observed during the latest inventory in the winter of 2003. The following table displays the estimated age structure for the Fifteenmile wild horse herd in 2003:

Fifteenmile Age Structure

Age Class	Estimated 2003		
	Female	Male	Total
Foals	18	17	35
1	7	6	13
2	14	10	24
3	5	12	17
4	11	10	21
5	5	1	6
6	4	2	6
7	3	7	10
8	6	5	11
9	4	7	11
10-14	7	17	24
15-19	1	6	7
20+	0	1	1
Total	85	101	186

The estimated 2003 population was used in the population modeling simulations. All simulations used the survival probabilities, foaling rates, and sex ratio at birth supplied with the WinEquus population model for the Garfield Range HMA (granites_berger.sin & granites_berger.fin). This data was extracted from, "Wild Horses of the Great Basin", by J. Berger (1986, University of Chicago Press, Chicago, IL, xxi + 326 pp.). It is based on Joel Berger's 6 year study in the Granite Range HMA in northwestern Nevada.

Survival probabilities and foaling rates utilized in the population model for three alternatives analyzed, including the Proposed Action and No Action Alternatives, and are displayed in the following table:

Survival Probabilities and Foaling Rates

Age Class	Survival Probabilities		Foaling Rates
	Females	Males	
Foals	.917	.917	0
1	.969	.969	0
2	.951	.951	.35
3	.951	.951	.40
4	.951	.951	.65
5	.951	.951	.75
6	.951	.951	.85
7	.951	.951	.90
8	.951	.951	.90
9	.951	.951	.90
10-14	.951	.951	.85
15-19	.951	.951	.70
20+	.951	.951	.70

The following is the sex ratio at birth utilized in the population modeling for Alternatives 1-3:

Sex ratio at Birth:

57% Males
43% Females

The following table displays the removal parameters utilized in the population model for Alternatives 1 and 2:

Removal Criteria
(Alternatives 1 and 2)

Age	Percentages for Removals	
	Females	Males
Foal	90%	90%
1	90%	90%
2	90%	90%
3	90%	90%
4	90%	90%
5	10%	10%
6	10%	10%
7	10%	10%
8	10%	10%
9	10%	10%
10-14	90%	90%
15-19	90%	90%
20+	90%	90%

To date, one herd area has been studied using the 2-year PZP vaccine. The Clan Alpine study, in Nevada, was started in January 2000 with the treatment of 96 mares. The test resulted in fertility rates in treated mares of 6% year one, 18% year two and 32% year three. This data must be compared to normal fertility rates in untreated mares of 50/60% in most populations. The Clan Alpine fertility rate in untreated mares collected in September of each year by direct observation averaged 51% over the course of the study.

The following percent effectiveness of fertility control was utilized in the population modeling for Alternative 2:

Year 1: 94%

Year 2: 82%

Year 3: 68%

The following table displays the contraception parameters utilized in the population model for Alternative 2:

Contraception Criteria
(Alternative 2)

Age	Percentages for Fertility Treatment
Foal	100%
1	100%
2	100%
3	100%
4	100%
5	75%
6	75%
7	75%
8	75%
9	75%
10-14	100%
15-19	100%
20+	100%

Population Modeling Criteria

The following summarizes the population modeling criteria that are common to the Alternatives:

- Starting Year: 2003
- Initial gather year: 2004
- Gather interval: minimum interval of three years
- Gather for fertility treatment regardless of population size: No
- Continue to gather after reduction to treat females: Yes
- Sex ratio at birth: 43% female, 57% male
- Percent of the population that can be gathered: 90%
- Minimum age for long term holding facility horses: 10 years old
- Foals are NOT included in the AML
- Simulations were run for ten years with 50 trials each

The following table displays the population modeling parameters utilized in the model:

Population Modeling Parameters

Modeling Parameter	Alternative 1 – Proposed Action Remove to 70 Mature Horses	Alternative 2 - Remove to 70 Mature Horses with Fertility Control	Alternative 3 - No Action No Removal & No Fertility Control
Management by removal only	Yes	No	N/A
Management by removal with fertility control	No	Yes	N/A
Threshold population size for gathers	160	160	N/A
Target population size following gathers	70	70	N/A
Foals included in AML	No	No	N/A
Gather for fertility control regardless of population size	No	No	N/A
Gathers continue after removals to treat additional females	No	Yes	N/A
Effectiveness of Fertility Control: year 1	N/A	92%	N/A
Effectiveness of Fertility Control: year 2	N/A	84%	N/A
Effectiveness of Fertility Control: year 3	N/A	68%	N/A

Population Modeling Results

Population size in ten years

Out of 50 trials in each simulation, the model tabulated minimum, average, and maximum population sizes. The model was run from 2004 to 2013 to determine what the potential effects would be on population size for the Proposed Action and Alternatives. These numbers are useful to make relative comparisons of the different alternatives, and potential outcomes under different management options. The data displayed within the tables is broken down into different levels. The lowest trial, highest trial, and several in between are displayed for each simulation completed. According to the creator of the modeling program, this output is probably the most important representation of the results of the program in terms of assessing the effects of proposed management, because it shows not only expected average results but also extreme results that might be possible.

Population Sizes in 11 years - Minimum

Alternative	Proposed Action	2	3
Lowest Trial	70	54	187
10th Percentile	79	85	190
25th Percentile	84	89	195
Median Trial	**94**	**94**	**204**
75th Percentile	100	101	218
90th Percentile	106	106	230
Highest Trial	114	136	248

This table shows that in eleven years and 50 trials for each alternative, the lowest number of 0-20+ year old horses ever obtained was 54 under Alternative 2. Half of the trials were greater than the median and half were less than the median. Additional interpretation may be made by comparing the various percentile points. For example, for the Proposed Action (selective removal to 70 mature horses), only 10% of the trials resulted in fewer than 79 wild horses as the minimum population, and 10% of the trials resulted in a minimum population larger than 106 wild horses. In other words, 80% of the time, one could expect a minimum population between these two values for the Proposed Action, given the assumptions about survival probabilities, foaling rates, initial age-sex distribution, and management options made for this simulation.

The Proposed Action (selective removal to 70 mature horses) and Alternative 2 (selective removal to 70 mature horses with fertility control) reflect the lowest minimum population size of all the alternatives. Alternative 3 (No Action) reflects the highest minimum population level of all of the trials.

None of the results obtained for any of the alternatives indicate that a crash of the population is likely to occur if the alternative were implemented. The level to which the population is gathered appears to be more of an influence to the population size than fertility control. The lowest population size ever obtained (54 head) is less than the lower level of the current management range of 70 mature wild horses. However, for 90% of the time the simulation indicates that the population would be 85 head or more, which is slightly higher than the lower level of the management range. However, the simulation results for Alternative 2 indicate that the lowest minimum population falls very near the level that genetic testing has indicated that genetic viability in the herd could be lost (< 50 animals).

Population Sizes in 11 years - Average

Alternative	Proposed Action	2	3
Lowest Trial	122	142	338
10th Percentile	142	144	374
25th Percentile	149	147	400
Median Trial	**155**	**154**	**444**
75th Percentile	161	159	516
90th Percentile	169	168	559
Highest Trial	186	181	645

This table displays the average population sizes obtained for the 50 trials ran for each alternative. The average population size across eleven years ranged from a low of 154 wild horses under Alternative 2, to a high of 444 wild horses under Alternative 3. The average population sizes indicated for the Proposed Action and Alternative 2 are nearly identical. This tends to indicate that when the population is gathered to the same number of horses, fertility control would have very little affect on the average population size.

Population Sizes in 11 years - Maximum

Alternative	Proposed Action	2	3
Lowest Trial	205	198	490
10th Percentile	221	220	621
25th Percentile	229	231	679
Median Trial	**242**	**244**	**788**
75th Percentile	254	255	1007
90th Percentile	270	286	1108
Highest Trial	324	350	1393

This table displays the largest populations that could be expected out of 50 trials for each alternative. The figures for the Lowest Trial represent what the population is likely to be in 2014. All figures are very similar under the Proposed Action and Alternative 2 because the same starting population, gather efficiency, etc., is assumed. The numbers vary due to randomness and assumptions inherent to the modeling program.

Average Growth Rates in ten years

Average growth rates were obtained by running the model for 50 trials from 2004 to 2014 for the Proposed Action and each alternative. The following table displays the results obtained from the model:

Average Growth Rate in 10 Years

Alternative	Proposed Action	2	3
Lowest Trial	7.2%	7.2%	9.0%
10th Percentile	12.2%	10.1%	11.5%
25th Percentile	14.3%	12.0%	12.8%
Median Trial	**16.7%**	**13.8%**	**14.1%**
75th Percentile	18.4%	15.7%	17.2%
90th Percentile	20.3%	16.7%	18.3%
Highest Trial	23.5%	21.8%	20.5%

As expected, Alternative 2, which implements fertility control, reflects the lowest overall median growth rate. For the median trial, Alternative 2 indicates a growth rate that is 2.9% lower than the Proposed Action and only 0.3% lower than the No Action Alternative. The lowest trial growth rates do not appear to be a direct result of the management options, but appear to reflect the random nature of the model and the ability to show extremes in possible outcomes. The range of growth rates is a reasonable representation of what could be expected to occur in a wild horse population.

Totals in eleven years – Gathered, Removed and Treated

The same type of tabular data was obtained from the population model (50 trials) for the numbers of wild horses gathered, removed, and treated under each alternative, over a ten year period. Under each alternative involving removals of wild horses (Alternatives 1 and 2), the population model indicates that two gathers would be necessary over the next ten year period, beginning with the proposed gather in 2004. For the Proposed Action, a second gather would be required in 2009, while under Alternative 2 a second gather would not be required until 2010 or 2011. This is due to the fact that Alternative 2, which implements fertility control, indicates a slightly lower growth rate than the Proposed Action. Under Alternative 3, no wild horses would be gathered or removed from the HMA.

Totals in 11 Years -- Gathered

Alternative	Proposed Action	2	3
Lowest Trial	175	157	0
10th Percentile	322	302	0
25th Percentile	336	358	0
Median Trial	**349**	**372**	**0**
75th Percentile	372	383	0
90th Percentile	434	415	0
Highest Trial	572	458	0

Totals in 11 Years -- Removed

Alternative	Proposed Action	2	3
Lowest Trial	110	100	0
10th Percentile	207	190	0
25th Percentile	217	221	0
Median Trial	**234**	**236**	**0**
75th Percentile	253	249	0
90th Percentile	294	272	0
Highest Trial	388	283	0

Totals in 11 Years – Treated

Alternative	Proposed Action	2	3
Lowest Trial	0	23	0
10th Percentile	0	35	0
25th Percentile	0	39	0
Median Trial	**0**	**43**	**0**
75th Percentile	0	46	0
90th Percentile	0	49	0
Highest Trial	0	59	0

The number of horses gathered does not differ greatly between the Proposed Action and Alternative 2, because gather criteria is the same for all alternatives. The number of horses removed over the ten year period also does not differ greatly between these alternatives. Again, under Alternative 3, no wild horses would be gathered, removed, or treated.

Population Modeling Summary – Fifteenmile HMA

Population Modeling Summary

To summarize the results obtained by simulating the range of alternatives for the proposed Fifteenmile HMA wild horse gather, the original questions can be addressed.

- Do any of the Alternatives "crash" the population?

None of the alternatives indicate that a "crash" is likely to occur to the population. Minimum population levels and growth rates are all within reasonable levels, and adverse impacts to the population are not likely. The only potential concern is the lowest minimum population size indicated under Alternative 2. A minimum population size of 54 horses would fall very near the level that genetic testing has indicated that genetic viability in the herd could be lost (< 50 animals).

- What effect does fertility control have on population growth rate?

Alternative 2 also reflects the lowest overall median growth rate, although by a small margin. For the median trial, Alternative 2 indicates a growth rate that is 2.9% lower than the Proposed Action. The target size to which the population is gathered to (70 mature horses) appears to have minimal impacts to growth rates, as demonstrated by the growth rates being quite similar for Alternative 3.

- What effect do the different alternatives have on the average population size?

The level to which the population is gathered appears to be more of an influence to average population size than fertility control. Both the Proposed Action and Alternative 2, which gather to 70 mature horses, indicate the lowest average population size. The use of fertility control in Alternative 2 did not result in a significantly lower average population size than the Proposed Action, which did not utilize fertility control. As expected, the No Action Alternative results in the highest minimum population.

- What effects do the different alternatives have on the genetic health of the herd?

The minimum population levels and growth rates are all within reasonable levels for the Proposed Action, therefore adverse impacts to the population are not likely under this alternative. Under Alternative 2, the minimum population level falls very close to the level at which Dr. Cothran indicated that genetic diversity could be lost. The drop in population numbers could have a detrimental/adverse impact to the genetic viability of the herd under Alternative 2.