APPENDIX IX

Population Modeling

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I. <u>INTRODUCTION</u> – From the inception of modern game management in the early 20th century through approximately the 1970s, wildlife managers relied on comparatively rudimentary techniques to formulate hunting season frameworks and harvest quotas. Although managers and researchers attempted to estimate animal numbers for various purposes, by today's standards, their methods were crude and inaccurate, often consisting of extrapolations based on rough counts.

For at least a half century, the wildlife profession devised, tested and applied various formulae and models to estimate population sizes. These "estimators" have been used in lieu of, or in conjunction with, other direct and indirect indicators of abundance. Many estimation techniques required large data sets and the calculations often took hours or days to complete. When computers became widely available in the early 1970s, more sophisticated techniques were much more practical to apply.

About the same time (by the 1970s), managers needed more dependable and precise means of estimating populations to address a number of emerging issues. Harvest pressure was increasing and the public began scrutinizing management programs, particularly after big game declined in the late 1970s following an extraordinary abundance during the 1950s and 60s. Competition and conflicts were increasing between wildlife and other resource demands, especially agriculture and mineral development. In the public's mind, boom and bust cycles of game populations were becoming less acceptable and state wildlife agencies were responsible for preventing the "busts." This required an improved understanding of big game population dynamics. The agencies also needed a more effective means of projecting population trends and conveying this information to the public. Land management agencies sought more accurate population estimates to support resource allocation decisions in long-term management plans. The increasing demands for accurate estimates and sound management objectives prompted development of estimation techniques that were more sophisticated, but also feasible for wildlife managers to use on a regular basis throughout the State.

Population models are designed to simulate (or mimic) what the wildlife manager observes in the field. Models help organize and analyze data, test different management scenarios, and generate questions or hypotheses about vital population parameters and other considerations. If data quality or sample adequacy are issues, these can almost always be identified during modeling exercises. A simulation model is essentially a computerized accounting system with a graphics package, and it relies on a life table to project a population's response to changes in reproduction and mortality. Among other things, a population model enables managers to rapidly simulate scenarios that test the effects of hunting seasons on big game populations, without actually having to conduct a hunting season to demonstrate the effects. Changes in other parameters can also be tested.

The first simulation model used by the Department was ONEPOP, developed by Jack Gross in the early 1970s. This early model was very cumbersome and slow because the data had to be entered on keypunch cards and processed in batches on a large, mainframe computer. Biologists were also required to do a great deal of data preparation beforehand.

ONEPOP-6, an improved version of ONEPOP, added effort values to the harvest function of the model and was easier to use, but still required batch processing. POP50 was developed to eliminate batch processing and provide a better system for modeling big game populations (Biological Services Section 1987). It was easier and faster to use, could be loaded and run in a desktop computer and had better graphics. Features added to POP50 included an annual mortality severity index, simplified control of the initial population size, and age class groupings by subadults and adults. POP50 also had a desired density feature that allowed managers to more easily test the effects of proposed hunting seasons.

The availability of personal computers led to the development of POP-II (Biological Services Section 1987). This program afforded personnel the convenience of modeling locally rather than having to travel and stay in one central location in the state during modeling exercises. Other improvements included the addition of mortality severity indices to adjust mortality both pre- and post-hunting season, the capability to direct harvest at certain age classes, and faster processing speeds. POP-II also enabled the user to update data and correct errors more easily, and to retrieve data more selectively.

POP-II has been revised several times for the Department and other state wildlife agencies since it was originally developed. During a 30-year history of modeling with POP-II and previous models,

the Department has been involved to some degree with all of the revisions. In some cases, the Department contracted the model's originator or other programmers to have revisions done. In other cases, we were asked to review the changes requested by others, suggest additional modifications, and participate in beta testing the new version because of our personnel's extensive knowledge of and experience with the product. The Department is currently using POP-II for Windows, version 1.2.5 (Bartholow 2000).

Wildlife managers have developed and applied many different computerized models to simulate wildlife populations. Each type of model has advantages and disadvantages. The Wyoming Game and Fish Department periodically evaluates other models, but to this date has elected to retain POP-II at it works best for us and has been revised repeatedly to meet our needs.

Over 150 big game herds are currently recognized in Wyoming. At one time or another, the Department has attempted to model all of them. Initially, over 200 herds were delineated. Many were consolidated because data from sources such as modeling, ear tagging, neck banding, or radio telemetry studies indicated they were not discrete.

II. <u>Modeling Considerations</u> – Anyone who uses a simulation model for management purposes should consider potential sources of error in a model's output. First and foremost, POP-II is intended for discrete or closed populations. Although some degree of interchange takes place between most adjoining herds in Wyoming, the Department considers populations sufficiently discrete if no more than 10% of the herd immigrates or emigrates. Models seem to function reasonably well when this assumption is met. For most herds, delineation is a practical compromise between assuring discreteness and identifying a reasonable geographic area for management. Herds that extend across state lines (interstate herds) are especially problematic. For years, biologists in Wyoming have attempted to improve data collection and management of interstate herds by coordinating with adjacent states, but have realized varying success.

The discreteness issue can compound the impact of data quality on model performance. We rely on the literature to define certain parameters such as sex ratio at birth, natural mortality, and wounding loss. Other parameters, particularly harvest and herd composition ratios, are estimated annually based on data collected from mail questionnaires (harvest statistics) and field surveys. However, accurately estimating age and sex ratios requires a statistically valid, well-distributed classification

sample. Adequate classifications are difficult to obtain for white-tailed deer and for specific herds of other species, most typically moose and bighorn sheep.

The primary independent (input) variables of the POP-II model are herd age and sex ratios (J:100♀ and ♂:100♀), harvest estimates, natural mortality rates before and after the hunting season (pre- and post-hunt), initial population size and proportions, wounding loss, number of age classes, sex ratio at birth, and reproductive rates. Beginning and ending years are also required to initialize a model. Secondary parameters include mortality severity indices and effort values, which can be modified once a model is functioning. The number of age classes in the population is generally based on the oldest animal of known age that is harvested, encountered as a road kill, or found during winter mortality surveys. Typically, older animals are encountered more often during winter mortality surveys than in samples taken from hunters.

Although biologists often use population models to archive data, generally, model runs should be limited to the most recent 5 years and should not project more than 3-5 years into the future. Projections can be used to evaluate outcomes of alternative harvest strategies such as antlerless hunting, spikes excluded, and changing license quotas, based on the assumption other parameters will approximate average conditions. However, errors associated with "real world" departures from average conditions are compounded [propagated] each year, rendering longer-term projections pointless. The population model doesn't seem to accommodate drastic changes in input values after a major perturbation, such as a severe winter with high mortality. Consequently, the model may have to be restarted the year following an extreme event.

Classification data should be collected based on well-distributed, statistically adequate sample to achieve a tight confidence interval. A model's performance can be checked against trend counts provided they are done at the appropriate time of year, under consistent conditions, and detection rates are both adequate and unbiased (or bias is consistent and accounted for). To afford a valid comparison against model estimates, detection rates assumed during trend counts must be verified or at least must be a reasonable approximation based on the literature. If they area accurate, the simulated population estimates should exceed the trend counts because not all animals are seen. The biologist must consider how much of the occupied habitat was surveyed, the distribution of animals, and the effects weather, light conditions, cover and terrain, and aircraft height and speed have on visibility and detection of animals. Most observers tend to overestimate their ability to see animals during trend surveys. Based on studies of aerial surveys for various species in various cover types

and topographies, detection rates can range from 30% to 80%. In locations where elk are fed, it may be possible to count up to 90% of a population. Even in this unique situation, some annual variation results from effects of weather and changing numbers of elk that winter off the feedgrounds. It is important to align the simulation within the range of correction for the detection bias, and the trends must agree. The fundamental use of trend counts in modeling is to assure the model mimics trends in the population itself.

Harvest estimates used for population modeling are derived from the Department's annual survey of big game harvest. If an adequate sample is obtained, the age composition of the harvest can be estimated from field-checked animals. Hunters do not selectively harvest specific age classes of adult females, so the age structure of field-checked animals affords an unbiased approximation of the age structure of the female segment of the population.

Mortality severity indices (MSIs) have been calculated from weather data, based on methods developed by Reeve and Lindzey (1991) and Christiansen (1991). Where this approach is used, field Biologists compile weather data annually from selected NOAA weather stations in their areas of responsibility. However, actual mortality rates are often influenced by several other factors including drought, forage quality on summer and transition ranges, condition of animals as they enter the winter, and the pattern and timing of winter storms, which are not reflected in weather data averages. In several cases, winter MSIs derived from weather data are not dependably correlated with measured changes in fawn:doe ratios (e.g., in western Wyoming). In some areas of the state, weather data are used in conjunction with body condition (fat deposition) of harvested animals to help assess the potential severity of winter mortality. A modification being tested in parts of western Wyoming is based on differences measured between post-hunt and spring classifications, combined with results of spring mortality transects and winter weather parameters. This method is being investigated for potentially broader application and may supplant the current method in locations where requisite data are collected. An effective means to calibrate elk population models is to align predicted yearling ratios with those observed in harvests (females) or classification surveys (males). This method can also be applied with caution to some mule deer and pronghorn models where adequate data are consistently collected (classifications of yearling bucks can be inherently inaccurate, however the proportion of yearling does in the harvest is a reasonable approximation of the proportion in the population where the harvest sample is sufficiently large). Alignment is achieved by adjusting winter severity indices to account for realized mortality of juveniles over the prior winter.

Herd classifications may underrepresent the yearling buck deer and pronghorn in a population because yearling males are sometimes misidentified as adult females or they are more difficult to observe due to behavioral differences. However, in herds where adequate classification samples are achieved annually and samples are well distributed throughout occupied habitat, yearling buck ratios may have some utility for estimating the prior winter's MIS values. The limitations and assumptions underlying this method should be disclosed and evaluated where it is applied.

A good model is constructed using the best data that are realistically attainable. And, it is important that the model align well with field data. However, datasets occasionally contain outlying values or "flyers" even when the sample sizes are large. Reasons for this can include improper sampling procedures, poor survey conditions, inexperienced personnel, or chance. A model that fits the data well may have one or two aberrant data points and it may be necessary to ignore them. Modeling is useful if data are adequate and model results are applied in their proper context. If a model mimics the observed data consistently and criteria for data adequacy are met, we presume the model provides a reasonable simulation of the population's trend and a plausible estimate of the population for the year in which harvest and classification data are most current and adequate. Modeling has contributed to improvements in management, but can also be misinterpreted. As a consequence, models can sometimes lead to suspicion or criticism from the public. Managers need to acknowledge the limitations of their data and the modeling process.

Population models can be excellent tools for depicting population trends. However, POP-II can generate a range of reasonable population estimates for a given herd depending on modeling assumptions, values used for standard modeling parameters, and adjustments made to align the model. In the introduction of the POP-II manual, Bartholow (1990) states, "POP-II is a computer program designed to simulate the *dynamics* (emphasis added) of wildlife populations." Statistically adequate data are often difficult to collect. To a large degree, models rely on generalized assumptions from the literature to define many parameters. Therefore, modeling results should be interpreted cautiously and other supporting information should be considered in management decisions or during public discussions of population estimates.

Although the accuracy of models can vary, the resulting trend in population estimates is valid and usable if error is held relatively constant through time. A population model is fundamentally based on measured changes in age or sex proportions resulting from known harvests, so the model will

cease to work if differences between the actual and simulated populations become too great. Nonetheless, it is important for managers to consider other types of data such as trends in harvest, hunter effort, hunter success, and perceptions of field personnel, landowners and hunters when evaluating a model's performance. If the model adequately represents actual changes in the population, the simulated population should follow comparable trends. To minimize the potential for personal bias to influence calibration of a model, the biologist should not consider the resulting population estimates (in Table 1 of the model output) until the model is performing satisfactorily.

Several years after Department personnel had begun using POP-II, we did a comparative analysis and discovered some inconsistencies in the values being used for fecundity rates, mortality rates, number of age classes, age- and sex-specific mortality rates, and other parameters. Although the majority of personnel were using comparable values, some deviations exceeded what was believed reasonable. In several instances, the values resulted from personnel aligning models by adjusting variables that should properly be treated as independent input parameters. To assure independent modeling parameters are assigned values within a range that is reasonably supported by the literature, in April 2003 the Wildlife Division established standardized ranges of modeling parameters for each big game species (Attachment 1). Values of independent parameters should be within the ranges recommended by this guidance unless deviations are rigorously supported by data from special studies or the scientific literature. The standardized ranges of modeling parameters will be reviewed periodically and may be updated when new data indicate adjustments are warranted.

The POP-II documentation (Bartholow 1990, Bartholow 2000) has instructions and tips for entering data, an explanation of the program and its components, general information about modeling, some precautionary statements, and details about information messages produced by the software. Novice users should read the documentation thoroughly and consult it often as they are learning to use POP-II. Even managers with considerable experience should periodically review the documentation to refresh their understanding of the model's purposes and limitations.

A. Considerations for Modeling –

    a. Pronghorn – Pronghorn are classified in August and September when they congregate in larger groups just prior to the breeding season and it is easier to distinguish fawns from adults. Since pronghorn are classified at the end of the summer, but prior to hunting seasons, estimating preseason mortality is a comparatively straightforward exercise. Estimating

postseason mortality is more difficult due to the time that lapses between herd classifications and the end of the biological year, and the influence various factors, such as long-term drought, have on susceptibility of pronghorn to winter mortality. Because of this, it is important to monitor summer habitat conditions. Insights about the probable condition of animals can also be inferred from summer severity indices that have been adjusted to align the model simulation with the observed ratio of juveniles per 100 females. This process accounts for preseason mortality.

Aerial line transect surveys are conducted to estimate sizes of most pronghorn herds in Wyoming. Refer to Chapter 1, Section II.D. (Pronghorn – Aerial Line Transects) and Appendix II (Line Transect Sampling Methodology). These surveys are done in late May or early June when pronghorn are highly visible against a contrasting background of green vegetation. Line transect surveys are scheduled on a 3-year rotation within each herd unit. The resulting estimates and measures of error afford an independent verification of end-of-year population estimates and are used to calibrate pronghorn population models. This capability is a distinct advantage because reliable means of directly estimating other big game populations are not generally available or feasible.

Pronghorn harvest data are very accurate, in part, because all pronghorn hunting seasons are limited quota and this simplifies the harvest survey sample frame. In addition, the Department has an accurate list of all license holders. Since pronghorn hunting seasons are typically held in early fall, harvest rates are less affected by weather. Therefore, estimates of pronghorn harvest, one of the most important model parameters, tend to be more consistent and reliable than harvest estimates for the other big game species.

Postseason mortality is difficult to estimate because pronghorn tend to be quite mobile and their distribution is dynamic on wintering areas. Few traditional wintering areas lend themselves to mortality surveys that can be compared among years. In addition, it is not possible to accurately estimate change in ratio of fawns to adults because it is difficult to distinguish the physical differences between fawn and yearling females in spring.

Pronghorn can be aged reliably to 4+ years by examining incisor replacement during field checks of harvested animals. This provides a partial age distribution of harvested animals. Harvested adult females are presumed to be an unbiased sample of the adult female segment

of the population. The availability of a simple field technique to age pronghorn through 4+ years provides some management advantage in that age distribution data can be compared against estimates in the population model.

b. <u>Mule Deer</u> – It can be more difficult to construct functioning models that simulate mule deer populations based on change of herd composition ratios, specifically age and sex ratios. In addition, a reliable, cost-effective method is not available to independently verify the population size or monitor trends in order to calibrate a model. In all likelihood, the modeling process yields more approximate estimates of mule deer population trends. Our ability to collect statistically valid data is also constrained by funding and personnel limitations. Department personnel make an effort to collect minimum classification samples and, to a large extent, rely on helicopters to cover herd units as uniformly as possible. However, we still have a tendency to classify disproportionately within the areas of known deer concentrations rather than covering all occupied habitats in a random or systematic fashion. This interjects an un-quantifiable bias in the observed ratios and in the model's calculations.

During herd classifications, the sample of does and fawns is typically large; therefore, the observed proportions of does and fawns are presumed accurate and representative of the overall population. We align simulated doe:fawn ratios so they agree with the observed ratios from classification data. However, the basic mechanism of modeling relies on the measured response of the buck:doe ratios to known harvests over time. Unfortunately, buck:doe ratios are considered less accurate. Bucks (particularly mature bucks) tend to be solitary or they associate in small groups, often markedly separated from doe and fawn groups. As a result, they are more difficult to observe. In concept, if classifications were done during the rut, bucks should be near doe/fawn groups and therefore observed in proportion to their presence in the population. However, classifications are commonly done outside this timeframe. Consequently, bucks are underrepresented in classification samples. To compensate for this in our population models, we usually simulate buck:doe ratios slightly above observed ratios. Underrepresenting males in classifications can substantially impact the accuracy and reliability of a model. This means sampling errors in the observed buck:doe ratios confound the ability to assess the model's performance and reliability.

Although mule deer models are subject to a number of potential biases and data problems, reasonable models can be constructed and are useful for many herds if managers maintain their objectivity and recognize and account for the limitations of the data. Models should always be used in conjunction with other corroborating information, such as trends in hunter success, effort, age composition of the harvest, and changes in the proportions of yearling and adult males in post-hunt classifications. These data are not without their own inherent biases and harvest data are frequently based on small samples. Apparent trends can be skewed by weather patterns affecting animal and hunter distribution, and ultimately harvest, success and effort. It is important to remember that changes in harvest statistics from one year to the next do not constitute a trend. Such analyses should consider at a minimum, 3 consecutive years of harvest data and preferably 5. The assumptions and potential limitations of modeling should always be conveyed to others when results are discussed.

c. Elk – Elk are easier to classify than other big game because they tend to congregate in larger herds during winter. In Wyoming, most winter ranges used by elk are open grass and shrub dominated vegetation, conifer savannahs or open woodlands where these large ungulates are readily observable. However, mature bulls tend to segrgate from large cow and calf groups and can be missed during ground and even aerial surveys unless all likley winter range is covered thoroughly. As with deer, modeling usually requires running the simulated bull:cow ratios slightly higher than the observed ratios. In more rugged terrain or forested winter ranges, animals are less detectable during surveys, and observability bias becomes more likely. On feedgrounds, the proportions of bulls and calves will often be significantly different from the proportions observed on native winter range. Precautions regarding the utility and accuracy of population models for deer similarly apply to elk.

Since accurate classifications of yearling bulls are fairly easy to obtain, the yearling bull:cow ratio provides a reliable means of estimating winter MSIs to account for overwinter mortality of calves. This is achieved by aligning adjusting winter MSIs to align the simulated and observed yearling bull:cow ratios in the model.

Elk are less susceptible to winter mortality than are mule deer, but substantial losses can take place during severe winters in areas where winter ranges are limited or of poor quality. Calf production is generally lower following a severe winter and in drought years. The mortality rate of neonatal calves can be a good indicator of habitat conditions and reproductive fitness.

In areas with high bear populations, predation of elk calves can be substantial. However, such predation is probably at least partially compensatory and unlikely to have a significant impact on overall recruitment. In poor quality habitat, predation can have a greater impact because calves are concentrated in smaller areas of suitable habitat and tend not to be as large or vigorous as calves born in better habitat. If calf survival is chronically low, it may be necessary to evaluate habitat conditions and conduct detailed population studies to identify specific causes.

d. <u>Moose</u> – Moose are difficult to survey because they tend to be solitary and, during winter, spend considerable time in dense stands of conifers. As a consequence, it's tough to obtain adequate classification samples. Generally, helicopter surveys are the best way to classify moose, but flight time is expensive making extensive use of this method impractical. Although moose utilize mountain shrub, aspen and willow stands in early winter, they move into closed conifer stands as deeper snow accumulates and crusts over later in the season. Detection is very poor within conifer habitats. Moose are generally classified in conjunction with elk surveys to save money. Typically, surveys only cover the best winter habitats, however moose have the ability to winter in a wide range of habitats and in relatively deep snow. "Sightability" surveys may be the best method of obtaining data for generating population and precision estimates in a Pop II model. However, sightability surveys take more time and effort compared to conventional trend and classification surveys.

When reliable classification data are not available, as is often the case, population trends can be evaluated based on harvest information. For some herds, harvest statistics, including ages obtained from tooth samples, are the only quantitative data collected. However, annual variation can be substantial because samples of teeth from harvested animals tend to be small and several factors, including weather and access, can impact harvest success and effort. Within some larger moose populations, biologists are able to obtain age and sex composition data from reasonable classification samples and from relatively large numbers of harvested moose. A population model is calibrated by aligning the proportion of yearling females simulated by the model with the proportion detected in the harvest, and by comparing the age composition of the harvest with the proportions of animals in each age class projected by the model. In addition, simple trends in hunter success and effort (days per animal taken) are useful indicators of population trends. However, these data can vary greatly from year to

year and should be interpreted cautiously. Ideally, harvest trends should be viewed over a relatively long period (5 to 10 years) before inferences are made regarding population trends.

The age at which female moose first conceive is an important variable impacting a model's performance. Most cow moose in the Jackson Moose Herd do not become pregnant until age 3 (Berger et al. 1999). By contrast, moose first give birth at age 2 in more productive regions. The proportion of twins in the Jackson Herd was also very low, indicating poor habitat conditions and low reproductive fitness. The modeling protocol for age at first reproduction and fecundity rates (Attachment 1) are based on data from the Jackson Moose Herd, but this may be atypical of other herds in better habitat, and of introduced populations such as the Bighorn or Snowy Range Moose Herds. Pregnancy rates within other Wyoming moose herds may warrant additional investigation for modeling purposes.

Bighorn sheep – Reliable estimates of the age and sex composition of a sheep population are essential to develop working simulation models. However, biologists' abilities to classify adequate samples vary greatly among sheep herds. For example, large sheep populations in the high elevations of the Wind and Absaroka Ranges typically occupy extensive, open habitats where they are readily observed. On the other hand, bighorn sheep can be difficult to locate in small, widely dispersed populations inhabiting partially forested habitats at lower elevations because they are usually scattered in small bands and often use timber for security or thermal cover.

Generally, bighorn sheep are classified in early December when they congregate during the rut. Known rutting sites should be checked, but all habitats occupied at that time of year should be surveyed. A helicopter is the most effective means of covering large, inaccessible areas to classify bighorn sheep. Unfortunately, yearling males are difficult to distinguish from ewes and 2-year old males during aerial surveys. The ratio of yearling males to ewes is compared to the lamb:ewe ratio from the prior year to estimate mortality and help calibrate the population model. For this purpose, the most accurate classifications of yearling males are done from the ground.

Like elk, female bighorn sheep do not conceive until they are 2 years old. This should be taken into account when defining age-specific reproductive rates for constructing a model.

III. <u>LITERATURE CITED</u>:

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ATTACHMENT 1

Standardized ranges of parameters recommended for modeling big game herds in Wyoming.[1]

	Mule Deer	Pronghorn	Elk	Moose	Bighorn Sheep
Wounding Loss Rate [2]	10%	10%	10%	10%	25% rams, 10% other
Number of Age Classes [3]	12-15	12-15	15-20	15-18	12-15
Fecundity Rates: Age Classes (No/100 ♀s)	$\underline{1}$ $\underline{2\rightarrow max.}$ 0 170	$\underline{1}$ $\underline{2\rightarrow max.}$ 0 180	$\underline{1}$ $\underline{2}$ $\underline{3\rightarrow max.}$ 0 0-30 90	$\underline{1}$ $\underline{2}$ $\underline{3\rightarrow max.}$ 0 0 90	$\underline{1}$ $\underline{2}$ $\underline{3\rightarrow max.}$ 0 0 90
Sex ratio at Birth [4]	50:50	50:50	50:50	50:50	50:50
Juvenile Mortality Rate (pre-season) [5]	50%	50%	40%	40%	40%
Juvenile Mortality Rate (post-season) [6]	30-55%	30-55%	10-20%	15-25%	20-35%
Adult Mortality Rate (pre-season) [7]	2%	2%	1%	1%	2%
Prime-age Adult Mortality Rate (post-season) [8]	3-10% for age classes 2-5	3-10% for age classes 2-5	3-10% for age classes 2-6	3-10% for age classes 2-6	3-10% for age classes 2-6
Post-prime Adult Mortality Rate (post-season) [9]	Increases incrementally after age class 5, reaching 100% in oldest age classes	Increases incrementally after age class 5, reaching 100% in oldest age classes	Increases incrementally after age class 6, reaching 100% in oldest age classes	Increases incrementally after age class 6, reaching 100% in oldest age classes	Increases incrementally after age class 6, reaching 100% in oldest age classes
Sex-Based Differential Mortality (post-hunt) [9]	♂ mortality > ♀ mortality after class 5	♂ mortality > ♀ mortality after class 5	♂ mortality > ♀ mortality after class 6	♂ mortality > ♀ mortality after class 6	♂ mortality > ♀ mortality after class 6
MSI (pre-season) [10]	1.0 = normal summer	1.0 = normal summer	1.0 = normal summer	1.0 = normal summer	1.0 = normal summer
MSI (post-season) [11]	1.0 = normal winter	1.0 = normal winter	1.0 = normal winter	1.0 = normal winter	1.0 = normal winter

[1] All model parameters are recommended for use with POP II, Version 1.2.5 by Fossil Creek Software. Ranges of "acceptable" values are provided for several modeling parameters, however biologists and coordinators should strive to use consistent parameter values among models unless data or other information support alternative values in specific herd models.

[2] Use of wounding rates other than those listed and use of age- or sex-based, differential wounding rates must be justified with data or studies applicable to the herd being modeled.

[3] The number of age classes is based on tooth data and recoveries or observations of known-age, marked animals. Generally, the number of age classes will be within the recommended ranges unless data or observations indicate otherwise. By convention, Age Class 1 represents young of the year, Age Class 2 represents yearlings, and Age Classes 3 and higher represents adults.

[4] Always assume 50:50 sex ratio at birth.

[5] Pre-season (summer) juvenile mortality rates are fixed. Alignment of fall fawn:doe ratios is achieved by adjusting the pre-season MSIs.

[6] Post-season juvenile mortality rates may be adjusted within the recommended ranges to align modeled ratios or population estimates consistently with observed values. Post-season mortality rates of juvenile males may be up to 10-20% higher than for females, based upon Wyoming data for pronghorn, and based upon findings of Unsworth et al. (1999) and Conolly (1981) for mule deer. However, mortality rates outside the recommended ranges must be documented with data or studies that are applicable to the herd being modeled.

[7] Pre-season adult mortality rates are fixed. These are modified by the pre-season MSI needed to align fawn:doe ratios, so it is assumed changes in fawn mortality are also reflected in the adult segment.

[8] Post-season mortality rates of prime adults may be adjusted within the recommended ranges to align modeled ratios or population estimates consistently with observed values. However, mortality rates outside the recommended ranges must be documented with data or studies that are applicable to the herd being modeled.

[9] Post-season mortality rates of post-prime adults increase incrementally to reach 100% by the oldest female age classes. Mortality rates of post-prime adult males generally increase at a faster rate, reaching 100% several years before the oldest female age class. The rates of increase and magnitude of differential should be determined from the best data or information that is available for each herd being modeled. These parameters may be developed through iterative modeling exercises until modeled sex or age ratios, or population estimates align consistently with observed values.

[10] Pre-season MSIs are adjusted as needed to align simulated ratios of juveniles to age 1+ females, with the ratios observed in pre- or post-season classifications.

[11] An MSI of 1 is assumed to represent "normal" conditions. The linear MSI option should be used unless there is good justification for use of a curvilinear model. Post-season MSIs should be adjusted based upon either environmental data, for example weather severity indices, or alignment of modeled parameters. When post-season MSIs are adjusted through iterative modeling exercises, the modeler should evaluate whether the resulting MSIs are a reasonable representation of environmental or biological factors such as severe weather, drought, habitat condition, disease, or population density.