1. Introduction to Deer Population Monitoring in Pennsylvania

How many deer are in the photo on the cover? The cover photo represents a best-case scenario – a still photograph of brown-coated deer in an open, snow-covered landscape. With time and a keen eye, one may see the 8 deer present in this photo. If it is difficult to count all the deer in a photograph, consider the difficulty in counting deer in the real world across the state of Pennsylvania, especially when that number is changing every day.

In a perfect deer management program, deer biologists would know exactly how many deer were in an area. All successful hunters would accurately report their deer harvests. And, relationships between deer populations and the environment would be known with certainty. Unfortunately, the Pennsylvania Game Commission does not manage deer in a perfect world.

It is impossible to count all the deer in Pennsylvania and no amount of desire will change this reality (Andrewartha 1961, White 2000). White-tailed deer are secretive, well camouflaged, and always difficult to count (Rice and Harder 1977, Ludwig 1981, Stoll et al. 1991, Beringer et al. 1998). Thus, most wildlife agencies monitor relative abundance, not absolute or actual numbers of deer, by analyzing deer harvest data (Creed et al. 1984, Roseberry and Woolf 1991). When monitoring relative abundance, the most important consideration is whether the deer population trend is increasing, decreasing, or stable; not how many deer are in an area.

Deer biologists often use mathematical models to monitor deer populations. A model combines various data inputs – for example, age and sex of deer and number of deer harvested – to generate a representation of the population. A model provides an estimate of deer abundance, not an absolute count. Often, available data will limit interpretation of model results to represent relative changes in deer numbers (i.e., population abundance is increasing, decreasing, or stable).

Deer numbers, although a part of the PGC's deer program, are not the primary management consideration. Deer impacts – not deer numbers – define the PGC's deer management goals and objectives. Rather than setting management objectives based on the number of deer in an area, management objectives are defined by deer health, forest habitat health, and deer-human conflicts measures. These measures, in conjunction with measures of deer population trends, form the basis for deer management recommendations.

The PGC and PCFWRU developed the PASAK model in 2005 to monitor deer population trends. The PASAK model is a sex-age-kill model (Eberhardt 1960, Creed et al. 1984, Skalski and Millspaugh 2002) with modifications for antler restrictions. When the PASAK model was subjected to a recent external review, it was determined to be a credible model for tracking population trends thereby fulfilling its intended function (Wildlife Management Institute 2010).

Since the PASAK model was developed, the PGC has emphasized the limitations and purpose of the model. The following passage has appeared in deer population annual reports posted on the PGC's website (www.pgc.state.pa.us) since 2006:

> *When interpreting results from the modified SAK [i.e., PASAK model] procedure, it is important to know that due to the nature of population reconstruction methods, such as those used in the SAK procedure, the most accurate population estimate for a particular year occurs at some point in the future when data for each cohort of deer is complete (Skalski et al. 2005). Consequently, for the most recent years, population numbers should be viewed as indices rather than estimates (Skalski et al. 2005). Second, due to necessary assumptions of this population monitoring procedure, population numbers used to assess*

trends should be viewed as relative (i.e., whether trends are increasing, decreasing, or remaining stable), not absolute numbers. As we accumulate more years of data and results from ongoing internal and external evaluations, refinements to this procedure will occur.

Changes in the PASAK model have occurred. However, assumptions remain that prevent the PASAK from estimating absolute numbers of deer in a WMU or statewide.

The PASAK model contains assumptions. Assumptions are needed because data necessary to determine annual deer numbers across large areas are typically not available as a result of time, money, and personnel constraints (Roseberry and Woolf 1991, White 2000, Morrellet et al. 2007). When working with assumptions, maintaining consistency in procedures and controllable variables is critical. For a hunted species, an important controllable variable would be maintaining consistent hunting regulations. When regulations change, uncertainty surrounding assumptions increases.

Rather than accept assumptions, the PGC continues to investigate performance of the PASAK model and evaluate assumptions. Since its initial development, the PASAK model has been subjected to external reviews and internal evaluations to assess its utility and reliability (See PASAK Model Timeline below). In addition, the PASAK model was reviewed recently as part of an evaluation sponsored by the Legislative Budget and Finance Committee (LBFC, Wildlife Management Institute 2010).

PASAK Model Timeline

2005 – PASAK model developed by PGC deer biologists and researchers at the Pennsylvania Cooperative Fish and Wildlife Research Unit (PCFWRU) at Penn State University

2006 – PGC deer biologists send PASAK model out for reviews by biologists and biometricians from 9 states, 1 Canadian province, and the U.S. Fish and Wildlife Service.

2007 – Based in part on findings from the 2006 peer-review, PGC and PCFWRU start in-depth evaluation of PASAK model precision, sensitivity, and assumptions

2008 – LBFC approves audit of deer management program and PASAK.

2009 – Wildlife Management Institute (WMI) conducts audit of PGC deer program and PASAK.

2009 – PCFWRU provides interim report to WMI of ongoing evaluations of PASAK.

2010 – WMI releases its report stating the PASAK model is a credible method of tracking deer population trends. WMI's report contains population estimates from PCFWRU interim report.

2010 – The PGC/PCFWRU evaluations of the PASAK model are completed.

2010 – The PGC and PCFWRU modify the PASAK model to reflect findings from evaluations and recommendations from WMI.

Present (January 2011) – The PGC and PCFWRU continue to evaluate assumptions of the PASAK model using marked deer in 4 WMUs and computer simulation.

The PASAK model can provide deer population trend information without providing absolute deer numbers. For example, assume a constant adult male harvest rate for all WMUs. If the harvest rate is higher in one WMU compared to the constant harvest rate, it will lead to differences in the number of deer. However, if the harvest rate is consistent over time the estimated trend will follow the actual trend (Example 1). As shown in this

example, it is possible to reliably track deer population trends even if the estimated population is not the same as the actual population. Likewise, presence of assumptions in the PASAK model prevent the PGC from saying there are a specific number of deer in a WMU, but do not necessarily prevent tracking of deer population trends.

Example 1. Adult male harvest rate assumption

Assume 50 percent of adult males are harvested. A harvest of 100 would result in a population estimate of 200 adult males because,

$$Population = \frac{Harvest}{Harvest\ Rate}$$

$$Population = \frac{100}{0.50}$$

$$Population = 200\ adult\ males$$

If the actual harvest rate is 60 percent, the actual population will be 167 adult males.

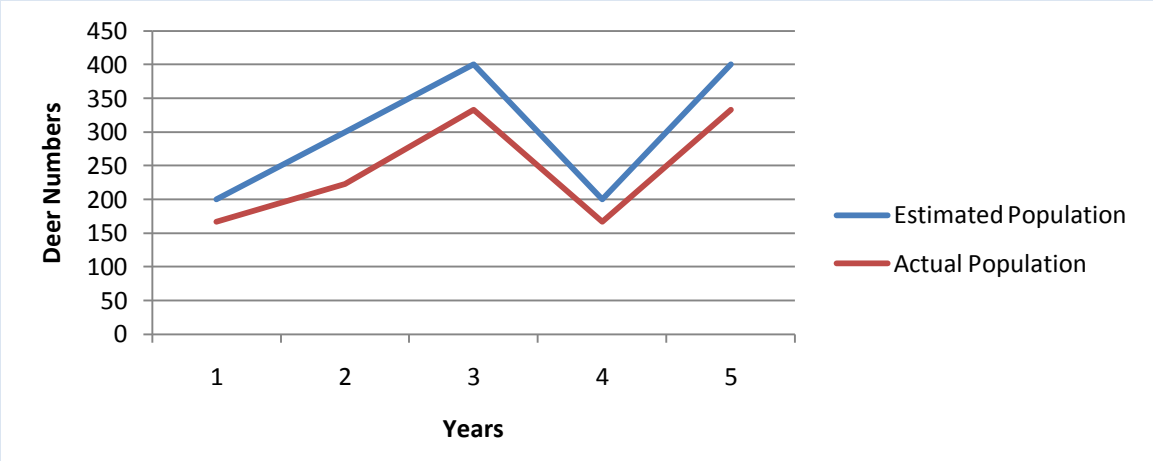
$$Population = \frac{100}{0.60}$$

$$Population = 167\ adult\ males$$

As a result, the estimate is higher (i.e. 200 adult males) than the actual number (i.e. 167 adult males).

If the harvest rate is consistently 60 percent over time, then the trend will be consistent with the population.

Year	Harvest	Estimated population assuming 50% harvest rate	Actual population
1	100	200	167
2	150	300	223
3	200	400	333
4	100	200	167
5	200	400	333



2. Questions about Deer Population Estimates

1. **How many deer are there in Pennsylvania?**

   Nobody knows because it is impossible to count every deer in the state. The Pennsylvania Game Commission (PGC) uses a modified sex-age-kill model to estimate deer population trends. The model is based on data from hunters, harvested and research deer, and hunter surveys. It is not used to determine the absolute number of deer in the state.

2. **How can the PGC manage deer without knowing the number of deer?**

   Like other states, the PGC monitors deer populations by tracking trends. Deer management recommendations are made to increase, decrease, or stabilize those trends. To make recommendations, the actual number of deer in a wildlife management unit (WMU) is not needed.

3. **But, if the PGC doesn't know how many deer there are, isn't there a chance too many deer will be harvested?**

   Not if seasons and harvests are carefully and incrementally managed and key indices monitored. Consistent season structure and adjustment of antlerless allocations has proven successful in Pennsylvania for decades. By maintaining consistent regulations and making incremental adjustments in antlerless allocations, deer populations can be managed to meet objectives. There is no substitute for consistency when managing WMU deer populations. By adjusting one variable – such as the antlerless allocation – changes to the deer population occur in a more predictable way and can be monitored to avoid unwanted consequences.

4. **What do wildlife professionals outside the PGC say about deer population numbers and trends?**

   The wildlife profession has long recognized the difficulty in counting deer and other wildlife. The following quotes cover decades of comments from wildlife professionals on the need for absolute numbers in deer and wildlife management:

   "Sometimes technical difficulties may make it impossible to measure the absolute density of the population no matter how desireable this may be, and to estimate relative densities may be the best that one can do." (H.G. Andrewartha in Introduction to the Study of Animal Populations, 1961)

   "Estimates of abundance have no intrinsic value and they should never be considered ends in themselves. Many biological problems require no estimate of abundance. Other problems, particularly those linked with utilization of habitat, rate of increase, dispersal, and the reaction of a population to management treatments, can often be solved with estimates of relative density." (G. Caughley in Analysis of Vertebrate Populations, 1977)

   "Estimates of whitetail population size interest the public and appeal to the media. Often, however, the importance of knowing the population size is overestimated as a tool for deer management. It is more important to know the relative abundance of deer – whether the population is increasing or decreasing,

and whether it is above, below or nearly in balance with carrying capacity of the environment." (D. W. Hayne in Population Dynamics and Analysis chapter of White-tailed deer: Ecology and Management, 1984)

"I propose that it is time for management to abandon the quest for the absolute estimate, which is difficult or impossible to obtain and of limited use if known." (D. R. McCullough in Lessons from the George Reserve chapter of White-tailed deer: Ecology and Management, 1984)

"*Even if we assume that counts are accurate and precise, population size in itself provides no information on the relationship between the population and its habitat (e.g. density-dependence) with respect to given management objectives*." *(N. Morellet et al. in article published in Journal of Animal Ecology, 2007)*

The position of PGC wildlife managers that knowing the number of deer in a WMU is not needed to have sound deer management is consistent with findings from decades of wildlife research and management experience from around the world.

5. How does the PGC determine whether a trend is increasing, decreasing, or stable?

Population trends are identified as increasing, decreasing, or stable based on a statistical procedure that compares population estimates to each other over a period of 6 years. The specific test used by the PGC is the Mann-Kendall Test for Trend (Mann 1945, Kendall and Gibbons 1990).

6. Who developed the PASAK model?

In 2006, the PASAK model was developed jointly by PGC deer biologists and researchers at the Pennsylvania Cooperative Fish and Wildlife Research Unit (PCFWRU) at Penn State University.

7. How does the PASAK model work?

In simple terms, the PASAK model estimates the deer population in 4 steps. First, the antlered deer population is estimated using antlered harvest estimates and antlered harvest rates. Second, the mature female population (females at least 1 year of age) is estimated by multiplying the antlered population by the adult sex ratio. Third, the juvenile population is estimated by multiplying the mature female population by the fawn:doe ratio from the harvest. Finally, the total population is estimated by adding together the antlered population, the mature female population, and the juvenile population.

A detailed explanation of the PASAK model procedures begins on page 15.

8. Are PASAK estimates accurate?

A comparison between PASAK estimates and the actual number of deer in a WMU is not possible. As a result, accuracy of PASAK estimates cannot be determined.

9. If you can't tell if the PASAK estimates are accurate, are they still useful?

Based on evaluations and an independent audit sponsored by the Legislature, the PASAK is a credible model for tracking deer population trends.

10. Why are there 3 numbers for each WMU?

PASAK provides a point estimate and 90 percent confidence interval limits. Providing only the point estimate (ex. 49,985 deer) would imply exactness. PASAK estimates are not exact. A confidence interval is provided to convey variation associated with each estimate.

11. What is a 90percent confidence interval?

A 90% confidence interval is a statistical measure of precision of a point estimate. The confidence interval is defined by a lower limit and an upper limit. These limits identify an interval for which there is 90% confidence that the interval includes the actual number of deer in a population. For example, if the lower limit is 10,000 and the upper limit is 20,000, one would be 90% confident the interval from 10,000 to 20,000 contained the actual population number.

12. How good is the precision of the PASAK model estimates?

Based on common wildlife population estimation benchmarks, precision of PASAK population estimates achieve the benchmark for management surveys such as tracking deer population trends.

13. Why do some of the point estimates increase or decrease a lot from year to year?

WMU 2G from 2005 to 2009 is a good example of dramatic annual changes. These changes may not reflect biologically possible population dynamics. For example, from 2005 to 2006 the antlered harvest in WMU 2G increased from 5,000 to 7,200 and the population estimate increased from 60,000 to 110,000. Then from 2008 to 2009, the population estimate dropped from 100,000 to 60,000 when the antlered harvest dropped from 6,800 to 5,200.

The PASAK model is sensitive to changes in antlered harvests. This sensitivity demonstrates why the PGC limits its use of the PASAK model to tracking trends, not annual counts of deer in a WMU. By looking at the trend in deer population estimates over a number of years, management recommendations are not erroneously affected by large changes in point estimates from the PASAK model.

14. Will smaller WMUs lead to better estimates?

Smaller WMUs will not improve the PASAK estimates. Sample sizes needed to estimate populations will only increase with more and smaller WMUs. Without an increase in data, variation of population estimates will increase. Collecting sufficient data for a large number of small management units is often not possible for wildlife agencies. This is why states such as Michigan and Wisconsin combine small management units into larger units for data analysis purposes.

15. How can precision of the PASAK estimates be improved?

More data will increase precision of the estimate and reduce the size of confidence intervals. Increased harvest reporting by hunters is the simplest method of adding data to the PASAK model. Continued field data collections also will improve the precision of PASAK estimates.

16. Why does the PASAK model have assumptions?

A deer population model is a mathematical representation of complex natural systems. Data cannot be collected on every individual deer or interaction between deer, habitat, and people. As a result, all deer population models have assumptions. For example, the PASAK model has the following assumptions:

a. Antlered harvest rates are related to hunter effort. This assumption is based on an analysis of observed harvest rates in 4 WMUs and hunter effort statistics. Based on this analysis, it is assumed the relationship between antlered harvest rates and hunter effort in these 4 WMUs is similar in other WMUs. Ongoing field studies in other WMUs will test the validity of this assumption.

b. Juveniles and mature females are harvested at the same rate. Mature females appear to be harvested at higher rates than juveniles. As a result, this assumption leads to underestimates of the population.

Personnel, time, and financial constraints will continue to require assumptions to compensate for gaps in field data. Much of the continuous evaluation of the PASAK focuses on strengthening critical assumptions.

Assumptions also prevent PASAK estimates from being used to represent the actual number of deer in a WMU. However, assumptions do not prevent the PASAK from tracking deer population trends.

17. Are PASAK estimates used to set antlerless allocations?

Yes, but the actual PASAK estimate (e.g., 49,985) is not used to calculate antlerless allocations. Antlerless allocations are based on WMU population trends. If the objective is to increase a deer population, the antlerless allocation will be reduced. If the objective is to decrease a deer population, the antlerless allocation will be increased. The population trend, not the number of deer, is critical to management recommendations. Management recommendations are based on trends over six years.

18. Has the PASAK model been reviewed and evaluated by other biologists?

Yes. The PASAK model was reviewed by biologists and biometricians from 9 states and 1 province in 2006. Based on comments from these reviews, the PGC and PCFWRU began an in-depth evaluation of the PASAK model in 2007. This evaluation was completed in August 2010. In addition, a Legislative Budget and Finance Committee-sponsored audit of the PASAK model was completed in February 2010.

19. What did the deer audit say about the PASAK model?

The auditors, provided by the Wildlife Management Institute (WMI) concluded that;

"The PGC has developed a credible model that factors in necessary adjustments to reflect antler restrictions. WMI also documented that the PGC strives continually to improve the precision of the model inputs by conducting field research. All parties interested in deer management in Pennsylvania can be confident in the ability of the PGC to track deer population trends at the statewide and WMU scales through the use of the PA SAK as long as PGC data collection thresholds for data input are met or exceeded." (page 60 of the audit report)

20. Did the PGC withhold deer population estimates as reported in the deer audit?

The deer population estimates in the audit (Appendix B, pages 80-81) came from a preliminary report of the PGC/PCFWRU's progress in evaluating the PASAK model that was requested by the auditors. These results were part of an ongoing study and were not used for management purposes.

Since the PGC began using the PASAK model for tracking deer population trends, population trend information has been released to the public in annual reports (Report 21001) available on the PGC's website, www.pgc.state.pa.us.

21. Why do current population estimates differ from Appendix B (pages 80-81) of the deer audit report?

The estimates in Appendix B of the deer audit are based on a preliminary report of PGC/PCFWRU's progress in evaluating the PASAK model. As noted on page 28 of the deer audit, these estimates were preliminary and subject to change. The PASAK model was modified based on the final results of the PGC/PCFWRU evaluation and recommendations from the deer audit report. These modifications led to recalculations in population estimates.

22. Will there be other modifications to the PASAK model in the future?

Yes. Current field studies are collecting more data on male and female harvest rates. These results will be used to improve the PGC's ability to monitor deer populations and likely lead to PASAK model updates.

23. Do PASAK estimates represent only hunted populations?

No. Unlike previous methods used by the PGC to estimate deer populations, the PASAK model includes data from deer on both hunted and unhunted land. Antlered harvest estimates are based on marked deer that are captured and then released. On average, the young bucks will travel 3 to 6 miles from where they were captured. Some will relocate to lands open to hunting; others to lands where no hunting occurs. The same is true for adult bucks. As a result, the antlered harvest rates represent a combination of animals from hunted and unhunted properties.

24. Where are the PASAK estimates for WMUs 2B, 5C, and 5D?

The PGC is not using the PASAK to estimate deer populations in WMUs 2B, 5C, and 5D. These WMUs are highly developed compared to other WMUs. The assumption regarding the relationship between

hunter effort and antlered harvest rates may be invalid in these WMUs. For this reason, the PGC does not use PASAK estimates to track deer population trends in these WMUs.