Chapter 6

APPLICATION TO MANAGEMENT

Wyoming's aerial line transect technique to estimate pronghorn abundance has been integrated into routine management for most pronghorn herds in the state (Guenzel 1994). The technique offers several advantages for wildlife managers:

1. provides independent population estimates corrected for undetected animals which can be used to compare and align herd simulations,
2. allows the quality of the line transect estimate (e.g., confidence intervals, model fit) to be evaluated,
3. requires fewer assumptions and parameters than population simulations, and
4. saves a tremendous amount of time and money over trend counts and other methods.

This chapter describes how to place line transect estimates in their proper perspective in management, how to use these estimates to align simulation results using the POP-II model (Bartholow 1990), and offers recommendations for further refinements..

How Much Faith Should Be Placed In Line Transect Estimates

The amount of faith managers should place in line transect estimates depends in part on the quality of the individual estimates from surveys in specific herds, and how well assumptions were met. Line transects seem to work reasonably well in many herds where surveys are properly designed and conducted, and where adequate sample sizes are obtained. Results are more variable in small, low density herds; where sample sizes are small; where participants did not properly follow survey procedures; and where errors were made during the analysis. In most cases where problems occur, these can be identified during data analysis. In a number of problem situations, acceptable estimates may be salvaged although these may require accepting additional assumptions. Users should strive to maintain the rigorous quality control prescribed for this technique so as to minimize such problems. The need for proper training cannot be overstated (Buckland et al. 1993, Guenzel 1994, Laake et al. 1997). Biologists should examine results of line transect surveys critically, but should also critically evaluate other management data (e.g., perceived trends, simulations, composition surveys, harvest statistics, public comments, and damage complaints) to which line transect estimates are compared (Guenzel 1994).

All sample-based estimates including line transects are subject to sampling error and uncertainty. True populations sizes for pronghorn populations are virtually never known. The point estimate obtained from a line transect survey will most likely deviate some from the true population size. Assuming adequate survey design and sample size, reasonably close estimates can be obtained. The magnitude of the deviation depends in part on the sample variance of the estimate and any bias. Line transect estimates are likely to be biased low because some animals one the line may go undetected. Managers should evaluate the acceptability of line transect estimates by examining the output from DISTANCE. The following questions may help:

1. Did you meet the basic assumptions for aerial line transect sampling? Review the basic assumptions from Chapter 1. Is there evidence from the histogram that you missed pronghorn clusters on and near the line, or that possibly animals moved farther away from the line before being detected? These may show up in the histogram where the B band is substantially higher than the A band or where the C band is nearly as high as the A band. You may need to interview the observers and pilots to determine if the problem was movement or missing animals on the line. That would make some difference in how you interpreted the results.

2. Is the shape of the histogram of observed distances reasonable? Does the histogram have a "shoulder" near the line and then decline? Those are desired characteristics. If the histogram is extremely flat or has a peak in the B or C bands, that may indicate that observers were not watching the line closely, which can lead to significant underestimates. Under good viewing conditions with relatively small sample sizes (<100 clusters), the B band may be slightly higher than A due to chance (you can test this with a Chi-square if necessary; see Johnson et al. 1991). Usually results from the latter situation will still be reasonable. The fit of the detection curve estimated by DISTANCE can also indicate how reasonable an estimate may be. While the overall fit to the histogram is important, the fit of the curve in the region near the line is most critical (Buckland et al. 1993:50-51). For some histograms where detection drops off rapidly with distance, the negative exponential key may provide the best fit to the histogram (see Fig. 5.4 C). However, it is not uncommon for that model to significantly "overshoot" the A band leading to a serious overestimate (see Fig. 5.5 A). In those cases, try the hazard rate model (see Fig. 5.5 B). For some histograms where the A band is substantially higher than the other bands, the detection curves using uniform or half normal keys may underestimate the population (see Appendix VII). The AIC and Chi-square Goodness-of-Fit results on the DISTANCE output can provide some indication of how well the detection curve modeled the observed histogram. However, the determination of adequacy of fit near the line is a subjective call.

3. Is the line transect estimate reasonable? The Quick & Dirty technique (calculating a narrow strip transect estimate from the A band) described in Chapter 5 provides a baseline estimate to compare with estimates calculated using DISTANCE. If the estimates are grossly different, you should scrutinize both for potential errors, violations of assumptions, or other factors. Sometimes an incorrect statement was entered into the DISTANCE input file. The Quick & Dirty technique will underestimate the true population density if the A band is lower than the B band, because animals in the A band were undetected.

Sometimes line transect estimates give higher populations than were thought to occur. This often causes a reaction similar to "sticker shock" (Guenzel 1994). It's hard to accept the higher estimates. However, several possible explanations should be considered: (1) the population is actually higher than presumed (due to increase or immigration - the population may not be closed); (2) the estimate is higher due to chance (wide confidence intervals and larger coefficients of variation may suggest this is due to sampling variation); or (3) the estimate is wrong. Managers should not confuse higher population estimates with increases from previous surveys. Past surveys could have underestimated the population, particularly if estimates were based on trend counts or other biased techniques. A perceived declining trend may be true, but the population may be declining from a higher level than was assumed. Examine the coefficient of variation, the point estimate, the confidence intervals, and the magnitude that cluster size, encounter rate, and detection probability "explain" of the variance. These are summarized in the DISTANCE output. Do confidence intervals capture the "presumed" population size? Did the analysis evaluate and correct for cluster size bias?

Line transect surveys provide estimates. Keep their interpretation in this context. Do not dismiss the line transect estimate just because "the POP-II model says" the herd can't be so large. What other sources (real or error) could account for the difference?

Commonly, initial line transect estimates were much higher than previous population estimates based on trend counts and herd simulations (Guenzel 1994). Limitations of the trend count technique and POP-II modeling (e.g., linear mortality severity indices acting equally on all sex and age classes, composition survey biases (Woolley 1995) used for alignment) may explain these initial differences. With repeated surveys, more confidence is gained in the line transect estimates.

4. How precise is the line transect estimate? Precise estimates are desirable and lend support that the true value is within the estimated confidence interval. Conversely, wide confidence limits indicate a high degree of uncertainty about the reliability of estimates and how much faith to place in them. DISTANCE outputs several measures to evaluate the precision of estimates. Coefficients of variation (CVs) for density estimates are useful measures of relative precision. For most line transect surveys using the Wyoming Technique, CVs $\leq$15% are considered good. CVs $\geq$20% raise concern about the reliability of the estimates. As with most large-scale monitoring techniques, obtaining the desired level of accuracy and precision is often beyond the budgetary, time and manpower resources of agencies (Otis 1994). Most current management-level surveys using the Wyoming line transect technique are not sensitive enough to detect subtle (i.e., $\pm$<10%) changes in population sizes (Guenzel 1994). Managers should recognize the limitations in survey data and interpret them in that light. This also illustrates the need for surveying herds relatively frequently (i.e., every 2-3 years) to minimize the impact of "outlier" estimates resulting from sampling variation. Line transect analyses provide statistical evidence to identify when estimates are poor. Under those circumstances, managers should adopt a conservative interpretation of the line transect results and weigh other management criteria more in management decisions.

Using Line Transect Estimates in Management

Aerial line transect surveys can be used for management in a number of ways including: (1) aligning POP-II simulations and revising population objectives, harvest strategies, and other management criteria; (2) determining significant changes in numbers due to weather, movements, or other factors; (3) evaluating herd assumptions such as closure and seasonal distributions; and (4) improving designs for subsequent surveys. The technique has been used successfully in Wyoming for all four of these purposes.

Aligning POP-II Simulations

Line transect estimates have been used to realign herd simulations using POP-II. Line transects provide independent, corrected estimates to which simulations can be adjusted, unlike trend counts where the proportion that was undetected must be subjectively assumed. Since most Wyoming line transect surveys estimate pre-fawning populations, these estimates can be compared to simulated population sizes at the end-of-the biological year. The POP-II model is adjusted until it simulates the end-of-year population reasonably close to the corresponding line transect estimate. Simulations can be similarly adjusted to fit surveys at other times of the year.

Usually, POP-II simulations are initially aligned on line transect estimates by adjusting the initial population size for the herd at the start of the simulation so that it simulates close to the line transect estimate. This usually involves iteratively increasing the initial population size. The rationale behind this approach is the assumption that herds have historically been underestimated. Most other model parameters (e.g., postseason mortality severity indices) require only minor adjustments to align with the initial line transect estimate. That tends to preserve much of the existing data trends in the simulation. Alignment of simulations on additional line transect estimates can usually be accomplished by adjusting postseason mortality severity indices. This approach has been used successfully where consecutive annual line transect surveys indicated major population declines (Guenzel 1994). When aligning POP-II simulations with line transect estimates, be sure to compare the line transect estimate to the proper POP-II period. For instance, if you conducted a line transect survey on June 1, 1997, be sure to use this estimate to align with the simulated population size for the end-of-1996 biological year.

Refined herd simulations based on multiple line transect estimates can be used to improve management direction. Revised herd simulations along with line transect estimates and their associated confidence intervals have been used to support raising population objectives. In some areas, harvests have been increased in recognition of herds exceeding objectives. Alternately, harvests have been reduced where consecutive line transect estimates indicated higher winter mortality than had been predicted.

Evaluating Significant Changes

When properly designed and conducted, sequential line transect surveys can be used to help assess the magnitude of population change due to weather (e.g., severe winter or drought), harvest, and land use impacts. As stated above, most management-level surveys as currently performed can only detect major (i.e., $\pm$>20%) population changes. Line transects have been used to estimate the magnitude of winter mortality from one year to the next (Guenzel 1994). However, potential exists to detect smaller changes with increased survey effort and refined survey design. Where the need for increased design sensitivity can be anticipated, users should consult with experienced statisticians and other line transect practitioners. Potential exists to use the technique under controlled, experimental designs to detect population changes due to various large scale land use impacts such as mining, petroleum development, habitat alteration or other treatments.

Evaluating Herd Assumptions

Similarly to the sections above, line transects can be used to evaluate some assumptions about pronghorn herd management required for modeling and other purposes. Line transects have been used to examine population closure and distribution shifts by conducting a series of surveys over a specified period (Christiansen 1992). Significant changes in numbers, particularly in adjacent herds during periods of low natural mortality, may indicate emigration or immigration, as well as the magnitude of change.

Positional data obtained by GPS during line transect surveys may be compared to results from other surveys in that herd to evaluate distribution shifts. Such changes may be correlated with plant phenology, forage quality, and weather. With designed experiments such as discussed above, line transect surveys can be used to assess impacts of land uses on pronghorn distributions.

Improving Design of Future Surveys

Ideally, the design of subsequent line transect surveys should be adaptive. That is, results from prior surveys should be used to help refine the design of future surveys. Survey designs have been improved in many Wyoming herds by examining sample sizes, cluster dynamics, precision, encounter rates and other results. Such results have been used to evaluate the statistical power to detect certain magnitudes of population change for some Wyoming pronghorn herds (Guenzel 1994).

Reviewing results of prior surveys helps plan subsequent surveys in several ways:

1) evaluating effective strip widths and line lengths needed to obtain desired sample sizes,
2) predicting cluster sizes and encounter rates which influence confidence intervals,
3) estimating time and budget needed to conduct the survey,
4) identifying hazardous regions in the survey area and optimal transect layout,
5) estimating sample sizes needed to detect specified levels of change, and
6) evaluating the year-to-year dynamics in the above considerations as they impact sample adequacy.

Additionally, the spatial dynamics of locations of observed clusters can be examined to evaluate their impact on sample size effectiveness. Positional data in conjunction with habitat and terrain maps can be used to identify potential density strata for stratified survey designs. In some instances, stratification may provide improved, more efficient estimates.

Reporting Line Transect Estimates

This section discusses recommendations for reporting results of line transect surveys for pronghorn in Wyoming's Annual Big Game Herd Unit Reports (a.k.a. Job Completion Reports (JCRs), Federal Aid or Pitman-Robertson (PR) Reports). The main purpose in proposing such guidelines is to assure that the minimum pertinent data are presented to critique and interpret the analysis, to facilitate comparison with previous and subsequent surveys, and to provide data to help replicate or improve surveys. Additionally, the presentation of cost and flight time can aid in planning future surveys and in justifying expenditures. The survey, its analysis, limitations and interpretations should still be discussed in the narrative section describing population status, dynamics and modeling. Summarizing results in the concise manner recommended will allow for rapid review and ease of access. Too often, such information is "buried" in administrative files or discarded.

The reported data are in two parts: (1) those that summarize the actual data obtained during the survey, and (2) results of the analysis using DISTANCE and selected diagnostics. Organizing data for the first part is helpful for building the input for DISTANCE. Results summarized in the second part allow others to evaluate the adequacy of the estimation process.

Describing Basic Data

The following data can be presented in an abbreviated listing:

- HERD NAME: This identifies the population (the Herd Number can also be provided),
- DATES OF SURVEY: List the dates on which the survey was conducted,
- OBSERVERS: Identify the participants in the survey.
- AIRCRAFT: Report the aircraft model, air charter service, and equipment (e.g., GPS and digital radar altimeter linked to onboard computer),
- PILOT: List the pilot(s) conducting the survey,
- COST AND TIME BREAKDOWN: Summarize the charter costs and times for ferrying, conducting the survey and the totals,
- DESIGN: Briefly describe the survey design, including transect orientation, spacing, desired sample size and any modifications such as stratification (e.g., north-south transects spaced 4 minutes starting at 105° 34' designed for a sample of 300 clusters),
- HEIGHT AGL: List the mean height AGL for the entire survey (e.g., 315 ft), and
- COMMENTS: Note any important considerations such as weather (e.g., wind), light conditions, new observers, pronghorn distributions, cluster dynamics, or problem, etc.

In tabular form, summarize results for the individual transect lines by listing the following:

1. transect number,
2. heading (degrees),
3. direction of flight (e.g., north, south, east, west, etc.),
4. number of clusters observed,
5. number of animals observed, and
6. actual transect length (in statute miles).

List the totals for clusters, individuals and miles of transect at the bottom of the table. This table would help in planning future surveys and examining precision.

Also in tabular form, summarize the following by distance band and for the total survey (all bands combined):

1. corrected outer distance limits (in meters, adjusted for actual height AGL),
2. number of clusters observed,
3. number of individual pronghorn observed, and
4. the average cluster size.

This table would allow users to reconstruct the histogram of observed distances. It also provides some indications of cluster size bias.

Summarizing DISTANCE Results

The presentation of selected output from DISTANCE in herd reports is helpful to readers in evaluating the adequacy of results. Usually only results for the selected (i.e., "best") estimator should be summarized. Normally, that will be the model identified by DISTANCE based on the minimum AIC. Results of analysis should be discussed in the narrative as well. Including DISTANCE output for the selected model helps readers understand why that model is adequate. Including selected results can also be helpful where biologists disagree with the estimate from DISTANCE by showing (1) how the estimated detection curve deviates from the histogram of observed distances, (2) diagnostics indicating poor precision and/or estimation problems, and (3) evidence that critical assumptions were violated.

Output from DISTANCE can be saved to an ASCII (or text) file (usually the file with the ".OUT" extension when assigned). Selected results can be copied and pasted into the completion report using several most processing packages. In some cases, margins should be adjusted to prevent lines wrapping around in graphs. Options exist in DISTANCE to export plot data to SAS/GRAPH, S-Plus and some other graphics packages (using some computer gymnastics) to produce higher quality charts (*see* Laake et al. 1996:9-10,56). For most purposes, presenting the graphs made up of ASCII characters will be sufficient.

The following results and diagnostics from the DISTANCE output are helpful in evaluating the adequacy of the estimates:

- Density Estimation Results Table: This table summarizes the total transect length ("effort"), number of lines ("samples"), effective width, number of observations; selected key and adjustment(s) model; and point estimates for various parameters and their associated precision (e.g., se, %cv, 95% confidence intervals). Some of the main parameters of interest include the density (D), the population total (N) if specified, the density of clusters (DS), and the encounter rate (n/L). DISTANCE 2.1 and higher also provide a breakdown of component percentages for the variance of density including the detection probability, the encounter rate and cluster size. These are helpful in accounting for the sources of variation in estimates and in planning surveys.
- Chi-Square Goodness of Fit Test: This test provides a measure of how adequately the detection curve "fits" the histogram of observed distances overall. Note that a particular model may be a poor estimator even though it "fits" the histogram pretty well but does not adequately model detection near the line (i.e., leads to serious under- or overestimates).
- Expected Cluster Size Estimation Table (when specified in the analysis): This table compares the "raw" mean cluster size with the expected cluster size calculated using the log-based regression. It provides a measure how strongly cluster size biases the results.
- Detection Probability Plot: This is the classic line transect graph showing the histogram of observed distances against the probability detection function estimated by DISTANCE. It is a visual representation of how well the curve fits the histogram and can be used to evaluate estimates provided by DISTANCE.

Comparison of line transect results will be facilitated by presenting line transect results in a consistent format on a statewide basis.

Some Comments, Conclusions and Recommendations

The use of aerial line transect surveys and their analytical procedures for pronghorn management in Wyoming should continue to evolve. Opportunities exist for further refinements to provide more reliable estimates, and to design more efficient surveys. The successful implementation of the technique requires a great deal of objectivity and care in the design, conduct and analysis of surveys. The technique appears to be a substantial improvement over trend counts in terms of cost and reliability (Guenzel 1994). Use of the technique outside Wyoming is growing. However, line transects may not be suited to every area and may not always work every time. The technique does offer many advantages over historical pronghorn inventory techniques. Additional improvements are possible.

Perhaps the biggest advances in line transect surveys to estimate pronghorn abundance in Wyoming will come through better, more rigorous survey designs rather than new computer programs or enhanced technologies. As currently used in many management inventories, only larger population changes and land use impacts can be reliably detected. For some populations, more rigorous survey designs are justified. Hopefully, use of the technique will evolve to address these monitoring needs.

Some lessons have already been learned since the Wyoming Technique was integrated into routine pronghorn management in the early 1990's. Discrepancies between simulated herd sizes and line transect estimates caused managers to seriously critique line transect estimates, and then other management data (Guenzel 1994). That has contributed to more objective evaluations of data quality and review of management assumptions. There is still much to learn about the dynamics of many Wyoming pronghorn herds. In some areas, populations appear to be responding differently to habitat, climate and land use changes than how they were thought to behave in the past.

A number of comments and recommendations have emerged from the use of the Wyoming Technique:

- There is a need for more formalized training for biologists, wildlife managers, and administrators on the use and interpretation of the Wyoming Technique in pronghorn management.
- There should be more oversight and guidance on the design, conduct and analysis of line transect surveys. A number of biologists have expressed interest in improving their understanding of selecting proper models, constructing confidence intervals, and interpreting survey results.
- For some herds, more elaborate survey designs are warranted, including stratified surveys, and analyses of spatial dynamics. Surveys can be designed to detect smaller changes.

- Because of budget limitations, some pronghorn populations of higher state and national interest should be prioritized as "benchmark" herds receiving more frequent and intensive monitoring.
- Research should be undertaken to improve aerial line transect surveys while gaining greater understanding of pronghorn population dynamics. Opportunities exist to expand the distance marking system to accommodate a fifth distance interval which may provide improved statistical performance of the technique. A more portable marking and data capture system could be developed for use in a wider range of aircraft.
- Wyoming biologists would like to see easier to use analysis software while reducing the amount of data handling. Much of the input to DISTANCE could be automated via the existing data acquisition system, thereby reducing transcription and other errors. Many have suggested easier file management options.
- Research is needed to better estimate small populations.
- Software for planning and analyzing line transect surveys should be standardized and updated uniformly across the state.
- Further investigation is needed in ways to correct estimates where observers fail to detect some pronghorn on and near the line. Potential exists to incorporate sightability models with line transect sampling.

While there will always be some problems with any survey technique to estimate free-ranging wildlife, the current system appears to be superior to what was available in the past. Hopefully, wildlife inventorying techniques will continue to improve, allowing better understanding of the how these wild populations behave and how best to conserve these resources.

The Wyoming Technique should be viewed as a continuing experiment rather than a finished product. It may not be suitable in all circumstances. The challenge will be to strive for improvements and not become complacent about the technique. I hope that Bruce Johnson and Fred Lindzey's (1990) predictions remain valid that procedures for line transect sampling and analysis will continue to evolve. Users of the Wyoming Technique should look for new improvements.