Chapter 1

INTRODUCTION

This manual describes the current procedures used by the Wyoming Game and Fish Department for estimating pronghorn (*Antilocapra americana*) population sizes using aerial line transect sampling. Be sure to read the preceding notice, "READ THIS FIRST!" before continuing! Line transect sampling is one type of technique for correcting counts for perception bias. Perception bias occurs when animals that are potentially visible to observers are not seen (Marsh and Sinclair 1989). Perception bias leads to underestimating populations. Line transect sampling is used to estimate the density of objects in an area based on perpendicular distances of observed objects from established transect lines and assumes that visibility decreases as a function of distance (Buckland et al. 1993). It should not be confused with line-intercept sampling which is a common technique for estimating cover of vegetation (Bonham 1989).

The aerial line transect technique described in this manual is conducted using specially-equipped fixed wing aircraft. The Wyoming Game and Fish Department uses the technique throughout the state to inventory pronghorn herds for routine management (Guenzel 1994). Population estimates obtained using this procedure can be used to help assess the status of pronghorn herds, and to help validate and align simulations (Guenzel 1994).

Several refinements have been added to this technique since publication of the first manual, *Guidelines for Estimating Pronghorn Numbers Using Line Transects* (Johnson and Lindzey 1990). This manual updates the procedures described in Johnson and Lindzey (1990) and informs users of basic considerations for designing, conducting and analyzing data from aerial line transect surveys. It is not intended as the final word on how to use this implementation of line transect sampling. Like the *Guidelines*, this manual should be viewed as another step in the continual refinement of this line transect application to aerial surveys. A fitting subtitle for this manual might be "Distance Sampling for Dummies." It is intended as a supplement to *Distance Sampling: Estimating Abundance of Biological Populations* (Buckland et al. 1993) and the User's Guide for the related analysis program, DISTANCE (Laake et al. 1996).The manual is not a substitute.

Advantages and Disadvantages

Line transect sampling offers several advantages over traditional aerial surveys to estimate pronghorn herd sizes (Guenzel 1994), including:

- provides more accurate estimates which are corrected for animals that should have been detected using data obtained during each survey,
- provides confidence intervals and other measures to evaluate the reliability of estimates, and
- is generally cheaper to conduct than traditional trend (complete) counts in both time and money.

Potential users of the technique should be aware of certain limitations and requirements. The technique requires a great deal of quality control. Specially equipped airplanes are needed to properly apply these procedures. Poor estimates may result where sample sizes are small, surveys are poorly designed, or where personnel do not follow proper protocols. Line transect surveys may not work in all situations, such as low density herds. Users should be aware of the potential effects of failing to meet assumptions before implementing the technique in new circumstances. There are, however, ways to address some of these problems (*see* Buckland et al. 1993). Success of the technique is heavily dependent on proper set-up and conduct of the survey, meeting assumptions, and proper data analysis.

Users should also recognize that estimating abundance of small, isolated or very low density populations presents unique problems. The amount of survey effort one is willing to put into such situations may influence the accuracy and precision of resulting estimates.

Purpose

The purpose of this manual is to describe the basic requirements and provide a general background for designing, conducting and analyzing basic aerial line transect surveys to estimate the size and density of pronghorn populations using the current procedures of the Wyoming Game and Fish Department. The manual assumes some background in biological sampling and statistics. It does not include in-depth discussions of the mathematical and statistical theories underlying line transect sampling, advanced survey designs, or analyses of complicated surveys. Those can be found in Buckland et al. (1993), Burnham et al. (1980) and other technical articles. Procedures for setting up the required markers on aircraft are not discussed in this edition of the manual although some background is provided on the rationale for the system that is currently used. The measurements and calculations necessary for marking planes are complicated and beyond the scope of this manual. As of January 1997, there are two experienced air charter companies that are properly equipped for conducting acceptable line transect services (*see* Appendix I). Anyone interested in setting up new aircraft for line transect surveys should contact the author for instructions and assistance.

How To Use This Manual

The manual is organized into sections roughly ordered in the manner they are performed: designing and conducting surveys, analyzing data, and using results. Some general background is also provided. Further information can be obtained from the references or by consulting persons experienced in conducting and analyzing these surveys. For most users, the manual does not necessarily need to be read cover-to-cover. Table 1.1 lists pertinent and supplemental sections and other texts for various readers, depending upon their level of involvement in aerial line transect surveys.

Those participating as observers in surveys may wish to read the introductory sections describing the assumptions, the Wyoming Technique, and quality control in addition to the section on how to participate as observers in these surveys. I strongly encourage all participants to be familiar with all phases of the survey in order to appreciate the rigor required by the technique. Those involved in design and analysis phases should review the previously mentioned sections along with the chapters on survey design and data analysis prior to initiating a survey. Administrators will find this introductory chapter useful. In addition, chapters on quality control and conducting surveys will give administrators a better understanding of this technique.

Table 1.1. References for persons involved in aerial line transect surveys. Required readings are listed by role in larger type. Sections listed in parentheses are strongly recommended.

	ROLE				
REFERENCE	ADMINISTRATOR	OBSERVER	PILOT	DESIGNER	ANALYST
Buckland et al. (1993)	(Chapter 1) (Chapter 2) (Chapter 7)	(Chapter 1) (Chapter 2) (Chapter 3) **Chapter 7**	(Chapter 1) (Chapter 2) (Chapter 3) **Chapter 7**	(Chapter 1) (Chapter 2) **Chapter 3** **Chapter 4** (Chapter 6) **Chapter 7**	(Chapter 1) **Chapter 2** **Chapter 3** **Chapter 4** (Chapter 6) **Chapter 7** (Chapter 8)
Laake et al. (1996)				**All**	**All**
This Manual	**Preface** **Chapter 1** **Chapter 2** (Chapter 3) (Chapter 4) **Chapter 6**	**Preface** **Chapter 1** **Chapter 2** (Chapter 3) **Chapter 4** (Chapter 5) (Chapter 6)	**Preface** **Chapter 1** (Chapter 2) (Chapter 3) **Chapter 4** (Chapter 5)	**Preface** **Chapter 1** **Chapter 2** **Chapter 3** **Chapter 4** (Chapter 5) **Chapter 6**	**Preface** **Chapter 1** **Chapter 2** **Chapter 3** **Chapter 4** **Chapter 5** **Chapter 6**

Aerial Survey Background

Aerial surveys using fixed-wing aircraft have been used extensively to count pronghorn and other wildlife for management and research (Guenzel 1986 and 1994, Firchow et al. 1990, Johnson et al. 1991, Pojar et al. 1995). Pronghorn populations are well suited to such aerial surveys because they tend to occupy open habitats of moderate to flat terrain and are widely distributed throughout occupied habitats at least part of the year. Wildlife managers need survey techniques that (1) allow them to survey a pronghorn herd in a cost- and time-efficient manner, (2) provide a reasonably accurate estimate of a herd's size, and (3) provide some indication of how much confidence managers should place on the estimate. Fixed wing aerial surveys are currently the only cost-effective techniques for estimating herd sizes over large areas in a short time. Most scientifically accepted techniques for estimating wildlife populations are based on sampling rather than trying to count all animals in a population. Sampling involves surveying a representative portion of a population to get an estimate of the density (e.g., number of animals per unit area, pronghorn/square mile). To estimate the total number of animals in a population, the density estimate is multiplied by the size of the area that the population occupies.

Unfortunately, not all pronghorn within a sample unit area are seen (Guenzel 1986, Firchow et al. 1990, Pojar et al. 1995). As discussed below, one of the biggest challenges for accurately estimating the number of pronghorn in a herd is how to objectively correct surveys for undetected animals that should have been counted. The problem of aerial surveys underestimating populations has long been the subject of considerable attention (*see* Swank et al. 1969, Graham and Bell 1969, Caughley and Goddard 1972, Cook and Martin 1974, Caughley 1974 and 1977a, Caughley et. al. 1976, Norton-Griffiths 1978, Cook and Jacobson 1979, Australian National Parks and Wildlife Service 1979, Jolly and Watson 1979, Routledge 1981, Gasaway et al. 1986, Samuel et al. 1987). Many factors contribute to observers failing to see all the animals in the area surveyed from the air: (1) observer experience, (2) fatigue, (3) airspeed, (4) height above ground, (5) distance from the observer to the animal, (6) number of animals in a group, (7) weather, (8) light conditions, (9) background, and (10) time-of-day. Most of these factors can be controlled by accounting for two main problems: distance from the observer, and the number of animals in each group (one or more animals; called "clusters" in line transect terminology). Animals are harder to see the farther away they are from the observer (Figure 1.1). Also, it is easier for an observer to see a cluster of more than one animal at some fixed distance than it is to see a single animal at the same distance. These relations still hold when viewing conditions change, although the actual proportion missed may vary. For example, as light conditions deteriorate, observers may fail to detect animals that are closer to them then when light conditions are ideal.

Some techniques are available to account for the various factors influencing the countability of animals from aerial surveys (e.g., Caughley 1977a, Samuel et al. 1984, Cook and Martin 1974). Sightability models based on logistic regression have been developed for several species of ungulates (*see* Unsworth et al. 1994). Unfortunately, some of these techniques are expensive to conduct over vast areas and many require the use of helicopters or the marking of animals. Another approach for correcting aerial surveys for undetected animals involves distance or line transect sampling (Burnham et al. 1980, Buckland et al. 1993, Guenzel 1986). The characteristics of pronghorn and their habitats make them well suited for aerial line transect surveys (Guenzel 1986).

Line transect sampling (Buckland et. al. 1993, Burnham et al 1980, Gates 1979) was adapted to aerial surveys to estimate pronghorn populations in Wyoming (Guenzel 1986 and 1994, Johnson et al. 1991). This technique appears to be a cost-efficient, practical means to improve traditional aerial surveys to estimate the abundance of pronghorn in Wyoming and may be applicable to many other species of wildlife occupying relatively open habitats outside of Wyoming. The technique should be superior in most situations where traditional aerial strip surveys have been used to estimate density or totals.

Historical Overview of Estimating Pronghorn Herd Sizes in Wyoming

The following discussion is provided for those readers desiring a review of how pronghorn populations have historically been enumerated in Wyoming, and the processes that led up to the

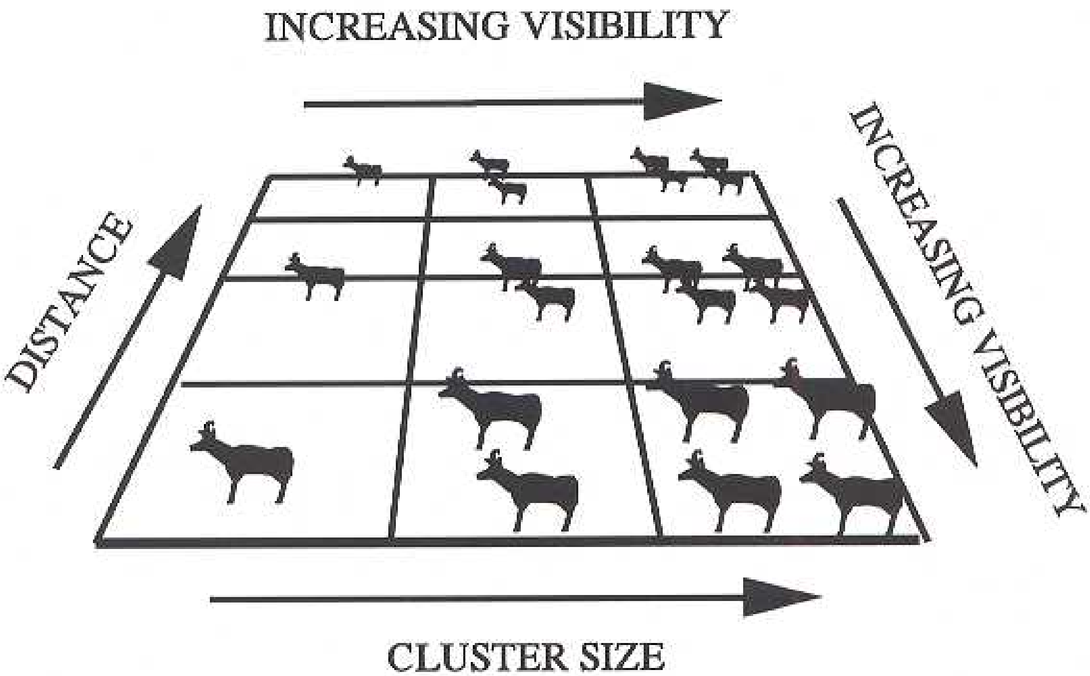

Figure 1.1. Effect of cluster size and distance on visibility. Larger clusters are easier to detect than smaller clusters at a given distance. Observers are more likely to detect animals that are closer to the observer than animals that are farther away.

current application of aerial line transect sampling in the state. A more complete discussion of how these line transect surveys were integrated into pronghorn management can be found in Guenzel (1994). Much of this review is based upon that report.

Total Counts

For decades, wildlife managers in Wyoming attempted to count all the pronghorn in a particular region from low-flying airplanes. These total counts, or censuses, were expensive and time-consuming. The state was divided into count blocks that were usually surveyed completely. In some areas, pronghorn were counted while they were concentrated in large groups on their winter ranges. Because of the costs and the vast area occupied by pronghorn in Wyoming, surveys could not always be done each year.

Many of the early aerial survey techniques for estimating densities of wildlife were based on strip transects. Typically, a series of parallel lines (i.e., "transects") of fixed length were flown throughout an area. The lines were often spaced about 1/2 mile (800 m) apart across the study area. In some cases, streamers were attached to the wing struts to define the outer edge of the strip when the plane was flown at a specific height above the ground (often 300-400 ft = 91.4-121.9 m). The pilot was responsible for maintaining the plane at the assumed height above ground while flying the proper heading. This approach assumed that all animals within the specified distance of the plane were counted. The population estimate for the area was the total counted. Density was calculated as the number of animals counted divided by the area sampled in the strip (i.e., the specified width of the strip multiplied by the total length of all transects flown).

Trend Counts

Research showed, however, that it is virtually impossible to reliably count all pronghorn in a survey area despite the fact that these animals live in relatively open country. Wildlife managers then tried to use the change from one aerial count to the next as a relative measure of population trend (i.e., increasing, decreasing or stable as a percent of the population). This required the assumption that a fixed proportion of the population was missed during each trend count. Attempts were made to standardize survey conditions (e.g., same observers, time of year, time of day, weather, degree of green-up, etc.) so that results of consecutive surveys could be compared. Unfortunately, an unpredictable proportion of the herd was missed from survey to survey, even when survey conditions were similar. Another problem with trend counts was that there was no good way to determine how accurate (i.e., how close the estimates were to the real population size) or how precise (i.e., repeatable) the estimates were using the available procedures.

Strategic Management

The Wyoming Game and Fish Department initiated strategic, long-term planning for wildlife resources of the state in 1974 (Crowe 1983). As part of this process, the Department defined individual pronghorn herds (called "Herd Units' or "Data Analysis Units") which were assumed to be relatively discrete populations. After considering public comments, the Department set target population levels for wintering herds. Harvests and other management activities were then designed to direct herd numbers towards those objectives. The Management-By-Objective system required the Department to better inventory populations to determine herd sizes in order to set and manage for target levels. Trend counts and other inventory procedures were refined (Wyoming Game and Fish Dept. 1982). Because of the expense and time involved in trend counts, they could only be conducted every 3 to 5 years for most herds.

Simulation Models

Wildlife managers then turned to simulation models in an attempt to make plausible estimates of population sizes over time (Pojar 1979 and 1981, Strickland 1979). These models were also used to evaluate the effects of alternative management strategies (mostly harvests) in directing populations toward objectives. Trend counts were compared to model predictions and often used to help realign models to simulate assumed population sizes. Models also helped wildlife managers identify weaknesses in their data. However, simulation models have many limitations (Conroy 1993). There was still no good way to know if the models simulated the correct population sizes because the accuracy of trend counts was unknown. Unfortunately, trend counts were some of the few sources of "real" information which were independent from the models that managers had to compare to simulations. Also, managers had to make some assumptions about these herds in order to use the models (e.g., that there were no substantial movements of animals in or out of the herd; mainly births and deaths influenced herd sizes, no density-dependent regulation). In a number of herds, these assumptions are not realistic.

Aerial Line Transects

Line transect sampling offers an alternative to trend counts by correcting population estimates for animals that should have been seen (Gates 1979, Burnham et al. 1980, Buckland et al. 1993). A detailed explanation of aerial line transect surveys appears later in this chapter. The technique is based on principles of statistical sampling. Most sample-based surveys use some way to randomly survey animals so that, at least initially, all individuals in the population have an equal chance of being included in the sample. The principles are similar to those used in most scientific polls. This type of sampling is intended to prevent having only areas with high or low densities from being included in the survey. That way, estimates should be more representative of the populations from which they come.

Line transect sampling and related techniques have been adapted to aerial surveys of many species of wildlife (see Burnham et al. 1980, Buckland et al. 1993, White et al. 1989, Beasom et al. 1981, Johnson et al. 1991). Banfield et al. (1955) described one of the earliest applications of a line transect-like approach to aerial surveys of caribou (*Rangifer tarandus*). The relatively recent use of advanced aviation instruments and data acquisition systems for wildlife surveys facilitated the development of line transect procedures from fixed-wing aircraft.

Guenzel (1986) demonstrated the feasibility of applying line transect sampling to aerial surveys of pronghorn in south-central Wyoming in 1981. Johnson et al. (1991) refined and further tested the technique on pronghorn in northeastern Wyoming in 1987 and 1988. This technique has now been integrated into routine pronghorn management by the Wyoming Game and Fish Department (Johnson and Lindzey 1990, Guenzel 1994). Aerial line transect surveys of pronghorn populations have also been used for management in Saskatchewan (Killaby et al. 1992) and for research in Colorado (Pojar et al. 1995).

Line Transect Sampling

Line transect sampling is one type of distance sampling used for estimating the abundance of wildlife populations by correcting surveys for animals that should have been detected. (Buckland et al. 1993). The correction factor is estimated as a function of perpendicular distance from a defined transect line. Techniques for estimating densities of wildlife populations using distances to correct for undetected animals have been around since the 1930s. Although line transect sampling has been around for over 60 years, most of the statistical theory and refinements were developed since 1968 (Buckland et al. 1993).

The philosophy behind line transect sampling is similar to strip transects in that animals are counted within a particular width along transect lines of fixed length. However, line transect sampling relaxes the strip transect assumption that all animals within a certain distance along the transects are seen. Instead, line transect surveys assume that all animals on the line are seen and allow some animals to go undetected the farther away animals are from the line (usually measured perpendicular to the line). Line transect surveys are designed to try to meet the assumptions of the technique. Figure 1.2 illustrates the similarities and differences between density estimates using strip transects and line transects.

The logic behind line transect sampling is fairly simple although the statistical theory on which population estimates are calculated is fairly complex. For example, if a transect line (or a series of lines) is randomly placed throughout occupied pronghorn habitat, there should be no inherent reason why pronghorn should consistently occur closer or farther away from the line. There should be as many animals close to the line as farther away (Figure 1.3A). Because observers fail to detect animals the farther away they occur from the line, the number of animals sighted tends to decline with distance (Figure 1.3B). The rate at which the sightings decline and the total number of animals observed may vary with conditions and observers. As long as all the animals that occur on the line are seen, line transect sampling should give reasonably accurate estimates of the population's density. The line transect technique calculates a correction factor to account for undetected animals based on the distribution of animals sighted as a function of distance. The more rapidly sightings decline, the larger the correction factor. For example, assume Figure 1.3A is the "true" density for a population and Figure 1.3B is the observed perpendicular distances from a survey. In this hypothetical example, half of the animals in the "true" population were seen during the survey as detectability declined in a linear fashion. Intuitively, one would expect the "correction" factor for this example to be "2" since only half the animals were observed. Line transect estimation performs an analogous adjustment using more rigorous mathematical procedures on more complicated data. The correction is calculated by fitting a curve to the frequencies of distances for animals observed during the survey. The curve is then rescaled to give the probability that an animal at a given distance will be detected. Ultimately, a correction factor derived from the actual survey data is applied to the observed counts to give a corrected density or total.

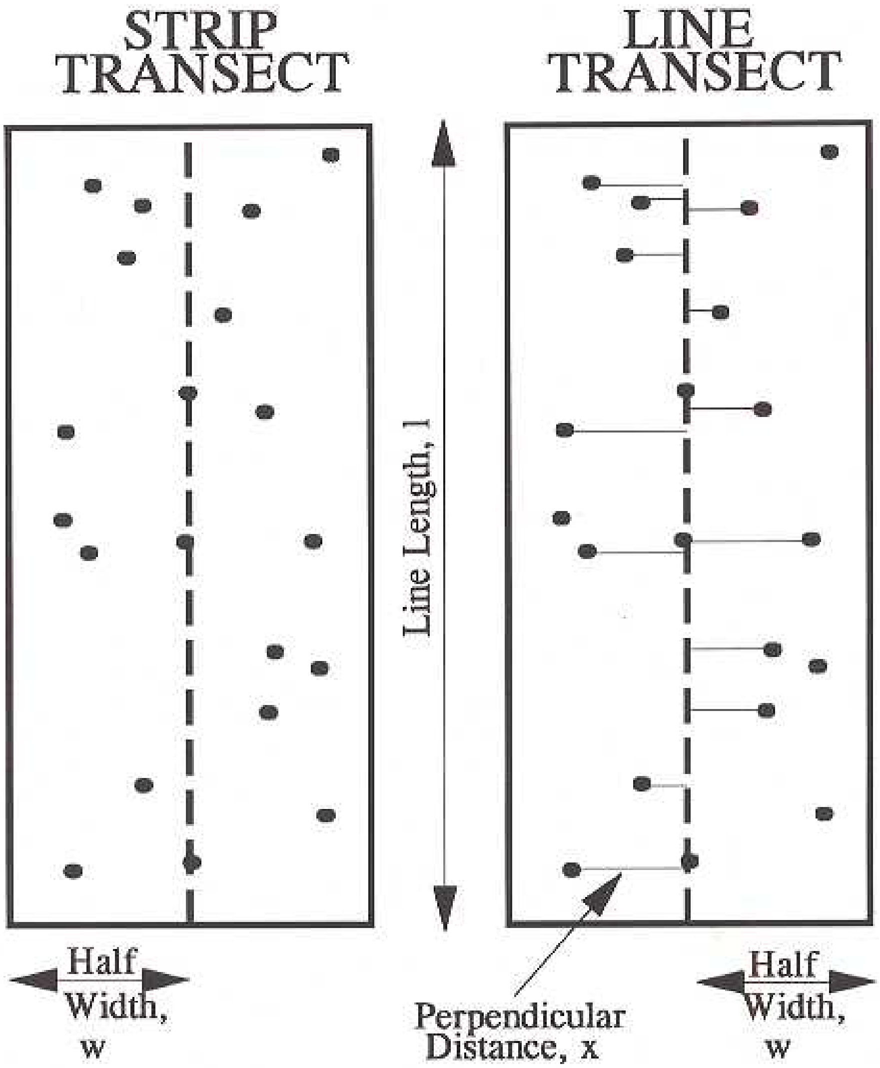

Figure 1.2. Comparison of strip and line transects for estimating density. Note that line transects allow some animals away from the line to be missed. Strip transects assume all animals in the strip are counted. The equations for density, D, are D = n/2*l*w for strip transects and D = n*f(0)/2*l for line transects where n is the number of objects counted, l is the line length, w is the half width, and f(0) is a correction factor derived from distance data in line transect sampling.

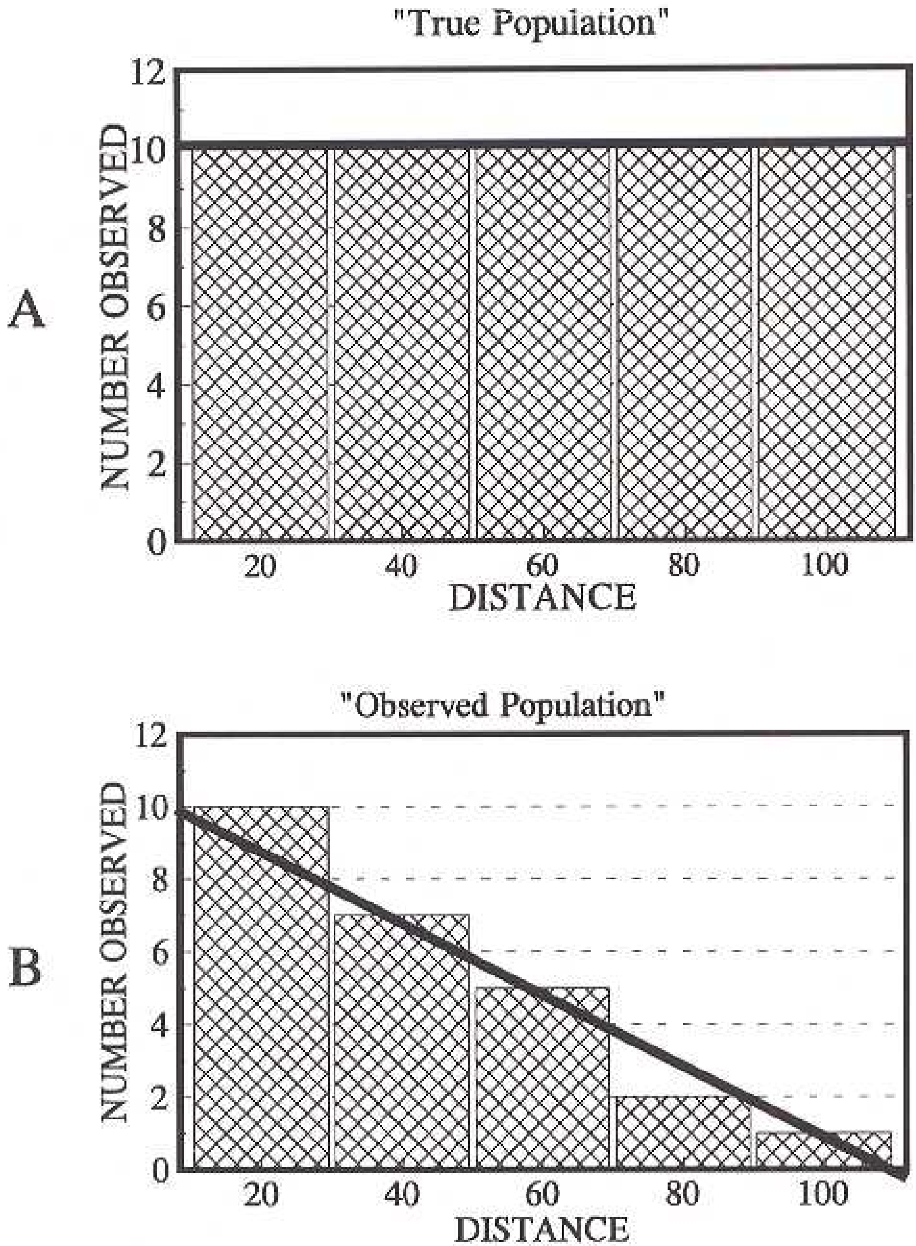

Figure 1.3. Hypothetical distribution of the "true" population with respect to distance from the line (A) compared to that for "observed" animals (B) where detection declines with distance. Line transects surveys correct for the animals that were missed as a function of distance.

Modern line transect procedures also account for differential observability of clusters of animals based on their size as well as distance. The chance of seeing an individual animal at a particular perpendicular distance away from the transect line is less than the chance of seeing a cluster of more than one animal at that same distance (see Fig. 1.1). DISTANCE, the recommended computer program to analyze line transect data, corrects for this cluster size bias (Laake et al. 1996). For an excellent explanation of line transect sampling and analysis, please refer to Buckland et al. (1993). This book also includes good discussion on practical considerations for survey design and aerial applications.

Basic Assumptions

There are three major assumptions required in order for line transect sampling to provide reliable population estimates (Buckland et al. 1993). The assumptions follow, in order of importance:

1. All animals on the line itself are seen. *Animals away from the line can be missed.*
2. Animals do not move in response to the observer before being detected. *Animals are sighted at their initial position before moving and none are counted twice. Movement is acceptable if it is independent of the observer and is slow relative to the speed of the observer.*
3. Distances and angles to animals are measured exactly. *Alternately, animals can be placed in the correct distance interval.*

Line transect sampling does not require assumptions about the spatial distribution of animals. Animals do not need to be randomly or independently distributed as long as the line is randomly located with respect to the distribution of animals. In practice, many of these assumptions can be relaxed (Buckland et al. 1993). As described below, these assumptions can be met in aerial pronghorn surveys (Johnson et al. 1991).

Adapting Line Transects to Aerial Surveys

The following discussion briefly addresses how line transect sampling is adapted to aerial pronghorn surveys using fixed wing aircraft. This manual explains these considerations in more detail in subsequent sections.

Meeting Assumptions

For the purposes of this manual, the basic assumptions are restated here in terms of aerial pronghorn surveys. The basic principles behind the physical set-up of the aircraft and procedures to meet assumptions are also described in this section. Johnson et al. (1991) demonstrated that these assumptions could be reasonably met during aerial line transect surveys of pronghorn.

1. Pronghorn on the line are seen. The survey must be designed to maximize the probability that all animals on and near the line are seen. This assumption is addressed in several ways. Because visibility is poor under and close to the plane, the line is offset a specified distance from directly beneath the plane so that observers can better meet the assumption of seeing animals on or near the line before they move. This area beneath the plane is referred to as the "blind area." The survey is designed so that the plane is flown as close as possible at a specific height above ground

level (AGL) that is not too high to miss animals on the line, but is high enough to minimize causing animals to move in response to the plane. The prescribed (or nominal) height AGL was also selected to allow the plane to be flown with reasonable safety in most occupied habitats. Based upon prior experience in aerial surveys, the nominal height AGL of 300 ft (91.4 m) was adopted to ensure that animals on the line were detected. Observers are also trained to focus their attention on and near the line.

2. Pronghorn do not move before being detected. Offsetting the line from beneath the plane helps observers to watch for evasive movements caused by the airplane. Offsetting the line also allows observers a slightly more forward view to help detect pronghorn movements. Animals running from one side of the plane to the other must go into the blind area where they may be detected as they cross underneath. Flying the survey at the prescribed height AGL also minimizes animals getting up and running before being seen. With the present survey procedures, pronghorn tend to stay in place before being detected and those that move tend to run parallel to the flight line (Johnson et al. 1991). Transect lines are generally spaced sufficiently apart so that animals that do run are not likely to be counted again on the next transect line. The groundspeed of the airplane is usually sufficient to allow the plane to be nearly perpendicular to the animal's position before it moves.

3. Pronghorn can be placed in the correct distance band. Line transect sampling allows observations to be assigned to distance intervals or bands (Buckland et al. 1993) as opposed to having to measure distances exactly. In practice, this usually means that observations can be assigned to the correct distance interval (e.g., 25-50 m). For most aerial surveys, assigning perpendicular distances to intervals is the only practical approach because exact measurements are not possible. Attempting to estimate exact distances or angles from airplanes usually result in heaping and other measurement errors. Distance data are typically analyzed by grouping into intervals anyway.

The Wyoming protocol emphasizes assigning pronghorn to perpendicular distance bands when the plane is perpendicular to the location where pronghorn were initially seen. This requires that wing struts are accurately marked (using dowels) as well as placing reference marks on windows (using tape) on specific high-winged aircraft. At the prescribed height AGL, these markings define the line and specified perpendicular distance bands to which observed animals are assigned. The placement of these markings on the struts is calculated for the plane's strut configuration and a specific eye position. Two strips of tape are placed on the window to help assure observers assign observations to distance bands from the defined eye position. Observers align these window marks with the strut markers defining the first distance band before assigning an observation to a perpendicular distance interval. By design, distance bands are unequal in width, with narrower bands near the line and wider bands farther out. The number of distance bands is limited so that observers do not have to cover too wide of a strip (thereby missing animals on the line) and to minimize errors in assigning observations to the correct band. Guenzel (1986) and Johnson et al. (1991) demonstrated that it was feasible to assign observations of pronghorn to the correct distance bands from the air using this set-up.

A digital radar altimeter installed on the plane helps pilots fly the survey as closely as possible to the prescribed height AGL for which the plane was marked. In all surveys, circumstances will necessitate some deviation from the planned height AGL. For each observation, the radar altimeter reading is stored in the computer to later correct observed distances for actual height AGL. Ideally, the radar altimeter is linked to the onboard computer for instantaneous recording.

The onboard computer is linked to a GPS to instantaneously record starting and ending points for each transect, locations for each observation, and to define flight paths in some cases (LORAN-C was used for earlier surveys). The GPS helps pilots fly transects as designed. Stored positions are used to estimate the actual line length surveyed.

For species like pronghorn, assuming that sightings of individuals are independent is not realistic. Pronghorn tend to occur in clusters (or "groups" of one or more animals). As noted earlier, the size of the cluster has some bearing on its probability of being detected (*see* Guenzel 1986, Buckland et al. 1993). Therefore, the sampling "object" for these line transect surveys is a pronghorn cluster. In practice, the term "cluster" should replace "animal" in the above discussion of assumptions. Fortunately, the DISTANCE program can correct for cluster size bias (Laake et al. 1996, Buckland et al. 1993).

Pronghorn clusters need not be uniformly, randomly or independently distributed as long as transect lines are random with respect to the distribution of clusters. There should be no inherent reason why pronghorn clusters should occur consistently closer or farther from the transect line. Transect lines should be designed so that they don't coincide with any natural pattern of clusters (e.g., riparian zones).

The Wyoming Technique

This section describes the Wyoming Game and Fish Department's implementation of aerial line transect sampling for estimating pronghorn abundance. The procedures described in this manual were developed to estimate sizes of pronghorn populations in Wyoming, although they can be adapted for some other species and circumstances. The term "Wyoming Technique" is used merely to distinguish this implementation of aerial line transect surveys from other aerial line transect approaches (*see* White et al. 1989, Buckland et al. 1993), rather than to imply any proprietary interest. The manner in which line transect sampling is applied to aerial surveys will make a difference in the reliability of estimates. That is one reason why some other investigators may not have as much success in applying line transect sampling to aerial surveys. The Wyoming Technique requires a great deal of quality control for successful implementation. Users of this technique should be prepared to properly conduct these surveys. Availability of equipment and experience of pilots and observers may vary. However, users should strive to conduct the best surveys feasible, to minimize deviations from the standard technique, and to recognize limitations resulting from not completely implementing the technique. As with all aerial survey procedures, conducting surveys safely should be the primary concern.

The Wyoming Technique involves the accurate marking of struts and windows on certain high-winged aircraft (see Chapter 2) as outlined above (Figure 1.4). This allows observations to be

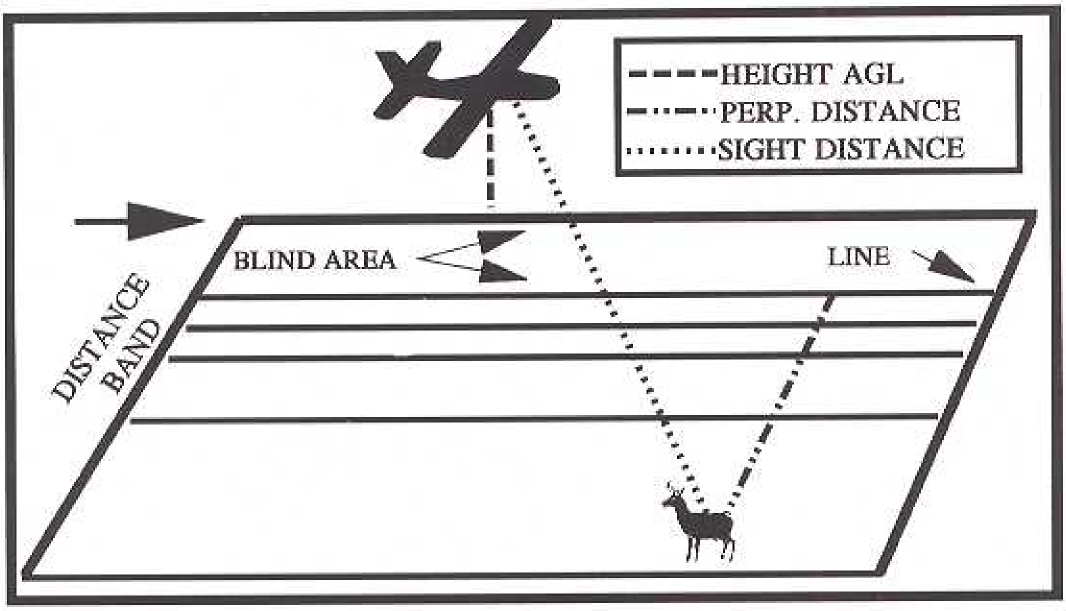

Figure 1.4. The basic arrangement for aerial line transect surveys showing one side of the plane. Normally, surveys are conducted using observers on both sides. Animals should not be assigned to distance bands until the plane is perpendicular to the location where the animals were initially seen.

accurately assigned to distance bands corrected for actual height AGL using a digital radar altimeter, GPS and onboard computer.

Two observers are used on most surveys. Each observes out separate sides of the plane. Usually one observer sits up front (copilot seat) while the other sits on the opposite side in the back seat. Because of the different seat positions, each side of the plane has to be marked specifically since the eye position for each side of the plane will be different (front vs. back seats).

For some two-place airplanes (e.g., SuperCubs, Scouts), only one observer can be used necessitating that the observer scans from only one side of the plane. Both sides of the plane can be marked the same as long as the observer only searches from one side during a transect. To optimize detection, the observer may alternate surveying sides of the plane from one transect to the next so that the observer is usually watching with the sun instead of looking into the sun. The analysis would have to be adjusted to account for only one observer. Currently, surveys in Wyoming are not performed with single observers. On rare occasions, a survey has been flown with only one observer when the other observer could not continue. That requires adjusting the survey effort in the analysis

The pilot's role is to safely fly the airplane, follow the design, and enter observations into the computer. The observers' responsibilities are to properly search for animals of the target species out to the defined outer distance limit (focusing most effort on and near the line), to count the number of animals in the cluster, to assign the location on the ground where the cluster was first observed to the correct distance band when the plane is perpendicular to that location, and to relay the distance band and cluster size to the pilot through the intercom so that he can capture the data in the computer. Observers should not perform other tasks (e.g., writing down data, looking on maps, trying to obtain composition data, etc.) which would divert their attention from surveying. Pilots and observers should be trained prior to conducting the survey.

The number and placement of markers to define prescribed distance bands depend in part on characteristics of the species to be surveyed and its habitat. While safety will be the primary concern dictating how low to fly the survey, one also needs to consider the angle of view needed to cover the desired ground distance intervals, airspeed, and disturbance to wildlife. Ideally, surveys should be flown as high above the ground as possible while still being able to see all animals of the target species on and near the line and most in the next inner bands. Figure 1.5 shows the general arrangement for the Wyoming Technique.

The set-up currently used for Wyoming's pronghorn surveys includes the following design:

1. Two observers on opposite sides of the plane (front and back).
2. Onboard computer for data acquisition linked to a GPS.
3. A digital radar altimeter.
4. Prescribed survey height AGL of 91.4 meters (300 feet).
5. Dowels attached to the struts at specific positions to mark the defined offset (blind area) and four perpendicular distance bands (Fig. 1.6) when the plane is flown at the prescribed height of 91.4 meters AGL:
    - Blind Area 0-65 meters,

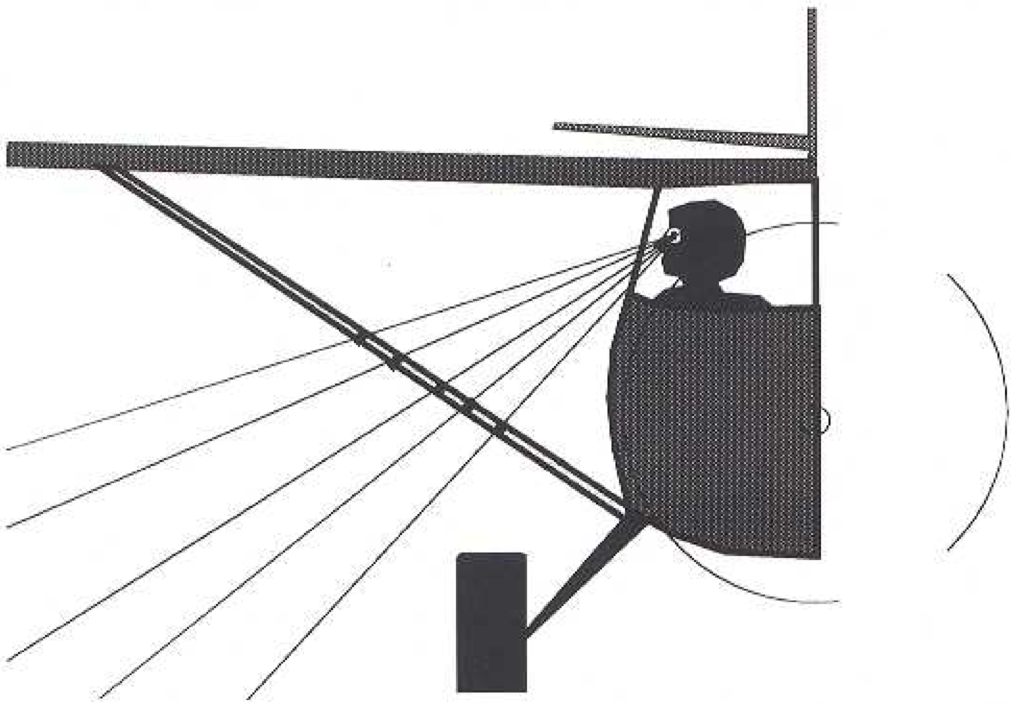

Figure 1.5. Viewing angles for the strut marker system for one side of the plane. Dowels attached to the struts define the prescribed distance band limits when the plane is flown at the proper height. Tape markers that define the first distance band are placed on the window at the prescribed position to maintain proper eye alignment when assigning observations to distance intervals.

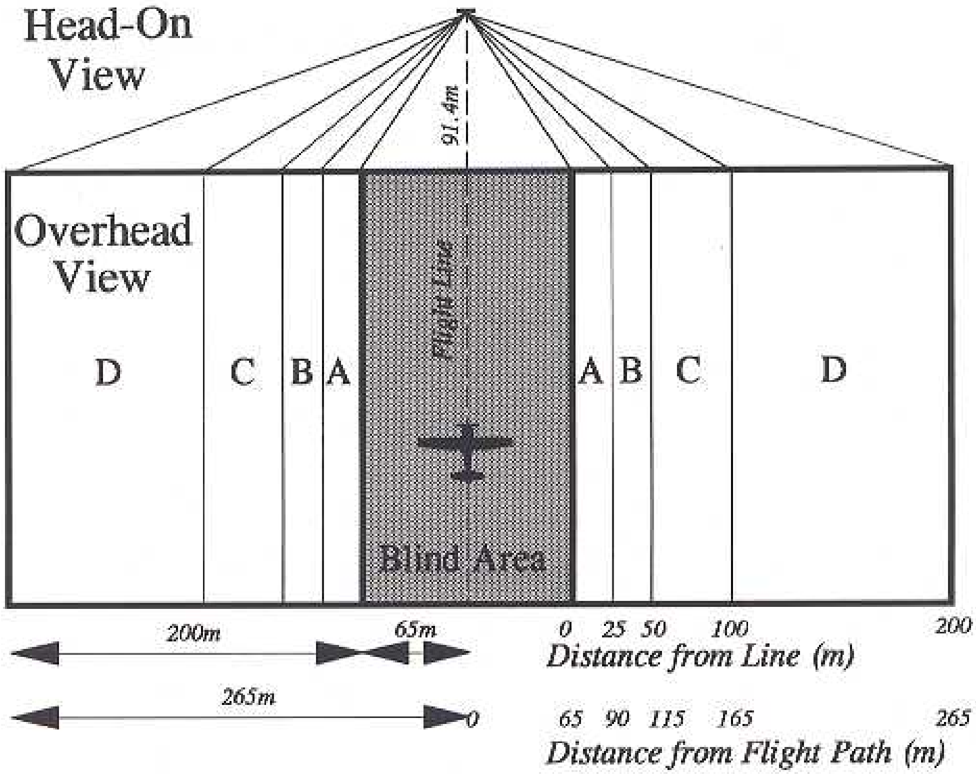

Figure 1.6. The geometry of the Wyoming Technique for aerial line transect surveys. The figure shows the relative widths of prescribed ground distance intervals when the plane is flown at the prescribed height above the ground.

- "A" Band (defines the line and a 25 meter wide first interval) 65-90 meters,
- "B" Band (defines another 25 meter wide band) 90-115 meters,
- "C" Band (defines a 50 meter wide band) 115-165 meters, and
- "D" Band (defines a 100 meter wide band and the outer distance limit) 165-265 meters.

6. Two window marks that align with the first distance band.
7. Pilot enters data into computer.

These characteristics distinguish the Wyoming Technique from other approaches where distances were be visually estimated or flown using a helicopter (e.g., White et al. 1989, Pojar et al. 1995), or where distances are later calculated from plots on photomosaics (e.g., Thompson 1979).

Changes From Johnson and Lindzey's (1990) "Guidelines"

As Johnson and Lindzey (1990) predicted, procedures used to conduct and analyze aerial line transect surveys of pronghorn populations in Wyoming continued to be refined. The following briefly describe the major changes in the current technique from the procedures in their *Guidelines*:

1. <u>Revised strut markings.</u> The line is now offset 65 m from directly below the plane when flown at 91.4 m (300 ft) AGL. It was previously offset 50 m. The ground distance intervals remain the same width with outer limits of 25, 50, 100 and 200 m from the line. Experience indicated we could expand the blind area under the plane to provide greater eye relief for observers while still being able to see animals on the line.

2. <u>Added two window marks.</u> We added two window marks for each observer which align with the strut markers denoting the "A" distance band. Prior to assigning an observation to a distance band, observers line up these window and strut markers. This helps assure that the observer's eye is in the correct position for which the struts were measured.

3. <u>Digital radar altimeter interfaced to onboard computer.</u> A digital radar altimeter is installed on survey aircraft. This helps pilots maintain the plane at the proper survey height AGL. Radar altimeter readings are now captured at the location of each observed pronghorn cluster. The altimeter readings are used to correct the midpoints of the distance bands for the actual heights AGL as the ratio of actual height AGL (in feet) to nominal height AGL (i.e., 300 ft). On some planes, the radar altimeter is interfaced to an onboard computer for instantaneous recording. The corrected distances are used in analyzing the data with the program DISTANCE.

4. <u>GPS to replace LORAN-C.</u> The LORAN-C navigation system on survey aircraft has been supplemented or replaced with GPSs to provide more accurate positions as well as improve navigation along transect lines.

5. <u>Improved in-flight procedures.</u> We've adopted more formalized protocols for observers to report observations for recording data during surveys. These procedures allow more efficient data capture and allow the pilot (who enters the data) to anticipate the next information to be reported.

6. Improved criteria. Criteria are now provided to define a cluster of pronghorn (e.g., are there two clusters or just one big one?) and whether or not a cluster is in or out of a particular distance band when the cluster overlaps bands. These criteria should allow decisions to be made more consistently among observers.

7. Improved survey design and sample size considerations. We encourage biologists to give greater attention to the desired sample sizes and layout of surveys when designing them. There has been confusion over what constitutes an adequate sample. Too often, biologists attempted to only obtain a minimum sample of 100 clusters. As a result, confidence intervals were often wide and estimates were less reliable. The general recommendation for a sample size of 100 is generally only adequate for estimating the detection function from which density is corrected. Many other factors contribute to the accuracy and the overall variance of estimates, including the encounter rate (number of clusters/length of transect) and the mean cluster size. Surveys should generally be designed to obtain considerably larger (e.g., $\geq$200 clusters) samples. This is particularly true for moderate to large populations occupying large geographic areas with relatively low densities and/or having fairly clumped distributions. Positional data from prior surveys should be used in designing future surveys and to determine whether or not a stratified or other special design would provide a significant improvement.

8. Improved analysis program. We no longer recommend that line transect data be analyzed using TRANSECT (Laake et al. 1979). Instead, we strongly advocate the use of the DISTANCE program (Laake et al. 1996). Although TRANSECT is easier for novices to use, we prefer DISTANCE because it includes many new or improved numerical procedures such as new estimators with more robust and objective model selection criteria. DISTANCE will calculate densities and totals for clustered populations directly. TRANSECT estimated the density of clusters, which then had to be manually corrected for mean cluster size and multiplied by hand to get a total. DISTANCE includes robust procedures for correcting for cluster size bias. DISTANCE accommodates more sophisticated survey designs and allows for bootstrapping confidence intervals.

Because of the availability of new analytical procedures, persons interested in the design and analysis of line transect and other distance surveys should refer to the new "bible" on line transect sampling:

> Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman & Hall, New York. 446 pp.

This reference replaces the previous standard by Burnham et al. (1980). Buckland et al. (1993) describes options incorporated into the computer program DISTANCE and is an excellent companion to the user's manual for DISTANCE (Laake et al. 1996).