Wild Ungulate Surveys in Grassland Habitats: Satisfying Methodological Assumptions


Richard B. Harris
Montana Cooperative Wildlife Research Unit
University of Montana
Missoula, MT 59812 USA

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2Present address: Wildlife Conservation Society, c/o Kunming Institute of Zoology, Kunming, Yunnan 650223

Abstract: Surveying grassland ungulates presents unique problems to the researcher. Appropriate statistical methods exist, but applying them in the field invariably requires ingenuity and compromise. I describe line-transect surveys I conducted of 3 plateau grassland species in Qinghai province, focusing on underlying statistical assumptions and specific measures I took to deal with each. I also suggest that authors take care to consider assumptions of whatever statistical model is chosen, and provide sufficient detail in reports that readers may assess strong and weak points of the survey.

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There is general agreement that accurate estimates of population size are fundamental to good management of wild ungulates, particularly those for which sustained utilization is practiced or contemplated. Because grassland ungulates are much easier to see than those inhabiting forest or brush habitats, investigators may be tempted to assume that censusing them accurately is correspondingly easy. However, while it is true that many of the difficulties of conducting surveys in forested regions are absent, estimating numbers of grassland species presents its own set of problems. Chief among these are (i) devising an appropriately objective sampling strategy (at least
in the absence of aircraft, which we can assume is the case in China), and (ii) meeting the underlying assumptions of whatever statistical model is chosen for analysis.

The experience of wildlife biologists in North America, Africa, Australia, and elsewhere, is that, even for relatively visible species, and even with the use of aircraft, there are no methods that can be applied to ungulate surveys simply and directly from book knowledge the way one might prepare a meal from the recipes in a cook-book. Instead, field contingencies inevitably necessitate compromises from the ideal. What differentiates effective from ineffective science (or even science from common observation) is the effort and creativity brought to bear on the problem of aligning as closely as possible messy (biological) field realities with elegant (lifeless) mathematical truths.

Further, those trained or experienced in wildlife survey work in such Western countries, naturally look to the "Methods" section of survey reports for guidance in assessing the quality and reliability of the population estimates reported. This is particularly so for species of interest to foreigners. Such species are either rare, and thus the object of attention by the World Conservation Union (IUCN); traded internationally, and thus the object of attention by the Convention on International Trade in Endangered Species (CITES); or simply stir the human imagination, and thus the object of attention by international trophy-hunters. Unfortunately, most surveys reported in the Chinese literature provide precious little detail about how methodological problems were solved or addressed. Instead, most simply state that such-and-such a method was used and that samples were obtained, as though it were perfectly obvious how one would go about doing so. Under real field conditions, it is usually far from obvious.

Here, I report on efforts I conducted to estimate numbers of three species of grassland ungulates in a remote area of Qinghai Province during 1991. Specifically, I focus on the assumptions of the method I chose (line transects), and how I addressed each. My purpose in doing so is not to suggest that other surveys follow identical steps; each survey will encounter unique field problems, and each investigator must solve them appropriately. There is no cook-book. Nor is my purpose to bestow honor on myself; the reader will quickly see that I was not able to solve all the problems presented, and my results were also compromised by the degree to which I failed to match the statistical ideal. Rather, my purpose is to provide a model of how one might lay out the
assumptions underlying one's chosen method, attempt to design field work to minimize violations of those assumptions, and finally, report fully on one's work, so as to allow readers a chance to understand its strengths and weaknesses.

**Study Area**

The survey was conducted in an unprotected region (i.e., pastoral area) in central Qinghai province, known colloquially as Yeniugou. Yeniugou is actually a series of connected valleys within the Kunlun Mountains, located in Haixi Mongolian People's Autonomous Prefecture at approximately 35° 50' N, 91 to 93° E. Elevations on valley floors vary from roughly 3800 to 4200 m. The study area measured approximately 1051 km². Yeniugou is characterized by low annual precipitation and shallow soils. Vegetation consists predominately of graminoids (notably *Stipa, Kobresia* and *Carex* spp., Harris and Miller, submitted) and forbs; there are no trees. Vegetation ground cover tends to be low, vegetation height is also low (5-25 cm, Zhou et al. 1990), and portions of the area at higher elevations are devoid of all vegetation.

Seven ungulate species inhabited Yeniugou: Tibetan wild ass, white-lipped deer (*Cervus albirostris*), Tibetan gazelle, Tibetan antelope, wild yak (*Bos grunniens*), blue sheep (*Pseudois nayaur*), and argali (*Ovis ammon*). Predators we documented in Yeniugou during 3 summers of survey work (1990-1992) included wolf (*Canis lupus*), lynx (*Felis lynx*), snow leopard (*Panthera uncia*), red and Tibetan fox (*Vulpes vulpes, V. ferrilata*), and brown bear (*Ursus arctos*). Tibetan wooly hares (*Lepus oiostolus*), Himalayan marmots (*Marmota himalayana*), and plateau pikas (*Ochotona curzoniae*) were all seemingly common, and observed daily. Details of the study are reported by Harris (1993) and Harris and Miller (submitted), and a summary is provided by Harris et al. (submitted).

**Overview of Methods and Results**

Three species that inhabited flat or relatively gently sloping terrain within Yeniugou were
the target of the surveys reported here: Tibetan wild ass, Tibetan gazelle, and Tibetan antelope. (Species inhabiting mountainous terrain were also surveyed, but using different methods; these efforts are reported by Harris [1993], and are not described here). All surveys were made between 18 September and 5 October 1991, inclusive.

Strip transects, using observations made from a vehicle, are commonly used for surveys of such species in China (e.g. Achuff and Petocz 1988; Feng 1990, 1993; Schaller et al. 1991). While useful for general indices of presence or absence, vehicle-based strip-transects suffer from strong limitations. Most often, they include no rigorous method of verifying that recorded animals are within the strip boundary, and no way of confirming the critical assumption that all animals within the boundary are indeed seen. Additionally, such surveys are limited to areas in which a vehicle can be used. If only roads are used, surveys are subject to various biases, chief among them that roads are usually located so as to facilitate vehicle travel (and they thus provide a biased sample of habitats), and that animals hunted by humans may tend to avoid using areas near roads. Conversely, if vehicles are driven over unroaded terrain, unacceptable levels of damage can occur to sensitive vegetation (Achuff and Petocz 1988).

Instead, I used randomly placed line-transects, in which distances from a center-line to each observed object are measured (Anderson et al. 1979), and a detection function, derived from the data, is used to estimate the density of groups. While line-transects avoid the above-mentioned problems of strip-transects, their use is not straight-forward, and application to these 3 species in Yeniugou necessitated careful planning and some compromises. These are discussed in the next section. Results of the surveys are presented in Table 1.

Methodological Assumptions, and Efforts to Minimize Violations

Numerous statistical models have been proposed for analyzing line-transect data (see Burnham et al. 1980 for summary). Regardless of which model is chosen, the following restrictions are assumed to characterize the field work and resulting data (Anderson et al. 1979):
1. Transect lines are placed randomly, or at least objectively, with respect to the population being studied;
2. Transect lines are straight;
3. Objects (i.e., animals or animal groups) do not move toward or away from the transect line in response to the observer before distances are measured;
4. Distances from the transect line to each object are measured accurately;
5. Objects encountered are independent (i.e., observing an object does not affect the probability of observing any other object);
6. The size of the object (or, if objects occur in groups, the size of the group) does not affect the probability of observation (if it does, alternative analyses that account for size-bias must be used); and
7. Sample sizes (number of objects observed) are sufficient to provide robust estimates of the detection function and its variance.

Meeting any one of these restrictions under field conditions is not easy; meeting all simultaneously is a real challenge. Here, I describe actions I took to minimize departures from each of the 7 assumptions.

Assumption 1: Transects are placed randomly or objectively.

Because the study area was large, I first divided it into census units (CU), ranging in size from 2.5 to 39.8 km², within each of which transect location would be randomly positioned. CUs were limited to known habitat of gazelle, ass, and antelope, thus did not include steep slopes. Each unit was drawn on 1:000,000 topographic maps; boundaries were generally along major drainages and/or divides between drainages to facilitate identification in the field. (This stratification ensured that, although randomly placed relative to ungulate distribution, transects would be evenly spread throughout the entire study area. An even better approach would have been to stratify according to approximate ungulate density, as determined by a pilot study, and allocate transects relative to density [Caughley 1977]. This was not possible because I lacked the time to perform a pilot study).

Within each CU, a point was randomly chosen as the starting point of the transect line by using the pseudo-random number generator of a pocket calculator and multiplying by the appropriate latitudinal and longitudinal Universal Transverse Mercator (UTM) axes of the unit, subject to the constraint that the starting point be at least 1 km from the northern and western boundary of the unit. This constraint was introduced to ensure that all transects be a minimum of 1
km (and a maximum of 3 km) in length, and to avoid walking transects into, or nearly into the
direction of the early morning sun (see also Assumption 7).

To find the starting point, I programmed its coordinates into a portable Geographic Position
System (GPS) and approached on horseback or foot until the GPS indicated arrival. The GPS I
used had a nominal standard error of 30m; tests I made of its precision confirmed this approximate
level of precision (Harris 1993).

Having determined a random starting point, I also had to determine a random bearing for
the transect. Permissible bearings for transects were limited to angles of between 250° and 50°,
again to keep the morning sun at my back. An initial bearing was selected randomly from among
the possible bearings by drawing another pseudo-random number and multiplying by the difference
between the largest and smallest permissible bearings, then adding the value of the smallest bearing.

Assumption 2: Transect lines are straight.

Once I had arrived at my starting point and determined an appropriate bearing, I still faced
the problem of maintaining a straight course through the open grasslands. In some situations, it is
possible to first lay down a tape or line; in others, an assistant, positioned ahead or behind the
observer, can be tasked with making sure the observer walks straight along the line. In my case,
doing either would have caused unacceptable disturbance to the very animals I was attempting to
observe (Assumption 3). However, I had the advantage that in Yeniugou, mountain peaks, ridges,
and saddles were almost always visible in the background, and I could use these as landmarks to
easily check my direction while still concentrating my attention on observing the animals. I
arbitrarily chose the closest landmark to the pre-selected bearing, then this new bearing was
recorded and taken to be the true bearing in all further analyses. This procedure compromised
randomness to a small extent (Assumption 1), but I never altered the bearing in response to
presence or absence of animals, only distant landmarks.

\(^3\) I used a Magellan Nav-Pro 1000; the only equipment needed for my survey was not easily available in China. However, they have recently become easily available, and cost about $1000.
Assumption 3: Objects don't move before being counted.

This was potentially the most difficult assumption to satisfy, because animals invariably flushed from me as I travelled along the transect line. However, I was usually able to determine the approximate position of the animal on the ground before it flushed, and noted whatever minor characteristic I could distinguish (e.g., bare patch of ground, small swale, protruding clump of vegetation). The first, and all subsequent distances were measured from the line to this initial position, not to the animals themselves, which had usually moved off (Fig. 1). An assistant, usually riding horseback behind me, monitored the position of those animals that had flushed, to ensure that I didn't inadvertently count them a second time.

Additionally, to avoid causing movement among animals in the area to be sampled prior to beginning the transect, I approached each transect line from behind it. In practice, this often meant detouring well around the area to be sampled while approaching.

However, in some CUs, animals were so dense that movement of those close to me would no doubt have caused movement of those farther away, whom I hadn't yet seen. A situation of general pandemonium would have been impossible to monitor. Under these conditions, I had no choice, despite my best efforts to minimize animal movement, but to abandon the line-transect method altogether. Instead I estimated densities in these CUs by conducting sample counts from a high vantage point using a spotting scope, and determining from the 1:100,000 map the area of the region counted. These estimates were added to those obtained using line-transects for the final total (Table 1). I considered this method sub-optimal, but did so because to have forged ahead with line-transects in these dense CUs would have made a mockery of this critical assumption.

Assumption 4: Distances from the line are measured accurately.

Two methods can be used to determine distances from the line to observed animals: 1) one can measure the perpendicular distance directly, or 2) one can measure angles from various points along the line and compute distances indirectly. I found that a portable range-finder (Model 1200, Forestry Suppliers, Inc., 1000m range) was too crude to reliably determine perpendicular distances. As well, had I walked from the line to the animals' initial position to measure the perpendicular
distance directly (e.g., using a cloth tape), I would have caused much disturbance to other animals, and thus again violated Assumption 3. Thus, the second, indirect option for determining distances was deemed more appropriate: it allowed for simpler, faster field procedures, while deferring the mathematical computations until later.

Angles between the transect line and the animals' initial position were easily recorded using a pocket compass. More difficult was the problem of determining where along the line I was when I recorded each angle. As noted above, use of a fixed measuring tape was impractical because of the length of the transects (up to 3 km) and disturbance to the animals. Instead, I counted paces along the line, and recorded this as my position (in meters). This no doubt introduced another source of imprecision, because, despite efforts to maintain a constant stride length, it certainly varied to some extent. However, the assumption that 1 stride equalled 1 meter was not unwarranted: in a pilot study, using a cloth tape, I found that my stride length, averaged over 100 paces, was 0.99 meter, with a standard error of only 0.01m (Harris 1993).

The number of bearings/animal group obtained varied; I always attempted to gather 3 or more, but occasionally only 2 were obtained because the initial site was only visible for a short segment of the transect line. In cases where only 2 angles were obtained, location of animal groups was calculated directly using the appropriate trigonometric formulas. When 3 or more bearings were obtained, locations of animal groups were taken as the geometric center of the region enclosed by the bearing lines (Fig. 1), using program PCPOLY (Rick Page, British Columbia Wildlife Branch, Victoria, B.C.).

Although distances were initially calculated to the nearest meter, in reality I knew that distance determinations were not this precise. To account for the various factors generating imprecision, all perpendicular distances were grouped into 200m-wide distance categories for analysis. Burnham et al. (1980) recommend against grouping data into distance categories because it reduces precision of the final density estimate. However, this compromise was appropriate because it reflected the imprecise nature of the data.

**Assumption 5: Objects are independent.**
All three species generally occurred in groups. Had I counted each individual seen as an "object" I would have grossly violated this assumption, because seeing 1 member of a group was not independent of seeing the other members. However, by considering "animal groups" as the objects counted, independence was not compromised.

Of course, the final result desired was the density of animals, not of animal groups. Thus, I also had to calculate mean group size, and apply this to the final density of groups. For mean density, this calculation was straight-forward:

\[ \bar{\theta}_i = \bar{\lambda}_i \theta_i \]

where:
- \( \bar{\theta}_i \) = point estimate of total number of species \( i \) within sampled area
- \( \bar{\lambda}_i \) = point estimate of density of groups of species \( i \) within sampled area (from Burnham et al. 1980)
- \( \theta_i \) = mean group size for species \( i \) within sampled area.

but for calculating the final confidence interval, a more complex formula was required (Raj 1968:12; see also a similar procedure used by Gasaway et al. (1986:39):

\[ \bar{\theta}_i \pm \bar{\lambda}_i V(\bar{\theta}_i) * t(0.1, \nu) \]

where:
- \( t(0.1) \) = Student's t for \( \alpha = 0.05 \)
- \( \nu \) = the lesser of the 2 degrees of freedom: number of transects for species \( i \), or number of groups for species \( i \), minus 1, and

\[ V(\bar{\theta}_i) = \bar{\theta}_i^2 V(\bar{\theta}_i) + \bar{\lambda}_i^2 V(\bar{\theta}_i) - (V(\bar{\theta}_i) V(\bar{\theta}_i)) \]

where:
- \( V(\bar{\theta}_i) \) = variance of \( \bar{\theta}_i \) for species \( i \)
- \( V(\bar{\lambda}_i) \) = variance of mean group size (equivalent to the square of the standard error of mean group size) for species \( i \)
- \( V(\bar{\lambda}_i) \) = variance of mean density (equivalent to the square of the standard error of the point estimate of density, Burnham et al. 1980) for species \( i \).

Assumption 6: Group size did not influence detection.
Standard analyses of line-transect data (e.g. Burnham et al. 1980) assume that detection of objects declines with distance, but is unaffected by other factors. If the probability of seeing a group is a function of its size as well as its distance, such analyses will be biased because mean group size will itself be biased (Drummer 1991, Drummer et al. 1990).

Size bias was tested in 2 ways. First, I reasoned that if sightability was a function of group size, groups of all sizes should be found near the center line, but small groups should be under-represented among those found far from the center line. Thus recorded group size would increase with distance, and a positive correlation between distance and group size should result. To test this, I performed correlations of group size on distance from the center line for all 3 species. Second, I used program SIZETRAN (Drummer 1991) to test for significant size bias directly. SIZETRAN fits a series of bivariate models to line transect data, where the 2 variables assumed to influence detectability are distance from center line and size of group. Tests of significance are made on the group size parameter.

In no case was a significantly positive (P = 0.1) correlation between group size and distance from center line found (Harris 1993). Similarly, group size was not found to be a significant variable for any of the species using program SIZETRAN. Thus, neither experiment provided reason for believing that my estimate of mean group size was biased by differential detectability, indicating no need to adjust population density estimates obtained using standard analyses (Burnham et al. 1980).

**Assumption 7: Samples sizes are reasonably large.**

It is theoretically possible to compute detection functions (and thus population densities) from as few as 2 distances; in truth, many more are needed for results to be meaningful. Burnham et al. (1980) suggested a minimum of 40 objects (i.e., distances) per study, better yet 60 or 80. Observing this many individual animals was not difficult, but sample sizes were number of animal groups, not individuals, and thus much smaller.

While potentially interesting insights might have come from calculating densities for each CU separately, sample sizes would have been so small that resulting differences would have been
primarily sampling error and not biologically meaningful. Thus I lumped data from all CUs for analysis (with one exception, see Harris 1993). To obtain the maximum possible sample sizes, I conducted surveys only during the optimal early morning hours (and also limited the bearings of transects to take advantage of the sun, see Assumption 1). Even so, despite 2 weeks of sampling effort (52 km of transect walked) within one of Qinghai's best areas for wildlife, only for Tibetan gazelle did I meet Burnham et al.'s (1980) recommendation for sample size. As a result, confidence intervals were relatively wide (Table 1).

Conclusion

Here, I have provided much more detail on field methods than would be appropriate in a published report, deliberately to emphasize efforts that are often needed to satisfy methodological assumptions. In practice, authors must find ways of abbreviating this process. However, if written "Methods" must be brief, it is still good practice to maintain a separate, longer report, which can be made available to interested readers on request, and that does contain such detail. Another partial solution is for editors of scientific journals to allow (or even demand) more details in "Methods" sections than is customarily the case. Failing either of these options, the reader who is familiar with the practical difficulties of applying statistical models -- even the best models available -- is left with only intuition or guesswork with which to assess strong and weak points of the resulting data.

Some interested foreign readers may view reports that ignore such methodological problems with skepticism. It would be unfortunate if such persons were to dismiss well-conducted work, often work that requires much hardship on the part of the researcher, because published reports lacked the supporting documentation needed to make them credible.

Literature Cited


Harris, R. B. and D. J. Miller (submitted). Overlap in summer habitats and diets of tibetan plateau ungulates. Mammalia. (in English).


Table 1. Results of line-transect surveys in Yeniugou, 1991, and resulting population estimates.

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<th>Group Size</th>
<th>Group Density</th>
<th>Population Size</th>
<th>Population Size</th>
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<td></td>
<td>ind./km²</td>
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4 From Eq. 1

5 Including individuals counted in blocks or sample counted from areas in which line transects were deemed inappropriate. See text.

6 Number of independent groups observed.
Fig 1. Schematic diagram of the line transect field methodology. The randomly selected bearing to be walked usually was altered slightly to correspond with a distant object (e.g., mountain peak) to facilitate maintaining a straight line. When animal groups (pictured, Tibetan wild ass) were first encountered, bearings were taken. Subsequent bearings were obtained at roughly 100m intervals, or as topography allowed. Although the animals usually flushed from their original location as I approached (but never before my 1st bearing), I recorded bearings, as nearly as possible, to the original location of the animals, not the location at the time of subsequent bearings.