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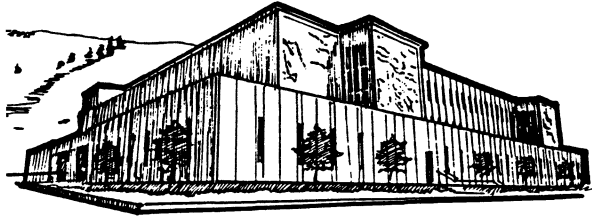
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EVALUATION OF TECHNIQUES TO MONITOR WHITE-TAILED DEER
POPULATIONS IN THE NORTH FORK OF THE FLATHEAD RIVER VALLEY,
MONTANA

By

Patricia A. Tucker

B.S., California State University, Chico, 1979

Presented in partial fulfillment of the requirements for
the degree of

Master of Science

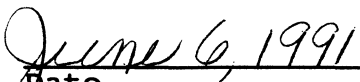
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ABSTRACT

Tucker, Patricia A., M.S., June 1991

Wildlife Biology

Evaluation of techniques to monitor white-tailed deer numbers in the North Fork of the Flathead River Valley, Montana. (90 pp.)



Director: Dr. Daniel Pletscher

Field investigations and literature review of methods to monitor white-tailed deer (Odocoileus virginianus) populations in the North Fork of the Flathead River Valley in northwestern Montana (NF) were conducted from December 1985 through June 1987. Aerial surveys, change-in-ratio, mark-recapture, spring pellet counts, spring road counts and winter track counts were assessed for feasibility in the area. Field investigations were undertaken on the last three to determine variability and sample sizes necessary to detect population changes with various levels of precision and confidence.

A pellet count survey could be instituted without further study. Increasing plots/transect beyond 10 to 30 did little to reduce the number of transects needed. Large numbers of workers could be involved in a pellet survey without greatly increasing variability, provided they were adequately trained and motivated.

The model developed to assess the sample size needed to monitor changes through track counts was extremely sensitive to the degree upon which individual transects tended to be lower or higher than average over the years. Further investigation of this is necessary before a track survey could be efficiently introduced. In general, however, it was found that adding more transects reduced sample size faster than adding within year replicates, especially when replicates increased beyond five. The variability introduced by using different observers appeared to be a minor component of the variability in this data.

A road count would be the least expensive way to monitor deer populations, but before one is instituted more data are needed to determine if spring use of open areas varies under differing environmental conditions.

Change-in-ratio and mark-recapture techniques have little utility in the NF. Further investigation of aerial counts should take place before they are accepted or dismissed.

All techniques have disadvantages and will require extensive time and/or monetary commitments on an annual basis. Without significant effort, only large changes in population (>20%) with moderate levels of confidence (80 to 90%) will be detectible.

ACKNOWLEDGEMENTS:

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I would be remiss if I didn't recognize the valuable assistance of 3 statisticians who provided concrete help when I was ready to tear my hair out. Dr. Dave Patterson suggested the methodology for analyzing my pellet data, Dr. Hans Zuring helped me get my statistical package up and running on my computer and Brian Steele provided the statistical and computer expertise to create a functioning model for the track data. Without them, I'd still be doing t tests and poking numbers into my calculator.

And then there are my friends and colleagues in the graduate program who always commiserated with me in my misery and told me I could do it. In particular Amy Johnston-Waller was there from the beginning as I pulled the first bloody tooth from the first check station deer. It was she that reminded me that the acknowledgement section is the most important part of a thesis and I should start making a list immediately. Thank you Amy. Rod Krahmer who was a co-graduate student on this project may be the only one who really understands what's it's like to do study plots day after day in the North Fork. We had some good laughs together and that was important.

Kathy McKay, Kent Solberg and Debby Brown deserve a medal for providing inexpensive to free assistance with the boring dirty jobs that are a major part of field research.

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The staff at Glacier National Park, Region 1 Montana Department of Fish, Wildlife and Parks and the Glacier View

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This thesis is dedicated to my father who, before it was trendy, expected his daughter to be as scientifically, mathematically and physically active as his son. I wish you were here to read this thesis Dad.

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CHAPTER I: INTRODUCTION

JUSTIFICATION OF RESEARCH:

Population parameters of white-tailed deer (Odocoileus virginianus) are virtually unknown in the North Fork of the Flathead River Valley (NF) in northwestern Montana. In 1985 a wolf (Canis lupus) pack began frequenting Glacier National Park (GNP) in the NF (Ream et al. 1987). Except for occasional dispersers from Canada, wolves have been absent in the NF since they were exterminated in the 1930's and the effect the return of these predators have on their prey is of intense interest to researchers and managers.

Research in Minnesota documented declines in white-tailed deer populations that were attributable to habitat deterioration and a series of harsh winters. This decline was increased and prolonged by heavy predation by wolves (Mech and Karns 1977). It was also found that deer were more abundant in buffer zones between wolf packs (Mech 1977). Other studies demonstrate that refuges such as lakes increase prey survivorship and lessen the impacts of wolf predation (Hoskinson and Mech 1976). Conservative management of human harvest of deer populations (Gasaway et al. 1983, Haber 1987) and maintaining high quality habitat (Seal et al. 1978, Nelson and Mech 1981) may reduce the chances of prey populations entering "predator pits".

Documenting the effects wolves have on deer populations,

as well as the benefits and need for various management strategies requires knowledge of prey population response, which in turn necessitates a technique or techniques to monitor changes in deer numbers.

OBJECTIVES:

The purpose of this study was to examine various methods of monitoring white-tailed deer populations and to assess the feasibility and effort required to employ them in the study area.

THESIS FORMAT:

The remainder of this chapter contains information on the general study area, white-tailed deer distribution in the study area, information pertinent to planning a population monitoring project in the NF and a discussion of various methods that were assessed for feasibility in the NF but not pursued further. The 3 chapters that follow look at 3 different monitoring methods which were evaluated through a pilot field study. These are followed by a short concluding chapter.

STUDY AREA:

The North Fork of the Flathead River flows out of British Columbia and forms the western border of GNP (Fig. 1). The NF drainage is defined by the Whitefish Range to the west and the Livingston Range to the east. Topography consists of a series of rolling lowland glacial benches and moraines with elevations ranging from 1067-1280 m (Ream et

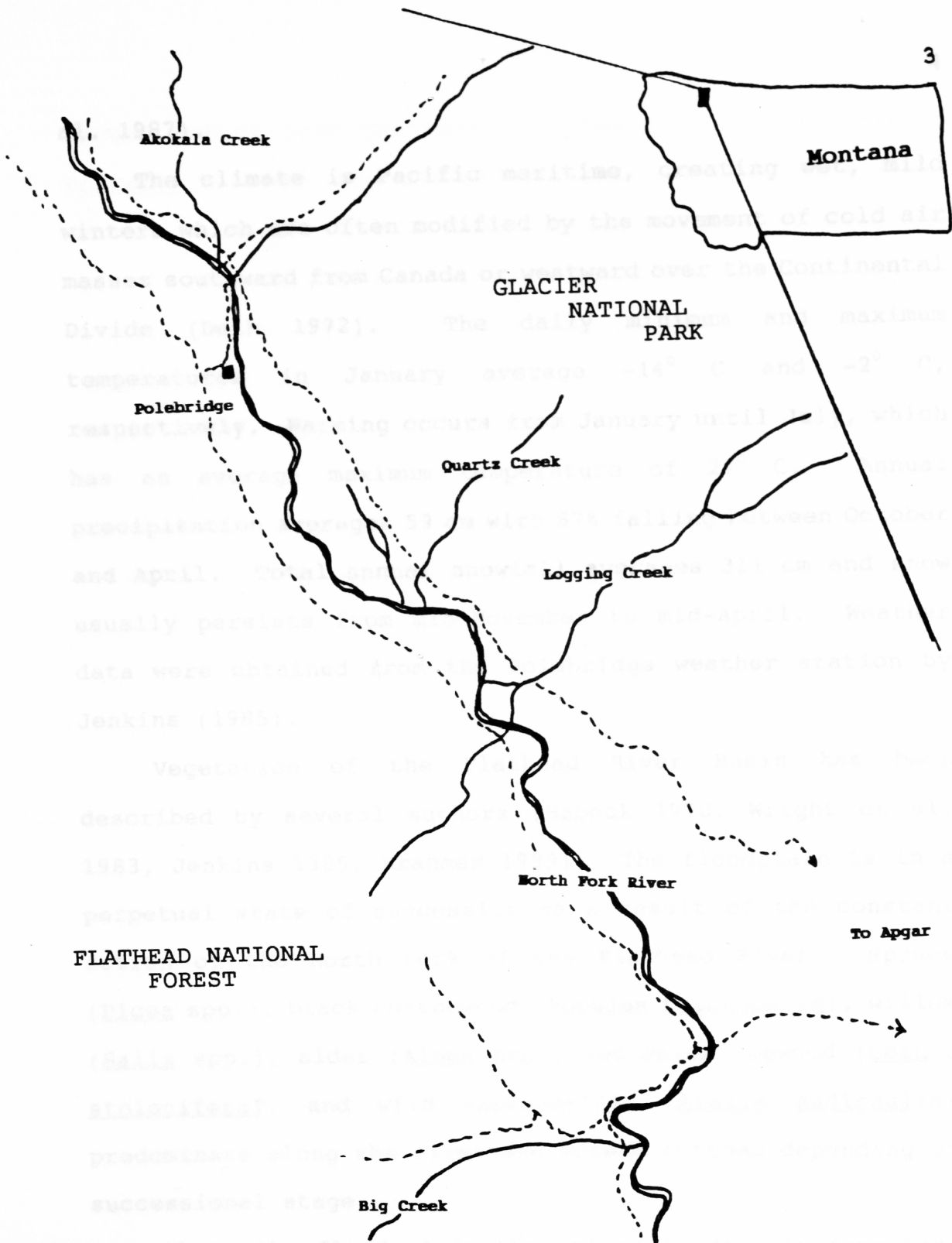


Fig. 1. Map of North Fork study area (dashed lines are roads, scale: 1 cm = 1 km).

al. 1987).

The climate is Pacific maritime, creating wet, mild winters which are often modified by the movement of cold air masses southward from Canada or westward over the Continental Divide (Delk 1972). The daily minimum and maximum temperatures in January average -14° C and -2° C, respectively. Warming occurs from January until July, which has an average maximum temperature of 27° C. Annual precipitation averages 59 cm with 67% falling between October and April. Total annual snowfall averages 311 cm and snow usually persists from mid-November to mid-April. Weather data were obtained from the Polebridge weather station by Jenkins (1985).

Vegetation of the Flathead River Basin has been described by several authors (Habeck 1970, Wright et al. 1983, Jenkins 1985, Krahmer 1989). The floodplain is in a perpetual state of succession as a result of the constant action of the North Fork of the Flathead River. Spruce (Picea spp.), black cottonwood (Populus trichocarpa), willow (Salix spp.), alder (Alnus spp.) red-osier dogwood (Cornus stolonifera), and wild sarsaparilla (Aralia nudicaulis) predominate along the river and stream bottoms depending on successional stage.

Above the flood plain the valley is densely forested, with lodgepole pine (Pinus contorta) as the dominant tree species. Many of the older lodgepole stands have been under

severe attack from the mountain pine beetle (Dendroctonus ponderosae) since the mid-1970's, resulting in large areas of dead timber. Other tree species associated with the upland forests include spruce, Douglas-fir (Pseudotsuga menziesii), sub-alpine fir (Abies lasiocarpa), ponderosa pine (Pinus ponderosa), and western larch (Larix occidentalis). Undergrowth strata of upland forests are often composed of deciduous shrub layers that are dominated by service berry (Amelanchier alnifolia), snowberry (Symphoricarpos albus), buffaloberry (Shepherdia canadensis) and thimbleberry (Rubus parviflorus).

Grasslands, dominated by rough fescue (Festuca scabrella), occur sporadically in the NF. Wetland shrub communities are also scattered throughout the valley on both the floodplain and upland drainages. Vegetation includes sedges (Carex spp.), rushes (Juncus spp.), and a variety of tall shrubs including willows, alder, and alderleaf buckthorn (Rhamnus alnifolia). Flooding, fire, insect infestations, and grazing by native cervids are the most important naturally occurring perturbations to vegetation.

Primary ownership of the NF is federal with the Flathead National Forest on the west side of the river and GNP on the east. The Coal Creek State Forest also occupies a small percentage of the west side of the valley.

Approximately 3% of the valley is privately owned, the vast majority of which is located adjacent to the west side

of the river. Approximately 50 residents reside in the NF year around but summer residents number 200 to 300. A gravel road connects the NF to Columbia Falls. Mail is delivered twice a week. There is no electrical service and the 2 public phones located at the small townsite of Polebridge and a few radio phones make up the NF phone service. By 21st century American standards the NF is quite "primitive". Lands outside GNP are influenced by humans in a variety of ways, including livestock grazing, timber harvesting, and homesite development. Within GNP the major influences of humans are from recreational activities, primarily hiking and camping.

This study was primarily conducted on a segment of the valley lowlands that encompassed an area 27 km in length, from Big Creek to 5 km north of Polebridge, and about 3 km east and west of the main channel. Intensive work was done near the mouths of the Akokala, Quartz, Logging, and Big Creek drainages (Fig. 1).

WHITE-TAILED DEER DISTRIBUTION IN THE STUDY AREA

General distribution and identification of white-tailed deer wintering areas in the NF were appraised through interviews with residents and agency personnel, literature review, and extensive searches for tracks during the winters of 1986 and 1987. Twelve adult does were captured in Clover traps and fitted with radio transmitters during the 1986 winter and monitored for 2 years, in part to assess fidelity

to winter range.

White-tailed deer, due to their small body size, experience great difficulty negotiating deep snow (Telfer and Kelsall 1979). Deer in the NF consistently selected areas where snow was less than 40 cm deep (Jenkins 1985). Singer (1979), Jenkins (1985), and Krahmer (1989) discuss habitat preferences of white-tailed deer in the NF.

During the 1986 and 1987 winters, deer sign was found primarily in the river bottom south of Polebridge and on southern or western exposures of east-west trending drainages in GNP. The most concentrated deer wintering range was adjacent to the North Fork River from the mouth of Camas Creek to the mouth of Big Creek. Snow depths were consistently shallower there due to the rain shadow created by Glacier View Mountain. Other white-tailed deer wintering areas were along the south facing slope of Bowman and Kintla Lakes, in the Bowman, Quartz and Logging drainages, and south of Logging Creek along the eastern terraces of the North Fork River. Deer also wintered, though in less dense concentrations, in the Akokala drainage, and in areas with dense cover along both sides of the North Fork River north of Logging Creek.

In early spring deer concentrated in cutover lodgepole stands and grasslands where snow first disappeared and herbaceous vegetation first appeared. As spring progressed, deer dispersed widely throughout the NF and remained there

until December when they began to congregate in wintering areas. These findings were consistent with Jenkins (1985) and with interviews with D. Boyd, M. Fairchild, J. DeSanto and T. Laddenberg.

Of the 12 deer fitted with radiotransmitters in the Big Creek area during winter of 1986, 2 died on summer range in 1986 and 4 remained on their summer range throughout the winter of 1986-87.

POINTS TO CONSIDER WHEN SELECTING A NF WHITE-TAILED DEER MONITORING METHOD:

White-tailed deer behavior makes their populations notoriously difficult to census or monitor, and ways to improve techniques and tailor them to specific areas are continuously suggested and studied (Ryel 1971, Hine and Nehls 1980, Mooty et al. 1984). Behavioral characteristics such as their tendency to avoid danger by hiding, and their preference for thick cover make techniques which rely on sightings frustrating, difficult, and highly variable. In addition, their ability to adapt to changing environmental conditions (Ozoga 1972, Drolet 1976, Johnson 1977, Jenkins 1985, Kraemer 1989) means that the entire area a population may use under varying environmental conditions must be encompassed to accurately monitor population changes. Additionally, it is well recognized that high variability is the norm for wildlife counts (Eberhart 1978, Harris 1986), necessitating wide confidence intervals, large sample sizes,

and/or many repetitions.

Besides the problems inherent in studying white-tailed deer populations in general, the NF presents some additional obstacles that must be understood before a reasonable monitoring attempt can be initiated.

Access to much of the NF is difficult and time consuming for at least 4 reasons.

1) Private landownership is divided among approximately 300 people and ownership changes frequently. Because many of the owners do not live in the NF or live there to avoid intrusions, obtaining permission to enter private land is often difficult.

2) Roads in GNP are not open to motorized vehicles from the time snow closes them in the fall until they dry out in late spring. This necessitates crossing the North Fork River and approaching the area of interest on foot or skis, or crossing on one of two bridges, often entailing a long approach. Permission of the landowner must be secured before the researcher can get from the North Fork Road to the river crossing. Crossings are dangerous and often impossible during the spring.

3) The NF has relatively few roads, especially within GNP; it can be a significant distance from the nearest road to the area of interest.

4) The vegetation and terrain in the NF is difficult and requires time and patience to negotiate. It is dense, large

areas of downfall stacked 1.5 m high are common, and swamps, braided sections of the river, and creeks are often encountered.

In addition to access problems, there are a number of other factors that make some techniques less practical in the NF than they may be elsewhere. While there are no obvious solutions, these factors should be considered before a monitoring program is begun.

1) Dense vegetation limits visibility in most areas both from the ground and from the air.

2) Low altitude flights are discouraged in GNP and may be prohibited in the future.

3) Capturing and marking wildlife and marking landscape is unpopular with local residents and requires permission that may be difficult to obtain in GNP.

4) The NF provides excellent habitat for the threatened grizzly bear (*Ursus arctos*). Techniques that require off road, off trail sampling, especially in preferred seasonal bear habitat should be assessed for risks to researchers and bears.

5) Mule deer (*Odocoileus hemionus*), while less common than white-tailed deer, do inhabit some areas of the NF. The winter ranges of the two species do not greatly overlap, but any monitoring technique not relying on direct observation will be subject to some unknown error as a result of counting the sign of both species.

REVIEW OF WHITE-TAILED DEER MONITORING TECHNIQUES AND DISCUSSION

Aerial surveys, change-in-ratio, mark-recapture, pellet counts, road counts and track counts were examined and their feasibility in the NF was assessed through review of the literature and discussion with residents. The literature review and discussion of the first 3 techniques follow. Pilot field studies were conducted for pellet counts, road counts and track counts. Results and discussion of these techniques are contained in separate chapters.

A number of sources compare and review many census and monitoring methods. These include Hazzard (1958), Bergerud (1968), Caughley (1977a), Davis and Winstead (1980), Hine and Nehls (1980) Davis (1982), and Kie (1988).

Aerial surveys:

Early in the history of flight it was recognized that animals could be counted from the air. While the technique works best in relatively level grasslands, aerial surveys have met with success in mountainous and/or forested regions (Siniff and Skoog 1964, Floyd et al. 1979). Animals in the whole area of interest are usually not counted. Instead the area is sampled along transects (Caugley 1977a, Gates 1979) or on randomly chosen quadrats (Siniff and Skoog 1964, Kufeld et al. 1980, Floyd et al. 1982) and total population extrapolated.

Factors affecting accuracy include amount of cover,

season, temperature, windspeed, time of day, altitude, speed, width of transects, skill and experience of the pilot, aircraft suitability, observer fatigue and observer skill (Caughley 1974, LeResche and Rausche 1974, Caughley et al. 1976, Dirschl et al. 1981, Bleich 1983, Hill et al. 1985). Other references on aerial surveys include Jolly (1969), Caughley (1972, 1977a and b), and Gasaway et al. (1986).

Deer in the NF were often seen while searching for radiocollared animals with aircraft and it may be feasible to monitor population trends by comparing aerial counts. The best time to carry out aerial monitoring would be January mornings or afternoons, preferably after a fresh snow. The animals are most visible when they cast a shadow and fresh snow cover also increases sightability. Other advantages of winter counts are that deer are more aggregated, so stratification of sampling effort is more efficient and the lack of deciduous cover increases visibility. Due to the rugged terrain and forested nature, stratified random sampling of quadrats would be most practical. If budgets allow and experienced pilots are available, rotary wing would be superior to fixed wing (Kufeld et al. 1980, Bleich 1983).

Experience in the NF suggests it is impractical to obtain a sightability index for use in estimating total population. Out of 9 flights (4 with snow cover) to locate 12 radiocollared deer, only one marked animal was seen, despite attempts to obtain visuals to ascertain deer

survival (D. Boyd, R. Krahmer, A. Blakesley, pers. commun.; pers. observ.)

If a trend monitoring effort is planned, a pilot study should be instituted to measure variability between replicates so that number of replicates and years needed to establish trends can be estimated (Harris 1986). A coefficient of variation greater than 0.50 would not be unexpected for these data (Floyd et al. 1979, LeResche and Rausche 1974). Harris (1986:167) provided a graph that indicated the number of annual replicates and years needed to establish population trends with desired precision.

There are a number of logistical problems involved with doing aerial surveys. Pilots and counters must have flexible schedules because rapid weather changes make planning flights difficult. Deer populations should be monitored in the Big Creek area because it is an important wintering area. However, excuting turns is difficult due to the narrowness of the canyon; a pilot who is familiar with the area should be included when a sampling design is planned for this area. As mentioned earlier, low altitude flights over GNP are not popular and may be prohibited in the future. Park officials should also be involved in plans for aerial surveys.

Change-in-ratio:

Kelker (1939) introduced the change in ratio (CIR) method as a means of estimating the number of deer in a population where males were predominantly hunted. CIR relies

on the following assumptions (Caughley 1977a:42):

1) the sexes are equally available at each survey and are distinguishable,

2) there is no natural mortality between surveys,

3) there is no recruitment or immigration between surveys, and

4) all removals and additions are recorded.

If the surveys are done just before and just after a relatively short hunting season, assumptions 2 and 3 are probably valid. Several studies have demonstrated that assumption 1 is questionable (Downing et al. 1977, McCullough 1982). Bowden et al. (1984) discuss planning a study to assess mule deer sex and age ratios. Assumption 4 is violated if the wounding rate resulting in death and illegal harvest are significant. The thoroughness of the reporting system also affects the degree to which assumption 4 holds.

Precision of the CIR method depends on the proportion of sexes or age classes before and after the harvest. With a pre-hunt estimate of antlered deer at 10% of the total herd, an estimate of the pre-removal population size within 25% of the true value with 95% confidence requires pre- and post-hunt sample sizes of about 1,600 deer each (Conner et al. 1986). However, if only antlerless deer were harvested from the same herd (90% antlerless deer), and the removal was sufficient to reduce the post-hunt estimate to 70% antlerless deer, the same level of precision could be achieved with pre-

and post-hunt sample sizes of only 325 deer.

Because of GNP, a large percentage of the NF deer population is un hunted, resulting in low numbers of harvested deer and sex ratios that are probably not highly skewed. This necessitates a sample size which is impossible to achieve in the NF with its poor visibility due to heavy vegetation (Conner et al. 1986). For these reasons CIR is not a useful method to monitor deer numbers in the NF.

Mark recapture:

Myriad variations of the mark-recapture method for censusing wildlife are available (e.g. Cormack 1968, Seber 1973, Caughley 1977a, Otis et al. 1978, White et al. 1982). Two assumptions underlie all mark-recapture studies: 1) geographic closure of the population and 2) equal catchability of all members of the population, both in the initial marking phase and in the recapture phase. Both these assumptions are likely false and analyses are quite sensitive to deviation from them. Miller et al. (1987) found that the population estimates of brown bears (Ursus arctos) were inflated by as much as 39% when the population was assumed to be closed. Roe deer (Capreolus capreolus) fawns represented 52% of the captured sample, but only 43% of the actual population (Strandgaard 1967).

Studies cited above and Bartman et al. (1987) indicate that 45% to 80% of the population must be marked to be 95% confident that the true population is within 12% of the

estimate. Rice and Harder (1977) calculated the number of replicates of aerial counts necessary to obtain an expected 95% confidence interval within 10% of the population mean given various percentages of marked white-tailed deer in an enclosure in Ohio. They found that unless populations were large (more than 1000 individuals), the only way to obtain 95% confidence within 10% of the estimate without marking more than 25% of the population was through repeated "recaptures".

Mark-recapture studies have little utility in the NF. Lack of visibility of animals due to dense vegetation and low road density would require tremendous investments of time and high percentages of marked animals to obtain reasonable confidence limits. The assumption of geographic closure is certainly violated, compelling adjustments in study design which would significantly increase costs (Miller et al. 1987). In addition, low road densities mean that for practical purposes, it is impossible to place traps in a random way. Heavy vegetation makes rocket netting from the air impractical. Equal catchability should not be assumed without studies designed to verify its validity. "Recaptures" from ground observations are also biased because of unequal "catchability". All of the twelve radiocollared deer were captured within 45 m of the North Fork Road and all had home ranges that encompassed the road; yet out of 28 observations of marked animals in the winter of 1986, 3 were

seen 6 or more times, 4 were seen 1 or 2 times and 5 were never seen.

SUMMARY

Generally, the logistical constraints of the NF increase the difficulties that are typically met with programs attempting to monitor white-tailed deer numbers. The following three chapters present the results of field tests that assessed the effort and feasibility of applying road counts, pellet counts and winter track counts to the problem of monitoring NF white-tailed deer population trends.

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CHAPTER II: SPRING PELLETT PLOTS

INTRODUCTION

The pellet group technique for monitoring deer populations is basically a systematic application of the hunter's method of reading "sign" to ascertain the abundance of wildlife (Bennett et al. 1940). It is based on the idea that the number of pellet groups found is directly related to the number of animals in the area. Ruhl (1932) first suggested use of pellet counts for big game species and the Cooperative Wildlife Research Units in 1938 were the first to use deer pellet group counts (Interstate Deer Herd Committee 1946). Since then, counts of pellet groups have been used in many places to census or monitor population trends of white-tailed deer (e.g. Smith et al. 1969, Ryel 1971, Freddy and Bowden 1983a and b, Rowland et al. 1984). They are still perhaps the most widely used indices of ungulate abundance (Kie 1988).

Since the pellet group technique has enjoyed wide use, and because the dense cover in the NF makes techniques requiring direct observations difficult, pellet counts were an obvious candidate for a method to monitor NF white-tailed deer populations. However, before pellet groups can be used to monitor population trend in an area, the manager must have knowledge of the variance that will be found in the counts and whether the amount of effort required to obtain desired

results is affordable. Accordingly, this study was designed to:

- 1) recommend a sampling design for a NF pellet count survey,
- 2) assess components of variation,
- 3) determine sample sizes necessary to detect changes in NF white-tailed deer populations with various levels of precision, and
- 4) estimate the amount of effort required to reach those levels of precision.

Information was gathered on 3 sources of variation: within-transect variation, between-transect variation and between-observer variation. Definitions of each of these are contained in the methods section of this paper.

Many pellet count studies use permanently marked plots that are cleared of pellets annually (Neff 1968, Ryel 1971). This is done to ensure that only pellets dropped within the designated time period are counted, because, depending on climatic and habitat conditions, pellets may persist for several years. Since maintaining permanent plots and clearing them annually increases effort, I evaluated the differences in "old" and "new" pellet groups found per plot on adjacent cleared and uncleared plots. This enabled me to assess the tradeoffs between increased effort and increased precision.

Pellet counts can be used to estimate deer populations

as well as monitor population trends (Kie 1988). However, population estimates made from pellet counts require knowledge of defecation rates which have been found to vary by as much as 330% depending on season, sex, diet, age and whether the deer are penned or not (Neff 1968, Ryel 1971, Rogers 1987). Rogers (1987) suggested that regional calibration of defecation rates should be done if pellet counts are to be used other than for determining population trends. Since I had no information on defecation rates, no attempt was made to link pellet group numbers to population size in this study.

STUDY AREA:

Pellet groups were counted in 4 areas in the NF: Big Creek (BC), Logging Creek (LC), Quartz Creek (QC) and Akokala Creek (AC) (Fig. 1). BC is easterly facing and, except in the creek bottom, rises steeply from the North Fork River. Old growth ponderosa pine, larch and cottonwood predominate. LC has extensive areas of willow and cottonwood, old growth ponderosa pine and live and mountain pine beetle-killed lodgepole pine. Meadows are interspersed throughout the area. QC is similar to LC but with less meadow and old growth and more live and beetle-killed lodgepole pine. AC has extensive areas of live and beetle-killed lodgepole pine with willow and cottonwood along the Creek. A more detailed description of the study area is found in Chapter 1.

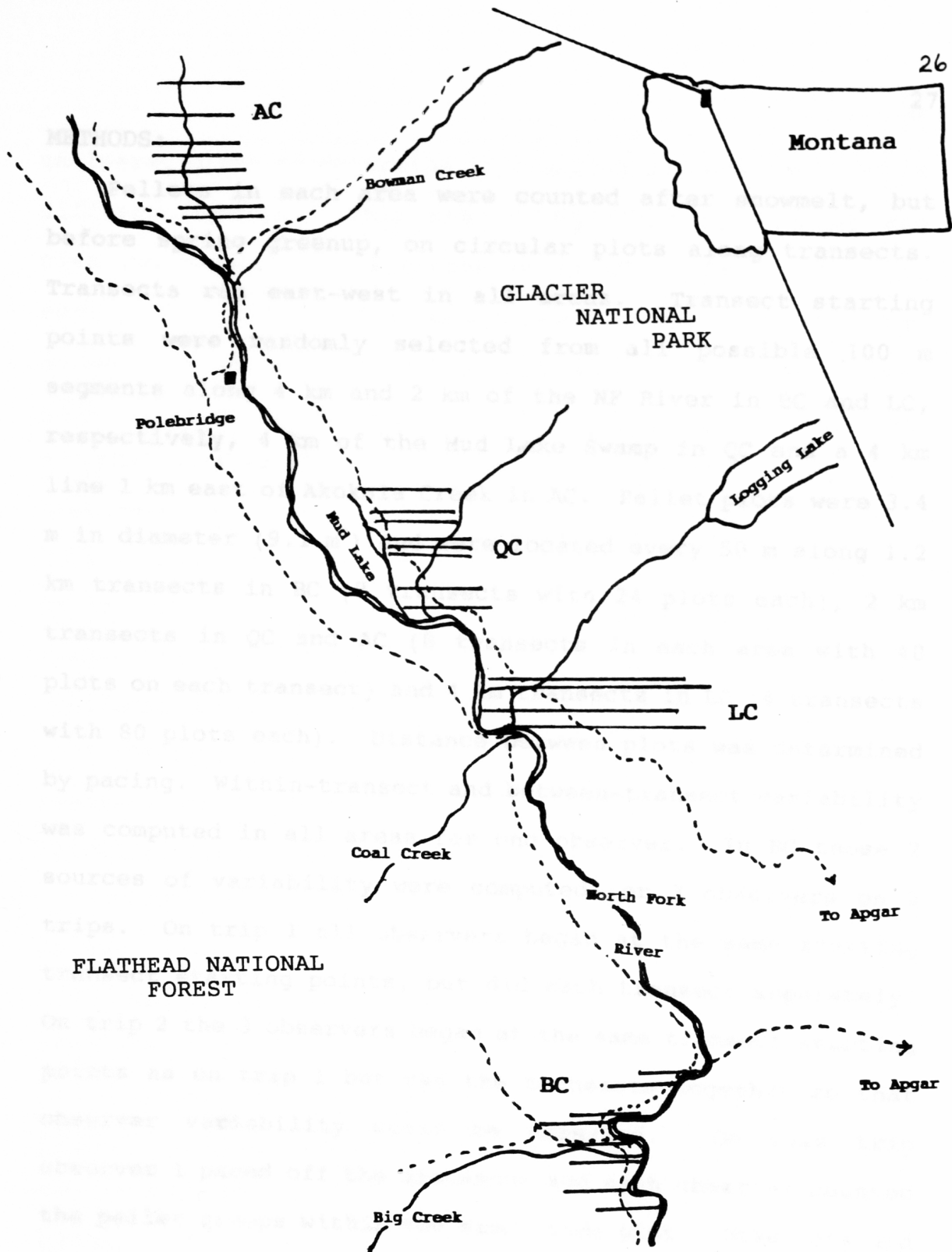


Fig. 1. Map of pellet transects (dashed lines are roads, AC is the Akokala Creek area, QC is the Quartz Creek area, LC is the Logging Creek area and BC is the Big Creek area, scale: 1 cm = 1 km).

METHODS:

Pellets in each area were counted after snowmelt, but before spring greenup, on circular plots along transects. Transects ran east-west in all areas. Transect starting points were randomly selected from all possible 100 m segments along 4 km and 2 km of the NF River in BC and LC, respectively, 4 km of the Mud Lake Swamp in QC and a 4 km line 1 km east of Akokala Creek in AC. Pellet plots were 3.4 m in diameter (9.1 m^2) and were located every 50 m along 1.2 km transects in BC (8 transects with 24 plots each), 2 km transects in QC and AC (8 transects in each area with 40 plots on each transect) and 4 km transects in LC (4 transects with 80 plots each). Distance between plots was determined by pacing. Within-transect and between-transect variability was computed in all areas for one observer. In BC those 2 sources of variability were computed for 3 observers on 2 trips. On trip 1 all observers began at the same starting transect starting points, but did each transect separately. On trip 2 the 3 observers began at the same transect starting points as on trip 1 but ran the transects together so that observer variability could be assessed. On this trip observer 1 paced off the distances and each observer counted the pellet groups within the exact same plot. Observers did not observe, communicate or in any way influence another observer's count.

Counts in cleared plots were compared to adjacent

uncleared plots to determine if clearing pellets resulted in different counts. This was accomplished by staking and clearing plots along 4 transects in LC in fall 1986. In spring 1987, the pellets were counted in the cleared plots, as well as in an equal sized plot adjacent to the cleared plot. Originally 8 transects (each 4 km long) were planned so that comparisons could be made between a few long transects and many short transects. However, wolves established a den site in the area and precluded running 4 of the planned transects, including one of the previously staked and cleared transects. As a result, a total of 320 uncleared plots and 240 cleared plots were examined.

The time taken to establish, travel to and examine each transect was recorded to ascertain the amount of effort needed to accomplish a pellet survey.

Twenty "aging plots" (Ferguson 1955) were established in BC. These plots encompassed a variety of habitats and contained pellets deposited at known times throughout the previous 2 years.

Instructions for reading plots followed Smith et al. (1969). A group was defined as anything over 30 pellets and was counted if more than 1/2 of the pellets occurred within the plot boundaries. Pellets were designated as old or new based on criteria established by Freddy and Bowden (1983a) and through examination of the aging plots.

Observers received 1/2 day of training in the field

which included examining the aging plots. Because all distances were determined by pacing, each observer determined how many of their paces made up 50 m.

Three sources of variability in the data were assessed so that the sample sizes necessary for desired levels of precision could be determined:

1) Variability between observers (s_{ob}^2), results from observers missing different numbers of pellet groups and/or not counting them the same way. This variability was defined as the variance of the differences in pellet groups found on each plot for an observer combination.

$$s_{ob}^2 = 1/(n-1) \sum^1 (d_p - \bar{d})^2, \text{ where:}$$

$d_p = x_{ip} - x_{i'p}$, x_{ip} = the number of pellet groups found by observer "i" on plot "p", and $x_{i'p}$ = the number of pellet groups found by observer "i'" on plot "p", and

$$\bar{d} = 1/n \sum^n d_p, \text{ n = number of plots on all transects.}$$

In further calculations, the average of the 3 between observer variances was used:

$$\text{mean}(s_{ob}^2) = 1/3 \sum^3 s_{ob}^2$$

2) Variability between-transects (s_t^2), results from deer dropping more pellets on some transects than others. This variability was defined as the variance of the transect means for an observer on a particular trip.

$$s_t^2 = 1/(k-1) \sum^k (\bar{x}_m - \bar{x})^2, \text{ where:}$$

x_{pm} = the number of pellet groups found on plot "p" on transect "m", and

$$\bar{x}_m = 1/n \sum^n x_{pm}, \quad n = \text{number of plots per transect,}$$

and

$$\bar{x} = 1/k \sum^k \bar{x}_m, \quad k = \text{number of transects.}$$

Since all 3 observers examined the same plots on trip 2, their between-transect variances on trip 2 were not independent. To be conservative, the largest of the 3 between-transect variances on trip 2 averaged with the 3 between-transect variances on trip 1 was used in further calculations.

3) Variability within-transects (s_{wt}^2), results from deer dropping more pellets on some plots than others. This variability was defined as the mean of the variances of the transects for an observer on a particular trip.

$$s_{wt}^2 = 1/k \sum^k s_m^2, \quad k = \text{number of transects, where:}$$

x_{pm} = number of pellet groups found on plot "p" on transect "m", and

$$\bar{x}_m = 1/n \sum^n x_{pm}, \quad \text{and}$$

$s_m^2 = 1/(n-1) \sum^n (x_{pm} - \bar{x}_m)^2$, n = number of plots on transect "m".

Again, since within-transect variances for the 3 observers on trip 2 were not independent, and to be conservative, the largest of the within-transect variances on trip 2 was averaged with the 3 within-transect variances on trip 1 for an overall within-transect variance.

Two sources of variability, (s_t^2) and (s_{wt}^2) were assessed for all 4 areas. Counts on uncleared plots were used to

assess this in LC. The other source of variability, (s_{ob}^2) was assumed to be the same as BC. This source of variability is likely to be lower in lower density areas. If so, my calculations of sample size in AC and QC are larger than needed. However, until (s_{ob}^2) is assessed for these areas, it is best to assume a higher variability.

The mean (\bar{x}) of each area was computed by determining the average number of pellet groups per plot on each transect and then averaging the transect means.

$$(\bar{x}) = 1/k \sum^k \bar{x}_m, \text{ k= number of transects, where:}$$

x_{pm} = number of pellet groups on plot "p" on transect "m", and

$$\bar{x}_m = 1/n \sum^n x_{pm}, \text{ n=number of plots per transect.}$$

To determine the overall mean for BC, the 3 observers' trip 1 means were averaged along with observer 2's trip 2 mean. The other observers' trip 2 means were not included because they were not independent of observer 2's on trip 2.

By components of variance, the variance of the area mean, ($s_{\bar{x}}^2$) = $s_t^2/k + s_{wt}^2/kn + s_{ob}^2/kn$, where k=number of transects and n=number of plots per transect.

The SE (standard error) of $\bar{x} = \sqrt{s_t^2/k + s_{wt}^2/kn + s_{ob}^2/kn}$

Using standard procedures (Wonnacott and Wonnacott 1977), 95% and 70% confidence intervals around the mean were developed for all four areas.

For BC, QC, and AC, numbers of transects and plots necessary to detect 10 and 20% changes in the mean with 90

and 75% confidence were estimated as follows:

Since the true mean (μ) = $\bar{x} \pm z\sqrt{\sigma_{\bar{x}}}$, where:

\bar{x} = the estimated mean,

$\sigma_{\bar{x}}$ = SE, and

z = the number of standard deviations $\pm \bar{x}$ that includes the area of the standard normal curve corresponding to the desired alpha level.

If "m%" is the amount of change that is desired to be detected, then, $(m\%)(\bar{x}) = z\sqrt{s_t^2/k + s_{wt}^2/kn + s_{ob}^2/kn}$ or,
 $k = \{z^2[s_t^2 + (s_{wt}^2 + s_{ob}^2)/n]\} / [(m\%)^2(\bar{x})^2]$. (Eq. 1)

Various "n's", "m's" and "z's" can then be entered into the equation to determine "k", the number of transects needed.

Differences between total numbers of new and old pellets found on cleared and adjacent uncleared plots in LC were graphed and visually compared to determine if clearing plots resulted in changes in groups counted.

RESULTS

It took 2-3 minutes to examine each plot and 2-3 minutes to pace 50 meters between the plots. At the end of each transect it took approximately 15 minutes per kilometer to regain the starting point and an average of 15 minutes to get to the starting point of the next transect. Staked and unstaked plots took the same amount of time to find and examine. Approximately 50 hours were needed to clear 320

plots.

The between-observer variability was quite similar for the different observer combinations (Table 1). Between-transect and within-transect variability increased as the area mean increased (Tables 2, 3 and 4). In BC, the between transect variability varied considerably between the different trips and observers, while there was proportionately less difference between the within-transect variabilities (Tables 2 and 3).

The standard errors for BC, LC, QC, and AC were 0.22, 0.14, 0.11 and 0.095, respectively. I was unable to detect a difference between the means of any 2 areas with 95% confidence. I was, however, able to detect a difference between BC and QC, BC and AC, LC and AC, and QC and AC at the 70% confidence level, the level recommended by Robinette et al. (1958).

It requires many more plots to detect 10% changes in pellet plot numbers than it does to detect 20% changes (more than 4 times as many transects with 20 plots per transect) (Fig. 2, 3, and 4). In contrast, lowering the confidence level from 90% to 75% did not greatly reduce the number of plots needed (Fig. 2, 3 and 4). The number of transects required to determine a change in pellet group number decreased sharply as the number of plots per transect increased from 1 to 10. The number of transects needed decreased less rapidly as plots increased from 10 to 20 and

Table 1. Between-observer variabilities (s_{ob}^2) for all observer combinations at BC and the average used for further analysis.

<u>Observer combination</u>	<u>(s_{ob}^2)</u>
1 and 2	0.378
1 and 3	0.346
2 and 3	0.378
mean	0.362

Table 2. Between-transect variability (s_t^2) for each observer on each trip in all areas. * denotes the variabilities averaged for the between-transect variability used for further analysis for BC.

<u>Observer</u>	<u>Area</u>	<u>Trip</u>	<u>(s_t^2)</u>
1	BC	1	0.175*
1	BC	2	0.436
2	BC	1	0.278*
2	BC	2	0.446*
3	BC	1	0.169*
3	BC	2	0.354
overall	BC		0.267
1	LC		0.058
1	QC		0.053
1	AC		0.047

Table 3. Within-transect variability (s_{wt}^2) for all observers on all trips in all areas. * denotes the within-transect variability used for further analysis for BC (n=number of transects).

<u>Observer</u>	<u>Area</u>	<u>Trip</u>	<u>n</u>	<u>(s_{wt}^2)</u>
1	BC	1	8	2.742*
1	BC	2	8	2.136
2	BC	1	8	2.697*
2	BC	2	8	2.294*
3	BC	1	8	1.892*
3	BC	2	8	1.866
overall	BC		8	2.406
1	LC		4	1.398
1	QC		8	1.178
1	AC		8	0.646

Table 4. Average pellet counts/plot for each observer on each trip in all areas. * denotes the means averaged for use in further analysis for BC.

<u>Observer</u>	<u>Area</u>	<u>Trip</u>	<u>Average pellet count/plot</u>
1	BC	1	1.031*
1	BC	2	0.948
2	BC	1	1.319*
2	BC	2	0.916*
3	BC	1	0.927*
3	BC	2	0.906
overall	BC		1.048
1	LC		0.788
1	QC		0.706
1	AC		0.441

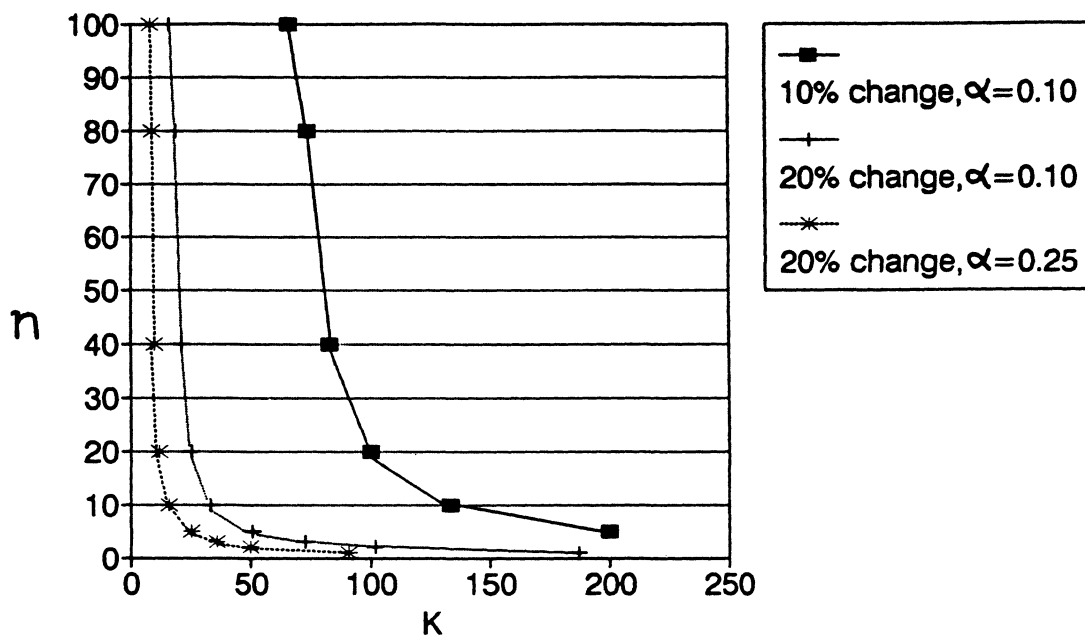


Fig. 2. Combinations of 1.2 km transects (k) and plots/transect (n) necessary to detect 10% and 20% changes in pellet group numbers with 90% and 75% confidence in a high density deer area (Big Creek).

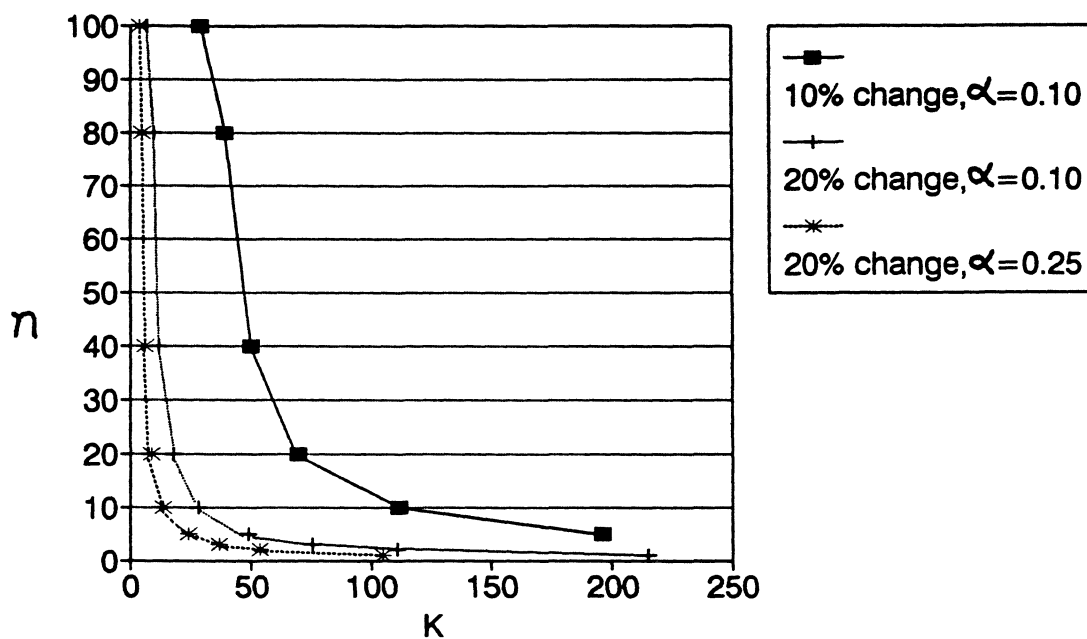


Fig. 3. Combinations of 2.0 km transects (k) and plots/transect (n) necessary to detect 10% and 20% changes in pellet group numbers with 90% and 75% confidence in a medium density deer area (Quartz Creek).

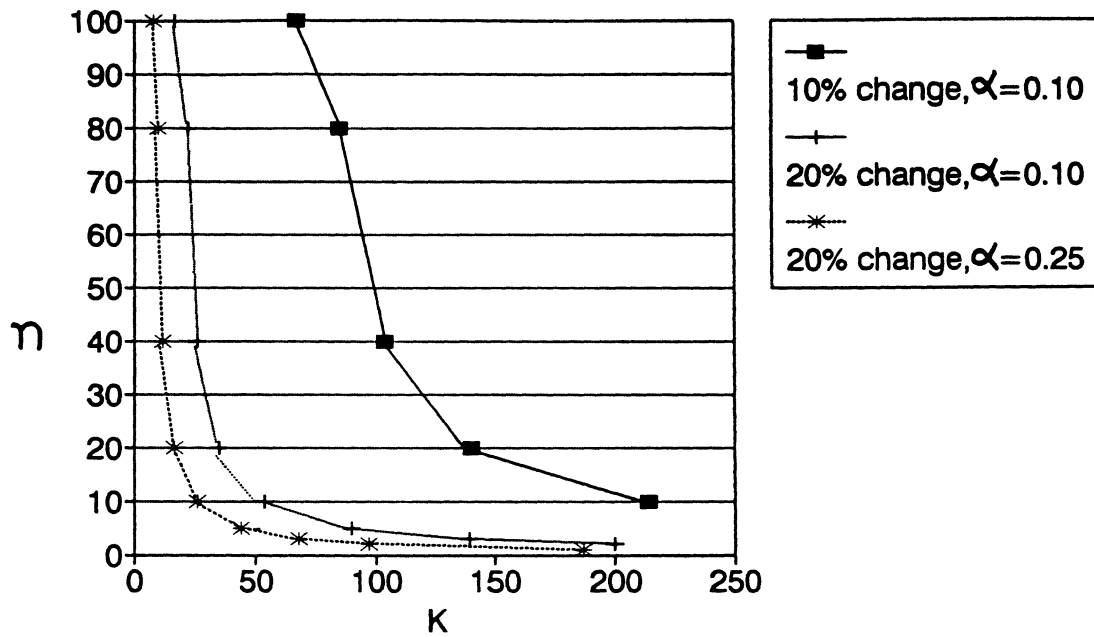


Fig. 4. Combinations of 2.0 km transects (k) and plots/transect (n) necessary to detect 10% and 20% changes in pellet group numbers with 90% and 75% confidence in a low density deer area (Akokala Creek).

very little when plots per transect were increased beyond 20 (Figs. 2, 3 and 4). As can be seen from Eq. 1, when the number of plots per transect increase, the between-transect variability plays an increasing role in the number of transects needed. For the range of variabilities and densities of pellet groups in this study, between-transect variability becomes the determining factor in the number of transects needed when plots/transect reaches is 10 to 20.

Visual examination of the data revealed no difference between the numbers of old or new pellet groups found on cleared versus uncleared plots in LC (Fig. 5a and b).

DISCUSSION

Assessing white-tailed deer population trends through annual pellet counts is feasible in the North Fork. It appears that 20% changes could be monitored with 90% confidence with an acceptable amount of effort.

Time and effort One crew can comfortably examine 80 plots per day. While I do not have data to substantiate this, I strongly feel that observer fatigue and boredom begins to introduce significant error if more plots are examined. With my sampling scheme, 80 plots took 5 to 7 hours to complete, depending on terrain. Therefore, even under a sampling scheme with twice the distance between plots and transects, there should still be time in a day for one

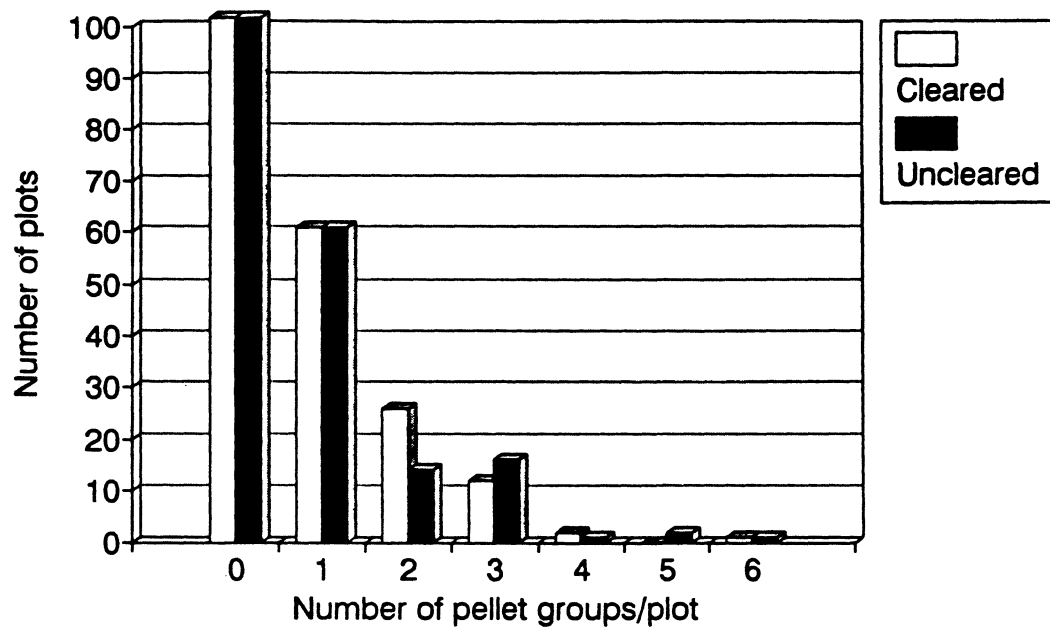


Fig. 5a. Numbers of cleared plots compared to uncleared plots with 1, 2, 3, 4, 5, and 6 new pellet groups/plot.

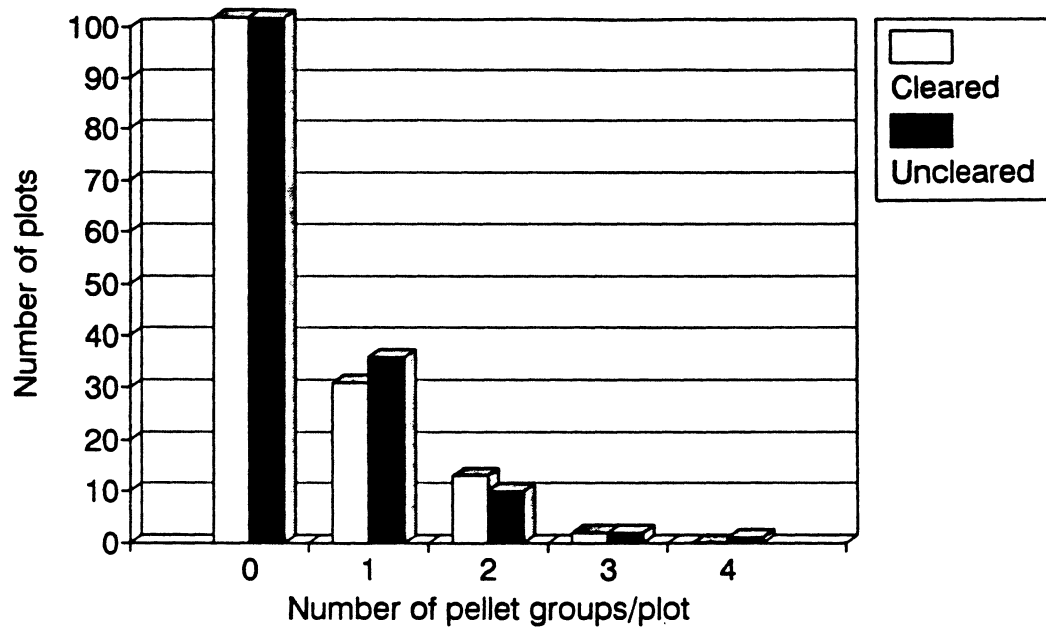


Fig. 5b. Numbers of cleared plots compared to uncleared plots with 1, 2, 3, and 4 pellet old pellet groups/plot.

person to complete at least 60 plots.

As greenup progressed, it became difficult to see pellet groups. Within 30 days of snow disappearance, pellet groups were significantly obscured by new growth.

Field work should be avoided when pellets are wet, because the difficulty of distinguishing between old and new groups is increased (Freddy and Bowden 1983a). This reduces the number of days available to complete field work in the NF.

Reducing variability

Between-observer variability arises from improper aging, counting a scattered group as more than one, lumping several groups together, or simply not seeing one or more groups (Ryel 1971, Smith et al. 1969, Robinette et al. 1958, and Neff 1968, Harestad and Bunnell 1987).

The error arising from mis-aged groups can theoretically be reduced by marking pellet groups with some substance (Kufeld 1968) or clearing permanently marked pellet plots (Robinette et al. 1958). Ryel (1971) found that it was extremely difficult to remove all the pellets from a group, and if any pellets remained, they were automatically counted the next time the plot was read because observers were not keyed into distinguishing old from new pellets. Additionally, some pellets that were not visible in September became visible at a later date due to decay, shifting of dead plant material and reduced standing vegetation. Ryel (1971)

and Freddy and Bowden (1983a) found insignificant differences between cleared and uncleared pellet plots. As was done in this study, they recommended the use of aging plots and careful instruction of field crews in differentiating between old and new pellets. An important point in a trend monitoring program is that methods are in place that ensure consistent ageing and counting of pellet groups by different observers.

Smith et al. (1969:17) gave step by step instructions for accurately counting the number of pellet groups in a plot. Neff (1968) suggested developing approximate observer correction factors if observers change over time.

I found it very difficult to clear pellet plots in the fall. Standing vegetation made seeing pellets nearly impossible unless an extraordinary amount of time was taken. I expended double the effort on the cleared and staked plots, yet it resulted in no decrease in the number of old pellets found the next spring. In addition, I found that observer variability was a relatively small component of the overall variance.

If field crews receive adequate instruction in distinguishing old from new pellets, much more can be gained per unit effort by increasing the number of pellet plots than by maintaining and clearing permanent plots. It is important to establish aging plots in a variety of habitats that contain known-age pellet groups from new to 3 years old. I

also recommend that inexperienced observers spend at least 1/2 day of field work with an experienced observer.

Between-transect variability can be decreased by having each transect encompass, to the extent possible, the entire range of habitat types and geographic variation of the area (Neff 1968, Robinette et al. 1958). This unavoidably increases within-transect variability.

Within-transect variability can be reduced by having each transect encompass as little geographic variation as possible, but this comes at the expense of increasing between-transect variability. Since the number of transects needed, when plots per transect are greater than 10, ultimately depends on the between-transect variability, and since the number of transects that can be done is logistically more limiting than the number of plots per transect, it is better to lay out transects to reduce between-transect variability as much as possible.

Plot size and shape: The bias and efficiency of different plot shapes and sizes have been discussed by several researchers (Robinette et al. 1958, Neff 1968, Smith 1968, Smith et al. 1969, Ryel 1971, Batcheler 1975). Circular plots have the advantage that the perimeter can be delineated accurately by one person with a center stake and rope of desired length for the radius. Rectangular plots, especially if they are large, require two people to delineate perimeters accurately (Robinette et al. 1958). However, in

shrubby or wooded areas, moving a rope in a fixed circle around a fixed point is difficult (Ryel 1971). In addition, Grieg-Smith (1957) points out that rectangular plots are generally the most efficient design (lowest variance) for sampling plant communities. Long narrow plots can be searched by stretching a rope down the center and searching the desired distance on either side. A measured stick can be used to determine if the pellet group is inside or outside the rectangle (Ryel 1971).

Several studies have demonstrated an inverse relationship between plot size and apparent density. Robinette et al. (1958) and Smith (1968) concluded this was because more pellet groups were missed on the larger plots. Batcheler (1975) felt that the lower counts on large plots were due to a more accurate determination of true centers of strung-out and scattered groups, as well as less of a tendency to count similar groups separately.

The smaller the plot size, the more plots required, but they can be placed closer together which reduces effort. Gerard and Berthet (1971) noted that for populations fitting the negative binomial distribution, greater precision was obtained by reducing plot size and increasing the number of plots. Green (1979) also noted that smaller sized sampling units result in increased precision of estimates with aggregated distributions. Taking all factors into consideration Robinette et al. (1958) and Smith (1968)

avored circular 9.1 m^2 (3.4 m diameter) plots.

As long as any inherent bias in plot size and shape stays the same on different years and at different deer densities, plot size and shape should not contribute to error for trend monitoring. The size and shape should be whatever is logistically most convenient. Like Ryel (1973), I found that circular plots were difficult to manage in thick brush. I would suggest the use of a 1.5 m x 6.0 m rectangular plot. Two people could efficiently examine this plot by each examining one 0.75 m x 6.0 m segment. Periodic checks on each other could be easily instituted.

Most efficient number of transects and plots per transect: Two to 20 plots per transect most efficiently reduces the number of transects necessary (Fig. 2-4). Beyond 20 plots per transect there is little decrease in the number of transects required. The finding that it is more efficient to have relatively few plots per transect agrees with Ryel (1971) who calculated that 5 plots per transect were optimal.

Conclusion

Pellet counts are logistically feasible in the NF. While it would require considerable effort to detect small changes with high levels of confidence, monitoring for a 20% change with 90% confidence could be done in approximately 12 person-days, even in low density areas.

If deer population declines occur first in low deer density, secondary habitats, these areas are the most

important areas to monitor. Because even gross changes in deer density could escape casual detection in these habitats, it may be important to monitor these areas, even for changes as large as 50%. Such a change could be monitored with approximately 6 transects that are 2 km long and have 20 plots per transect.

Before a long-term monitoring program using pellet groups is instituted, careful consideration should be given to what the objectives are and what precision is required to reach those objectives. If these decisions are made before field work begins, the amount of effort will be minimized and more importantly, an inadequate survey can be avoided.

The most difficult aspect of a pellet plot survey is in locating transects so that deer range is adequately covered through a variety of environmental conditions. This consideration argues for many short transects with relatively few plots per transect. The transects should be located so that the variety of locations and habitats throughout the valley are adequately represented.

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CHAPTER III: SPRING ROAD COUNTS

INTRODUCTION:

Counts of deer from roads have been used extensively to monitor ungulate populations (Dasmann and Mossman 1962, Progulske and Duerre 1964, Johnson 1977, Fafarman 1978, Gunson 1979, Harwell et al. 1979, Harestad and Jones 1981). The technique has been primarily used in open habitat where animals are highly visible. However, Harestad and Jones (1981) reported on the successful use of this method on Vancouver Island which is densely forested with interspersed cutover areas. They found that when transect lengths were long enough to count an average of 100 deer, the coefficient of variation (CV) was 0.10 and 95% confidence limits within 10% of the mean could be obtained with 7 replicates. If less deer were sighted and a CV of 0.20 resulted, it took 18 replicates to obtain the same level of precision. They emphasized that while counts should be conducted in as short a time as possible to avoid variation contributed by inter-seasonal changes in the dispersion of deer, they should also encompass a sufficient time period to ensure that annual differences in the dates of use of openings by deer (caused primarily by climatic variation) are not mistaken for changes in numbers. They also pointed out that the efficiency of counts can be increased by counting during periods when animals are concentrated and in habitats with good

visibility.

Harris (1986) found that when count variability cannot be reduced, the only way to achieve precision of a population trend estimate within a set number of years is to perform multiple counts each year. He analytically derived standard errors (SE) of trend lines arising from variable counts of animals for assorted count variabilities, number of years of trend monitoring and number of replicate counts each year.

The objectives of this study were to determine:

- 1) the variability of road count data,
- 2) the level of effort necessary to detect trends in deer numbers in the NF through road counts and
- 3) if a trend could be detected with the data collected.

STUDY AREA:

Road counts were done from Coal Creek to the north end of Home Ranch Bottoms, a distance of 5.7 km along the North Fork Road. The road in this area passes through several large meadows and much of the rest was clear-cut in the early 1980's. An in-depth review of the study area is found in Chapter 1.

METHODS:

I (obs. 1) drove and counted deer just before sunset during spring greenup in 1986 and 1987. Mr. and Mrs. Tom Laddenberg (obs. 2) also counted deer in 1984, 1985, 1986,

and 1987. Drivers drove no faster than 20 km/hr and stopped if a deer was observed to search for more. Binoculars were not used. Obs. 2's routine differed from obs. 1 in that 2 people were in the vehicle instead of one.

To assure that counts were taken during the same general phenological period, counts were begun when the Polebridge weather station reported no snow accumulation on the ground and ended 40 days after that date.

The Wilcoxon signed ranks test was used to compare same day counts between sets of observers.

Trend in counts was assessed by determining the yearly instantaneous/capita rate of change (r) as outlined by Harris (1986:166) where, $r = (\ln N_t - \ln N_0) / t$, t is time, and N is the mean number of animals counted per evening on year 0 and year t . The standard error of r , $(SE_r) = 12s^2 / nk(k^2 - 1)$, where s^2 is the average variance of the natural log of the counts for each year, n is the average number of counts taken each year, and k is the number of years counts were taken. Confidence limits for r were determined using standard procedures (Wannacott and Wonnacott 1977).

The average variance of the lognormally transformed counts for all observers in all years was used with equation 4 to explore the standard error of the observed population trend as a function of trend monitoring time period for various numbers of replicate counts each year.

RESULTS:

No significant difference between counts on the same day and different observers were found (Table 1).

Mean number of deer sighted was highest in 1984 and decreased every year the counts were taken. CV's were lower than for many road count studies reviewed by Eberhardt (1978:227) (Table 2).

For any 2 year period, the sign of the instantaneous rate of increase could not be determined with 95% confidence. However, over the 4 year period of counts of obs. 2, "r" was negative with greater than 95% confidence.

The average variance of the lognormally transformed counts for all observers over all years was 0.16. This is probably high, because only one observer in one year out of the 6 observer years, obtained a variance higher than this (Table 2). Using 0.16 as the variance in counts and following Harris (1986:167-168), the decrease in SE(r) obtained by increasing the number of years deer are counted was not linear. In general the greatest increases in precision were gained by increasing years of trend monitoring from 2 to 3 or 3 to 4. Beyond 6 years, only small increments of precision were gained with increased replicates or years (Fig. 1).

DISCUSSION:

Road counts should be further evaluated as a monitoring method for white-tailed deer numbers in the NF. It's

Table 1. Results of Wilcoxon signed ranks test for NF road counts of deer done the same day by different observers.

<u>Obs. 1</u>	<u>Obs. 2</u>	<u>Diff.</u>	<u>Rank</u>	<u>Rank with less freq. sign</u>
31	57	-26	7	
51	44	+ 7	4	4
49	50	- 1	1	
66	62	+ 4	2.5	2.5
51	63	-12	5	
40	36	+ 4	2.5	2.5
41	56	-15	6	

T=9 p>0.05

(unable to detect difference between observers)

Table 2. Results of annual NF road counts of deer. (obs.=observer, n=number of replicate counts, x=mean number of deer sighted per evening, s^2 =standard deviation of counts, CV=coefficient of variation, var.ln(ct)=variance of the natural log of the counts)

<u>year</u>	<u>obs.</u>	<u>n</u>	<u>x</u>	<u>s^2</u>	<u>CV</u>	<u>var. of ln(ct)</u>
1986	1	11	50.8	13.06	0.26	0.073
1987	1	10	45.2	12.80	0.28	0.076
1984	2	14	79.5	19.37	0.24	0.066
1985	2	18	64.5	24.50	0.38	0.143
1986	2	22	48.0	18.28	0.38	0.442
1987	2	17	36.3	13.25	0.37	0.157

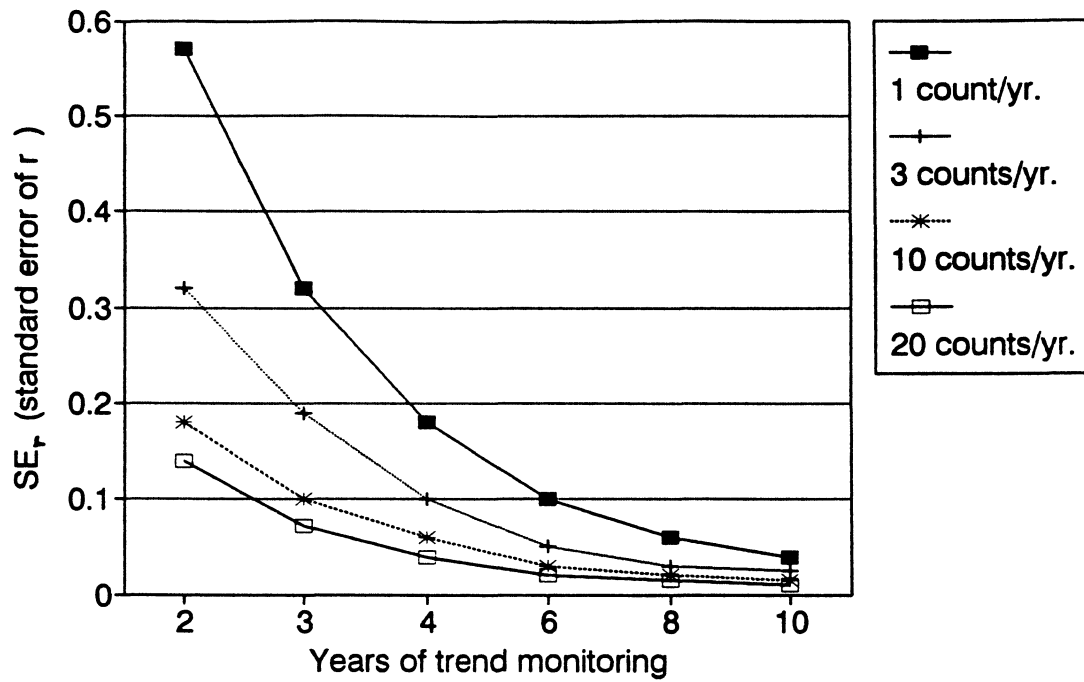


Fig. 1. The standard error of the observed population trend (SE_r) as a function of trend monitoring time period for 1, 3, 10 and 20 annual replicates.

disadvantages are that road access in GNP is limited during the greenup period and the dense vegetation makes counting large numbers of deer difficult. Therefore, if managers need to detect trends over short periods of time with high precision, large numbers of replicates must be taken. The advantages are that road counts are inexpensive, unintrusive, interesting for personnel and can be done in a short amount of time relative to many of the other methods.

While there was no statistically detectible significant differences between observers (Table 1), the sample size was small. There is a need for further investigation of this source of variability.

A decreasing number of deer were seen along Home Ranch Bottoms over the 4 year period, but more information is needed on how spring use varies due to environmental conditions before these counts could be used to assess population changes (McCullough 1982). This could be accomplished by monitoring spring use of radiocollared deer in the area during years with differing environmental conditions.

The time period for road counts should be further evaluated. The apparent increasing trend in counts from the beginning of each year's counting period to the end (Fig. 2a and b) indicate that counts should begin 10 to 15 days after snow disappearance and continue for longer than 40 days. The number of deer seen using spotlights at night could be

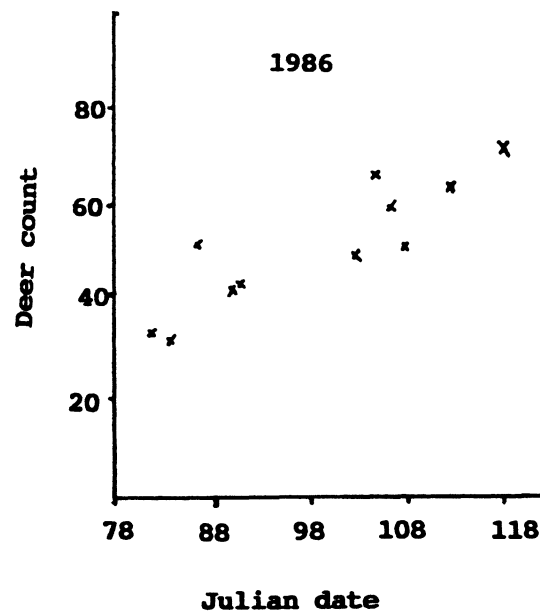
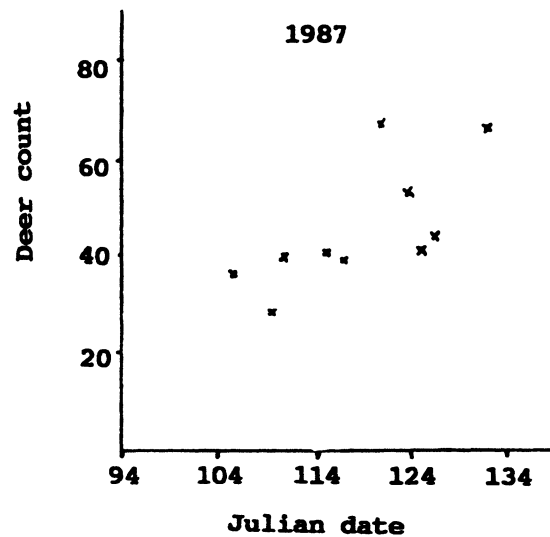


Fig. 2a. Annual road counts of deer by observer 1 for 1986 and 1987 (lefthand number on x axis is Julian date when there was no snow at the Polebridge weather station).

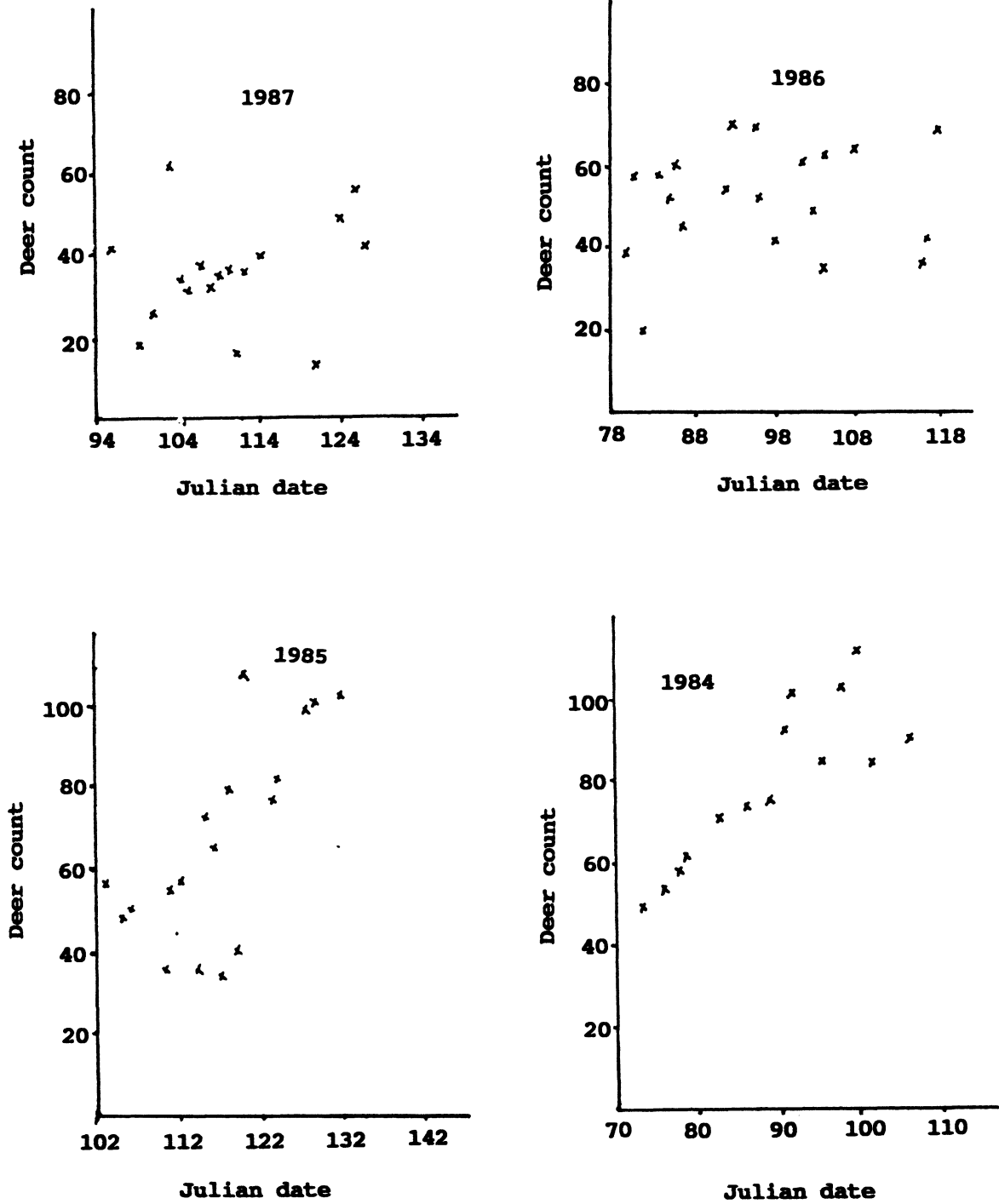


Fig. 2b. Annual road counts of deer by observer 2 for 1984 through 1987 (lefthand number on x axis is Julian date when there was no snow at the Polebridge weather station).

compared to observations at dusk. An advantage of night counts is that more time would be available, so observers could cover more kilometers of roads. If this resulted in higher counts, fewer replicates would be required. If counts were done over a several hour period, travel routes should be standardized so that variability due to counting areas at different times during the deer's daily cycle is reduced.

Logistically, 20 NF road counts per year would be easily obtainable. If this number were done a SE(r) of <0.05 could be obtained with 3 to 4 years of monitoring (Fig.1) A higher or lower level of precision could be chosen resulting in more or less years of monitoring and more or fewer replicates. These numbers should be selected based on the researchers' or managers' needs.

Harris (1986) cautioned that changing sightability, either with time or population density, biases "r". This possibility would be difficult to investigate with NF road counts, but the manager should keep it firmly in mind when making decisions based on partial counts of any kind. In addition, populations of many species often cycle due to unknown factors. Thus, even if the deer numbers are declining overall, there may be years when the population shows an increasing trend. This would be difficult to assess with road counts and is a good example of why trend counts must be taken over a number of years before results should be taken as certainty. This of course is the familiar bind:

if the wildlife manager waits long enough to be absolutely sure that a trend is upward or downward before changing management, populations may be dangerously low or high. On the horns of this dilemma lies the art of wildlife management.

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CHAPTER IV: WINTER TRACK COUNTS

INTRODUCTION

Track surveys have been used extensively in Europe and North America to monitor changes in ungulate numbers and habitat use (Pucek et al. 1975, Dzieciolowski 1976, Kucera 1976, Singer 1979, Rogers et al. 1980, Jenkins 1985, Messier and Barrette 1985). Despite the widespread use of track counts, little work has been done to assess the variability and sample sizes necessary to monitor changes in ungulate numbers or habitat use.

Daniel and Frels (1971) reported detecting population changes as low as 8% with 95% confidence with a sample size of 12 half-mile transects and 5 replicates, if counts averaged at least 45 tracks per mile. If the average number of tracks per mile was less than 45, population changes as great as 36% were undetectable with 95% confidence. They found that reducing replication of transects from 10 to 5 resulted in little loss of precision. They assumed the counts were normally distributed and did not provide information on how increasing the number of transects might increase precision.

Mooty et al. (1984) found that track counts had a high variability and that precision increased more rapidly with increases in transect numbers than with increases in replicates. They found it was necessary to obtain a count

on 19 transects, each 16 kilometers in length to obtain a precision of $\pm 20\%$.

Mooty et al. (1984) found that track counts correlated well with results of pellet counts, while Pucek et al. (1975) and Dzieciolowski (1976) found track counts correlated well with drive count results.

The objectives of my study were to:

- 1) assess the feasibility of using track counts to monitor white-tailed deer numbers in the NF.

- 2) recommend the most efficient combination of transects and replicates needed for a track monitoring study.

- 3) provide managers and researchers with guidelines for statistically testing track count data.

STUDY AREA

The study was carried out in 2 areas of the NF (Fig. 1). The Big Creek area (BC) is easterly facing and except in the creek bottom, rises steeply from the North Fork River. Old growth ponderosa pine, larch and cottonwood predominate. The Akokala Creek area (AC) has extensive areas of dead and living lodgepole pine with willow and cottonwood along Akokala Creek. A more detailed description of the NF is found in Chapter 1.

METHODS

Field methods consisted of counting sets of deer tracks

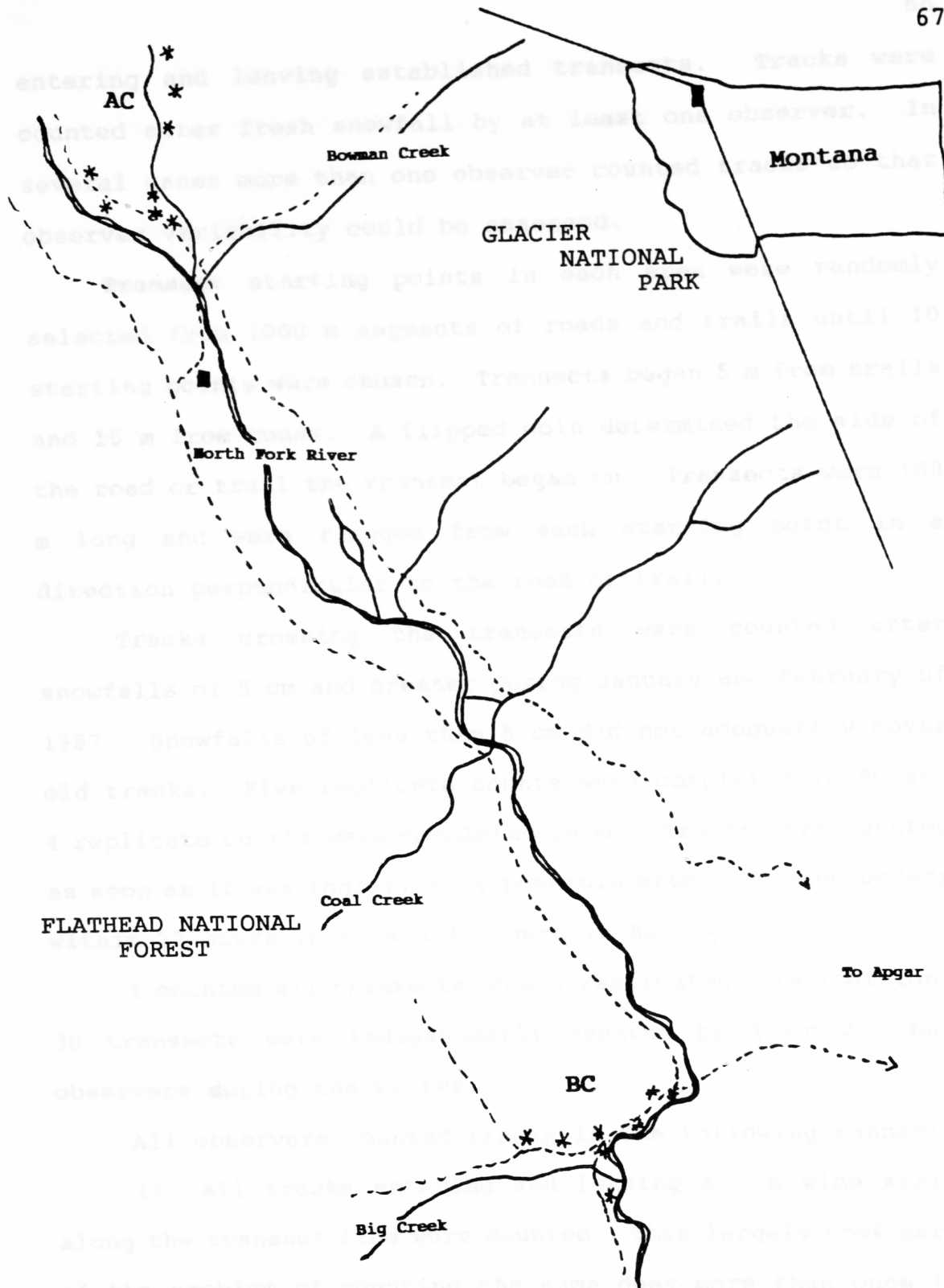


Fig. 1. Map of track transects (* are transect locations, dashed lines are roads, AC is the Akokala Creek area and BC is the Big Creek area, scale: 1 cm = 1 km).

entering and leaving established transects. Tracks were counted after fresh snowfall by at least one observer. In several cases more than one observer counted tracks so that observer variability could be assessed.

Transect starting points in each area were randomly selected from 1000 m segments of roads and trails until 10 starting points were chosen. Transects began 5 m from trails and 15 m from roads. A flipped coin determined the side of the road or trail the transect began on. Transects were 100 m long and were flagged from each starting point in a direction perpendicular to the road or trail.

Tracks crossing the transects were counted after snowfalls of 5 cm and greater during January and February of 1987. Snowfalls of less than 5 cm did not adequately cover old tracks. Five replicate counts were completed in BC and 4 replicate counts were completed in AC. Tracks were counted as soon as it was logistically possible after the snow ended; within 27 hours in BC and 42 hours in AC.

I counted all transects on all replicates. In addition, 30 transects were independently counted by 1 or 2 other observers during the winter.

All observers counted tracks in the following manner:

- 1) All tracks entering and leaving a 1 m wide strip along the transect line were counted. This largely took care of the problem of counting the same deer more than once if it wandered down the transect line.

2) Tracks that obviously exited the line and then reentered were not counted again. Tracks were not followed off the transect path. If it was not obvious that a set of tracks came from a deer that had exited, it was counted as a fresh set.

3) If 2 or more deer were following in each others' footsteps and the observer could not determine how many, 6 track sets were recorded.

4) The resulting numbers were halved so that numbers of track sets corresponded to actual numbers of deer crossing the transects.

The time it took to complete all 10 transects in each area was recorded each time the transects were run.

Differences between observers were tested using the Wilcoxon Matched-Pairs test.

A model was developed to determine how sampling efficiency is changed by varying the numbers of transects and replicates. The model simulated transect replicate counts and population changes over time. In this way various combinations of replicates and transects were assessed for power (the probability of correctly rejecting the null hypothesis that track counts did not change, if in fact they did). Optimal sampling strategies were then developed. In the interests of simplicity, and because it did not appear to add significantly to overall variability, observer variability was ignored in the model.

Model development took the following steps:

1) Distribution of the data was assessed. The frequency distribution of the counts " r_{ti} ", where r_{ti} =the " i^{th} " replicate on transect " t ", was examined for evidence of non-normality. A transformation that normalized the counts was determined through inspection of normal probability plots. One was added to each count and counts were then lognormally transformed so that $l_{ti}=\ln(r_{ti}+1)$.

The distribution of the sample means " \bar{l}_t ", where $\bar{l}_t=1/n\sum_{i=1}^n l_{ti}$, and n is the number of replicates on transect t was assessed through construction of a normal probability plot.

The probability plot of the sample variances of the lognormally transformed data " s^2 ", where $s^2=1/(n-1)\sum_{i=1}^n (l_{ti}-\bar{l}_t)^2$ was examined for evidence of non-normality. A probability plot of the natural log transformation of the sample variances ($\ln(s^2)$) was constructed to assess normality of the transformed data.

2) A method for simulating baseline replicate counts was developed. To simulate " m " transects with " r " replicates each, the following procedure was used:

a) For the t^{th} transect in year 1 ($t=1,\dots,m$) a sample transect mean " k_{t1} " was randomly drawn from a normal distribution with mean " \bar{l} " and variance " s_1^2 ", where $\bar{l}=1/m\sum_{t=1}^m \bar{l}_t$, $s_1^2=1/m\sum_{t=1}^m (\bar{l}_t-\bar{l})^2$ and m =number of transects. " \bar{l} " and s_1^2 were taken from the BC data set or the AC data set.

b) A sample transect variance " s_t^2 " was randomly drawn from a lognormal distribution with parameters " \bar{y} " and " z^2 " where $y = 1/m \sum \ln(s^2)$ and $z^2 = 1/(m-1) \sum (\ln(s^2) - \bar{y})$. " \bar{y} " and " z^2 " were taken from the BC data set or the AC data set.

c) Replicate counts " $l_{t,i}$ " ($i=1, \dots, r$) were generated from a normal distribution with mean $k_{t,1}$ and variance s_t^2 .

d) "Actual counts" ($r_{t,i}$) were obtained by taking the antilog of the generated counts ($l_{t,i}$), subtracting 1 and rounding the result to the nearest whole number. If the result was negative it was assigned a zero value.

e) "a" through "d" were repeated for various numbers of transects (e.g. 5, 10, 15, ..., 65) and replicates (e.g. 1, 3, 5, 10, and 20).

3) A method for simulating replicate counts from a population that had increased or decreased by $m\%$ was developed:

a) A 2nd sample transect mean ($k_{t,1a}$) was drawn from a normal distribution with the same mean \bar{l} and variance s_1^2 as $k_{t,1}$ was drawn from.

b) The same sample transect variance (s_t^2) as was used for the series of baseline replicates for that transect was employed.

c) The sample transect mean for the t^{th} transect on year 2, " $k_{t,2}$ ", was generated in one of 3 ways:

1> $k_{t,2} = m\%(k_{t,1})$ under the assumption that

transect means are completely dependent¹ between years.

2> $k_{t2} = m\%(k_{t1a} + k_{t1b})/2$ under the assumption that transect means are partially (50%) dependent between years.

3> $k_{t2} = m\%(k_{t1a})$ under the assumption that transect means are completely independent between years.

d) Desired numbers of replicate counts were generated from a normal distribution with mean k_{t2} and variance s_t^2 .

e) "Actual" counts (r_{ti}) were obtained by taking the antilog of the generated counts (l_{ti}), subtracting 1 and rounding the result to the nearest whole number. If the result was negative it was assigned a zero value.

f) "a" through "e" were repeated for the same combinations of transects and replicates as for the simulated year 1 track data.

4) The following method was used to test for differences between years:

a) Replicates for each transect were summed.

b) Each sum of replicates was matched with the sum of replicates for the same transect in the next year.

c) A p-value for the matched pairs was obtained using the Wilcoxon Signed Rank test.

5) Step 4 was repeated 500 times for the previously

¹Dependence of transects means between years depends on the degree to which the same transects tend to have either higher or lower counts than the average every year.

noted combinations of transects and replicates and estimates of the power were obtained by determining the fraction of the time the p-value was less than the critical p-value for the desired significance level of the test.

Isopleths of power for various simulated increases and decreases in track counts at BC and AC were developed for $\alpha=0.10$ and $\alpha=0.25$. Because I did not have data on the amount of independence between years, the sensitivity of the model to assumptions about this was tested.

RESULTS

BC and AC track counts had high variability, both between replicates on the same transect and between transects on the same day (Table 1).

There was no evidence of differences between any of the observers (Table 2). It took approximately 4 1/2 hours from the beginning of transect 1 to complete 10 transects in BC. AC took longer (6 hours) we could not drive between transect lines.

The actual counts displayed evidence of non-normality (Table 1), while a natural log transformation of the data (Table 3) normalized the data. Because it is impossible to obtain a negative count, these distributions are necessarily bounded by zero. Therefore, data from areas with low means (AC) will not appear normal.

The sample means (l_t) appeared normally distributed.

Table 1. Winter 1987 deer track counts (t=transect number, r_{jt} =replicate count on transect t, \bar{x} =mean of transect counts, w^2 =variance of transect counts, \bar{a} =mean of replicate counts and b^2 =variance of replicate counts).

Big Creek Area

Julian date:	002	004	025	049	055		
cm fresh snow:	07	30	12	10	15		
hours after snow							
stopped that tran-							
sects were begun:	19	18	13	11	27		
t \ r _t	1	2	3	4	5	\bar{a}	b^2
1	11	8	7	4	5	7	7
2	10	16	7	50	22	21	296
3	18	30	18	52	34	30	197
4	21	11	0	12	16	12	60
5	9	7	2	12	8	8	13
6	6	20	0	10	26	12	111
7	0	2	1	0	2	1	1
8	4	12	9	14	8	9	15
9	11	19	6	8	18	12	34
10	6	8	2	2	17	7	38
\bar{x}	10	13	5	16	16		
w^2	39	66	31	354	101		

Akokala area

Julian date:	005	045	050	055		
cm fresh snow:	30	07	10	15		
hours after snow						
stopped that tran-						
sects were begun:	42	39	35	34	\bar{a}	b^2
1	0	3	2	2	2	2
2	3	0	0	4	2	4
3	0	0	0	4	1	4
4	7	3	0	2	3	9
5	8	7	0	0	4	19
6	1	10	14	3	7	37
7	9	7	2	6	6	9
8	0	0	3	0	1	2
9	2	2	1	0	1	1
10	0	0	0	0	0	0
\bar{x}	3	3	2	2		
w^2	13	13	18	4		

Table 2. Results of Wilcoxon matched-pairs test for differences between observers (T=sum of ranks with less frequent sign, N=number of pairs minus any pair whose difference is 0, p=alpha level and op=observer pair).

<u>op</u>	<u>N</u>	<u>T</u>	<u>p</u>
1 & 2	25	141.0	0.56
1 & 3	17	69.5	0.74
2 & 3	13	38.5	0.62

Table 3. Natural log transformation of winter track counts (t =transect, l_{ti} =replicate count on transect t where $l_{ti}=\ln(r_{ti}+1)$, $\bar{l}_t=1/n \sum (l_{ti})$ and $s^2=1/(n-1) \sum (l_{ti}-\bar{l}_t)^2$).

$t \backslash l_t$	1	2	3	4	5	\bar{l}_t	s^2	$\ln(s^2)$
<u>Big Creek area</u>								
1	2.48	2.08	1.95	1.61	1.79	1.98	0.11	0.10
2	2.40	2.83	2.08	4.11	3.14	2.91	0.61	0.48
3	2.94	3.43	2.94	4.01	3.56	3.38	0.20	0.18
4	3.09	2.48	0.00	2.56	3.30	2.29	1.75	0.56
5	2.30	2.08	1.10	2.56	2.20	2.05	0.31	0.27
6	1.95	3.04	0.00	2.40	3.30	2.14	1.71	1.00
7	0.00	1.10	0.69	0.00	1.10	0.58	0.31	0.27
8	1.61	2.56	2.30	2.71	2.20	2.28	0.18	0.16
9	2.48	3.00	1.95	2.20	2.94	2.51	0.21	0.19
10	1.95	2.20	1.10	1.10	2.89	1.85	0.59	0.46
<u>Akokala area</u>								
1	0.00	1.39	1.10	1.10		0.90	0.38	0.32
2	1.39	0.00	0.00	1.61		0.75	0.75	0.56
3	0.00	0.00	0.69	1.79		0.62	0.71	0.53
4	2.08	1.39	0.00	1.10		1.14	0.75	0.56
5	2.20	2.08	0.00	0.00		1.07	1.53	0.93
6	1.10	2.40	2.71	1.39		1.90	0.60	0.47
7	2.30	2.08	1.10	1.95		1.86	0.28	0.25
8	0.00	0.00	1.39	0.00		0.35	0.48	0.39
9	1.10	1.10	0.69	0.00		0.72	0.27	0.24
10	0.00	0.00	0.00	0.00		0.00	0.00	0.00

The distribution of sample variances (s^2) did not appear normally distributed; the natural logarithm of the sample variances normalized the data.

When the frequency distributions of the simulated replicates from BC and AC (Fig. 2a and 3a) were compared to the frequency distributions of the actual replicate counts from BC and AC (Fig. 2b and 3b), they appeared very similar. This is indicative of a well-performing model.

Model sensitivity to assumptions about independence of transects between years.

The model was quite sensitive to assumptions about independence of transects between years. When area (BC), alpha level (0.25) and population change (20% decrease) were kept constant while simulations were run under each of the 3 assumptions about independence of transects between years, the number of transects necessary to obtain a power of 0.70 varied by as much as 5 times (Fig. 4a, b and c). Constraints on computer time prohibited estimating power of 0.90 under complete independence. Sensitivity to assumptions about independence of transects between years was most pronounced when power was above 0.70 and replicates were less than 7.

Varying alpha levels

As many as 100% more replicates or transects were needed to obtain an alpha level of 0.10 versus an alpha level of 0.25 when other factors (area, independence of transects between years, population change and power) were kept

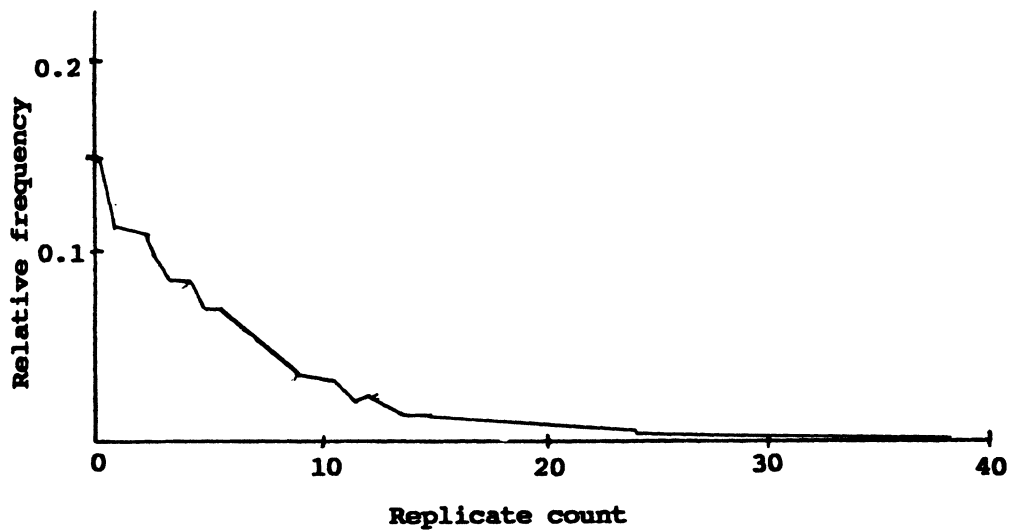


Fig. 2a. Relative frequency of simulated replicate counts for Big Creek (5 transects, 200 replicates).

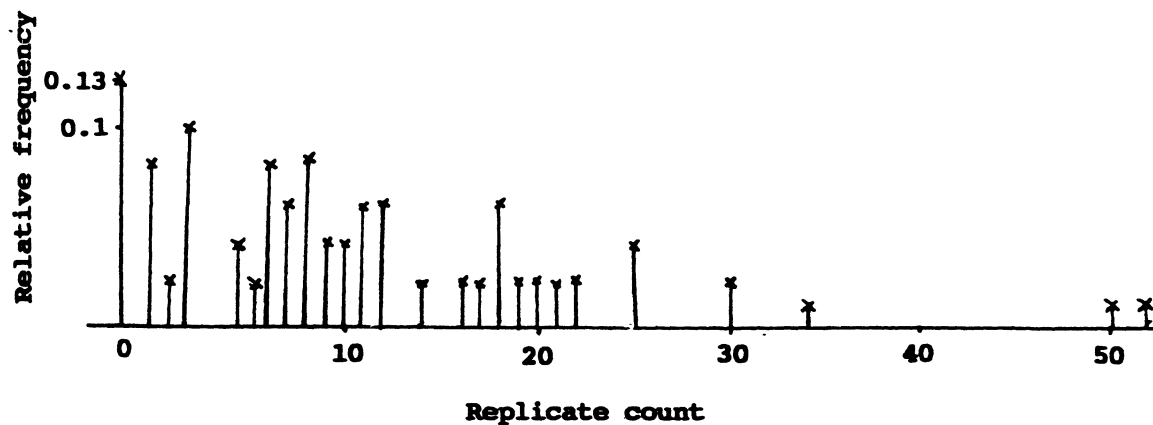


Fig. 2b. Relative frequency of actual replicate counts for Big Creek (10 transects, 5 replicates).

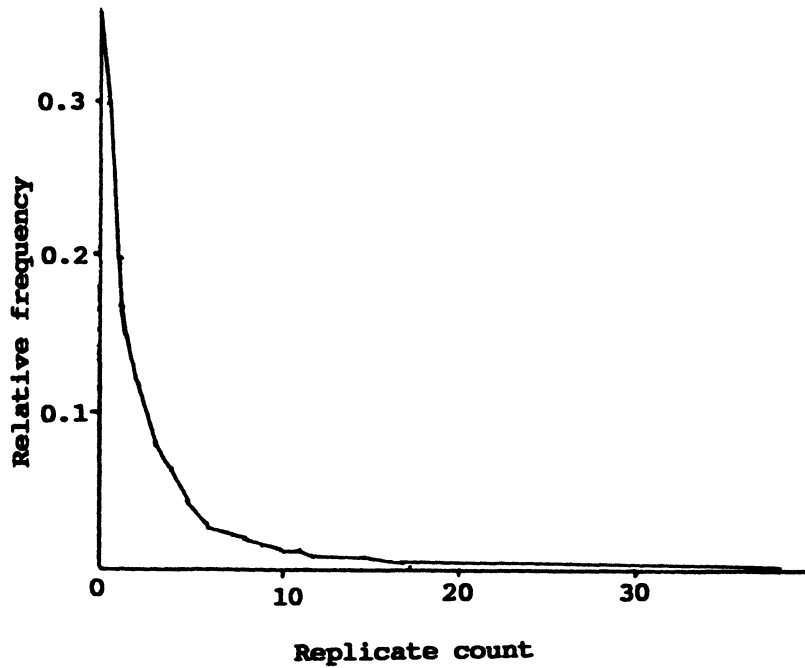


Fig. 3a. Relative frequency of simulated replicate counts for Akokala Creek (5 transects, 200 replicates).

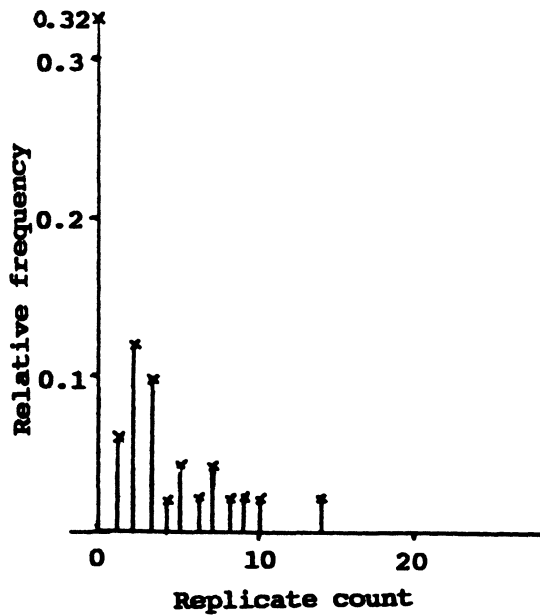


Fig. 3b. Relative frequency of actual replicate counts for Akokala Creek (10 transects, 4 replicates).

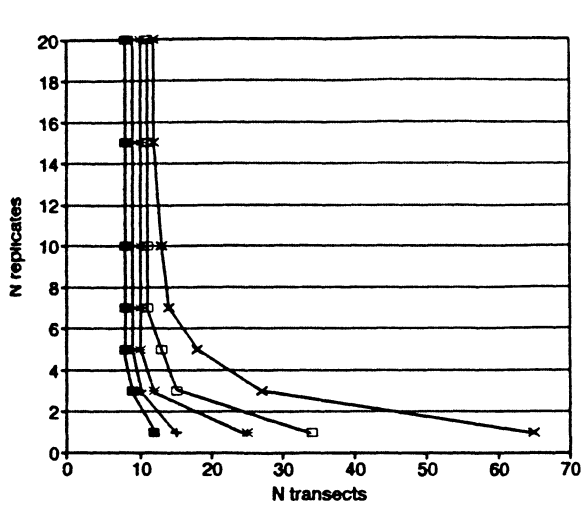


Fig. 4a. 20% decrease, BC, alpha = 0.25, CD.

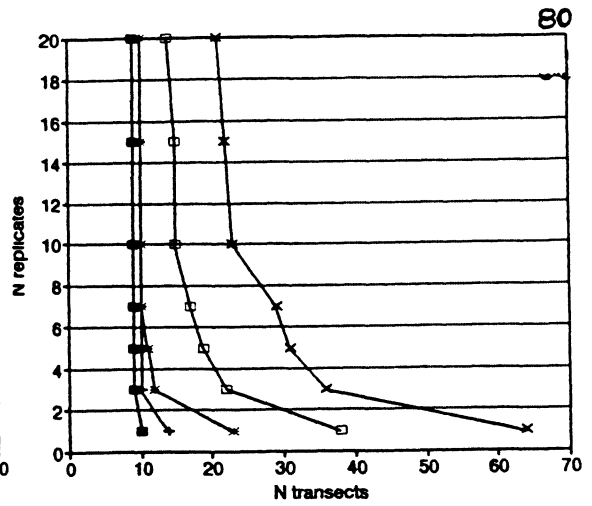


Fig. 4b. 20% decrease, BC, alpha = 0.25, MIX.

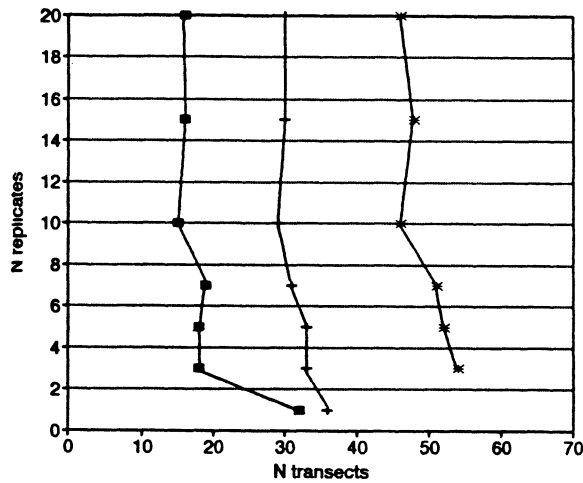


Fig. 4c. 20% decrease, BC, alpha = 0.25, I.

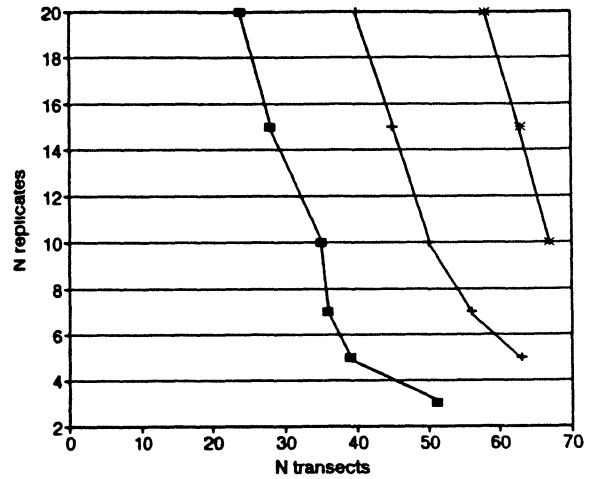


Fig. 4d. 10% decrease, BC, alpha = 0.10, MIX.

Fig. 4. Power isopleths for detecting the change noted for the one-sided Wilcoxon signed rank test in high density (Big Creek) and low density (Akokala Creek) deer areas. Contours reveal the sample sizes (number of transects and replicates) required to achieve a given probability of correctly rejecting the null hypothesis of no difference between years. (-■- = 50% power, -+- = 60% power, -* = 70% power, -□- = 80% power, -x- = 90% power, BC = Big Creek, AC = Akokala Creek, CD = complete dependence of transect pairs between years, MIX = 50% dependence of transect pairs between years, I = complete independence of transect pairs between years).

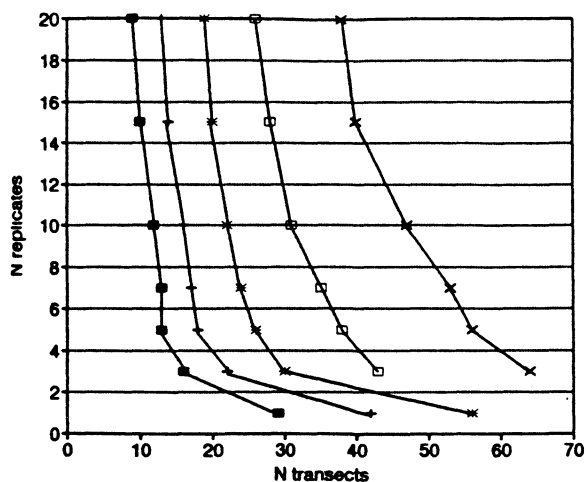


Fig. 4e. 20% decrease, BC, $\alpha = 0.10$, MIX.

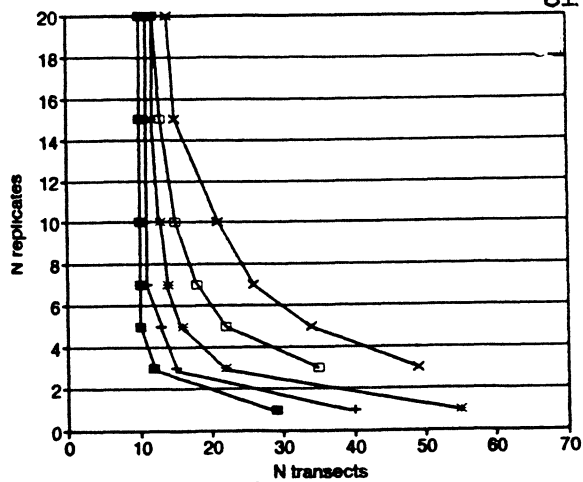


Fig. 4f. 20% decrease, BC, $\alpha = 0.10$, CD.

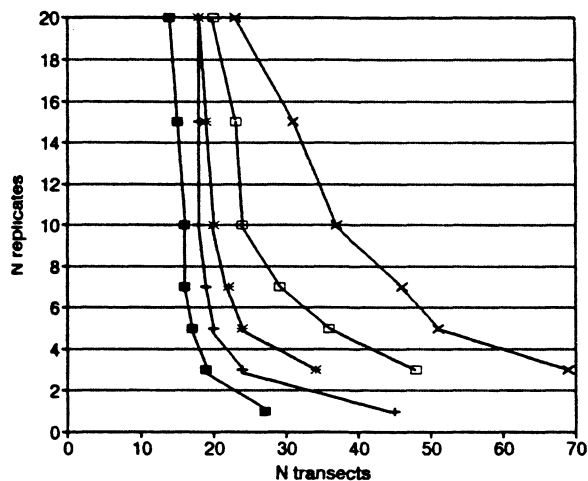


Fig. 4g. 20% decrease, AC, $\alpha = 0.10$, CD.

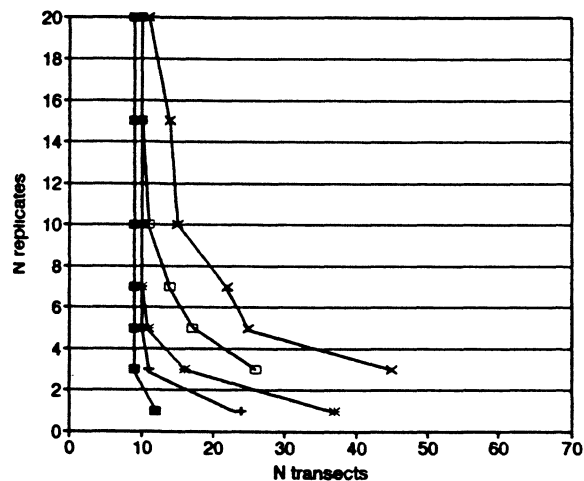


Fig. 4h. 20% increase, BC, $\alpha = 0.10$, CD.

Fig. 4 (cont.). Power isopleths for detecting the change noted for the one-sided Wilcoxon signed rank test in high density (Big Creek) and low density (Akokala Creek) deer areas. Contours reveal the sample sizes (number of transects and replicates) required to achieve a given probability of correctly rejecting the null hypothesis of no difference between years. (\blacksquare = 50% power, $+$ = 60% power, $*$ = 70% power, \square = 80% power, \times = 90% power, BC = Big Creek, AC = Akokala Creek, CD = complete dependence of transect pairs between years, MIX = 50% dependence of transect pairs between years, I = complete independence of transect pairs between years).

constant (Fig. 4a and f).

Deer density

Nearly twice as many transects were needed to detect changes in a low density deer area (AC) as in a high density deer area (BC) all other factors being constant (power, replicates, complete dependence of transects between years, alpha level, and amount of population change, Fig. 4f and g).

Detecting population increases versus decreases

As many as 50% fewer transects were required to detect population increases of 20% than decreases of 20% at high levels of power (Fig. 4f and h).

Detecting a 10% change versus a 20% change

Up to 200% more transects or replicates were required to detect a 10% population size than were needed to detect a 20% change even when power was low (Fig. 4d and e).

Increasing replicates versus increasing transects

The number of transects needed for desired levels of precision were reduced by as much as 70% when replicates were increased from 1 to 5. This was especially apparent when power was 0.8 or greater. Replicates beyond 5 did not lead to much reduction in number of transects needed (Fig. 4a through h). This agreed with the findings of Daniels and Frels (1971) and Mooty et al. (1984).

DISCUSSION

The following discussion is based on the model described above. Readers should be aware that this model was not completely evaluated. It is useful as a starting point, but more years of data are needed so that assumptions such as dependence of transects between years and the degree to which the variance of transect means changes from year to year could be assessed. It would be especially useful to evaluate the technique in an area where populations are known.

Given that the model does reflect reality, in readily accessible areas where personnel are available, winter track counts would be a relatively inexpensive way to monitor white-tailed deer populations, especially if further research demonstrates that dependence of transects between years is high.

If the beginning of each transect can be driven or snowmobiled to, one observer could complete 20 to 25 transects that are 100 m long in a day. If transects must be skied or snowshoed between, one observer could complete 10 to 20 per day, depending on the distance between transects and the distance of the transects to the vehicle or home base. Assuming a high dependence of transects between years, two people could conceivably do enough transects annually in even a low density deer area such as AC, to detect a 20% decrease in track numbers with 90% confidence and have only a 10% chance of a beta error.

Unfortunately, I had no data on the dependence of transects between years because the study encompassed only one field season. The model is very sensitive to this assumption, especially when there are few replicates and desired power is high. I hypothesize that transects are somewhere between completely dependent and 50% dependent between years. However, until further data are available, the conservative approach is to choose a sample size consistent with complete independence. This implies much larger sample sizes. Under the scenario of complete independence of transects between years it would be difficult for 2 people to sample enough transects to determine a 20% population decline in even a high density deer area such as BC with 25% confidence and that would be with a high chance of making a beta error.

Given the large differences in sample sizes necessary depending on assumptions about dependence of transects between years, it would behoove managers to do a pilot study to look at this assumption before this method employed.

There was no evidence of deer following observer "paths" along the transects. However, this could be a problem if transects were longer or if snow depths were greater and should be monitored. Whether or not the assumption that "trails" were 3 deer was true or not had little effect in my study. Out of 90 transects, observers reported only 5 trails. However, during winters with greater snow depths

this assumption could have more effect on results.

When there were less than 10 tracks per 100 m, observers found it easy to distinguish track sets. It became increasingly difficult beyond that density. Even so, the differences between observers was small compared to the high variability of the data. It appears that many different observers could be used without greatly affecting the variability of the data.

Since fewer transects and replicates are necessary when track densities are high, allowing more time after a snowfall for tracks to accumulate would reduce the amount of effort needed. For low density areas such as AC this could be an important strategy. At the point that there are more than 30 tracks per 100 m, the longer length of time needed to "read" the transect would probably begin to offset the benefits of needing less total transects.

Between the beginning of January and the last of February there were 5 snowfalls of 5 cm or greater. The number of replicates are limited to numbers of snowfalls because there is no other way to reliably "age" tracks. For this technique to be feasible, observers must have flexible schedules with a priority put on counting tracks when conditions are suitable because snowfall commencement, duration and depth are unpredictable.

Managers should note that little is bought by increasing replicates beyond 5 in most cases anyway. Above 5 replicates

the power isopleths are nearly vertical and power is not increased significantly by adding more. Much more power can be bought by increasing numbers of transects than by increasing replicates beyond 5. The most practical approach is to assume that 3 replicates can be done annually and then determine the number of transects necessary to monitor a given population change with desired confidence and power. If the number of transects necessary to do this is logistically infeasible, another method must be selected.

Before embarking on a track survey, managers must decide the level of risk they are willing to take. If it is important that an alpha error not be made (saying the population is increasing or decreasing when in reality it is not) then the manager should choose a low alpha level. For instance, if the manager selects an alpha level of 0.20 he must realize that 2 times out of 10 he will make the mistake of saying the population is changing when it is not. If he desires more confidence than that, but does not or cannot increase sample sizes, the risk of a beta error (saying the population has stayed the same when in fact it has not) will increase. Reducing power from 0.90 to 0.70 increases the chance of a beta error from 1 time in 10 to 3 in 10. This could be a significant mistake for a population of special concern. The only way to keep power and confidence high is to increase the number of transects and/or replicates.

The trade offs between effort, and making an alpha error

or beta error should be carefully assessed. If a manager announces deer populations in the NF are decreasing, a segment of the public will undoubtedly blame wolves. If a mistake has been made and the population is in fact stable, the controversy may have been avoided by choosing a lower alpha level. On the other hand, if deer populations are indeed decreasing, yet the manager fails to recognize it, drastic changes in deer management could become necessary. If higher power (low possibility of a beta error) had been demanded, and the decrease detected early, moderate changes in management may have taken care of the problem.

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CHAPTER V: CONCLUSION

Monitoring white-tailed deer population trends in the NF will be costly if high levels of precision are needed. Of the 3 methods I field tested, the pellet count technique is the only one I would feel comfortable instituting without further study. Given adequate manpower this method could achieve nearly any level of precision desired. The disadvantages are that pellet plots are boring for most people, and in the NF there is a hazard of a grizzly bear confrontation.

Both the road count and the track count should be evaluated further before being instituted. The assumption that deer use along roads does not vary according to environmental conditions needs to be tested with radio-collared deer. Road counts would be the least expensive and require the least planning of the 3 methods. It is also, in my opinion, the most likely to actually be done every year.

As mentioned previously, track counts would require many people with very flexible schedules if there is little dependence of transects between years. Since the numbers of transects and replicates are considerably reduced if there is dependence of transects between years, this should be assessed before the method is instituted.

The only other method that may have merit in the NF is an aerial survey. Variability could be assessed with 4 or 5 flights within a short period of time. Once this is done

the number of years and replicates per year to reach desired levels of precision could be assessed in the same manner as with road counts.

Before any method is decided on, researchers and managers should seriously consider their objectives and whether they might be reached in ways other than population monitoring. For example, mortality rates and sources for different age groups, coupled with information on natality and recruitment rates, may meet objectives better than monitoring population trends. If population monitoring is needed, the relative dangers of beta and alpha errors should be assessed and the precision needed to realize objectives should be carefully evaluated. Without adequate planning, monitoring deer populations in the NF could easily become a frustrating exercise that results in information that does not adequately meet the desired objectives.