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APPRAISAL OF A QUADRAT CENSUS FOR MULE DEER IN PINYON-JUNIPER VEGETATION[1]

Quadrat sample units have been used in aerial census of caribou *(Rangifer tarandus)* (Siniff and Skoog 1964), moose *(Alces alces)* (Evans et al. 1966, Bergerud and Manuel 1969), white-tailed deer *(Odocoileus virginianus)* (Mangold 1966), mule deer *(O. hemionus)* (Gill 1969, Kufeld et al. 1980), and pronghorn *(Antilocapra americana)* (Pojar et al. 1982) in a variety of habitats. Diversity in counting conditions has prompted differences in quadrat size ranging from 0.648 km^2 for mule deer in rugged pinyon-juniper *(Pinus edulis-Juniperus osteosperma)* habitat in Colorado (Kufeld et al. 1980) to 10.36 km^2 for caribou in more open vegetation in Alaska (Siniff and Skoog 1964). Further variation in technique was use of fixed-wing aircraft to count caribou and moose and helicopters to count deer and pronghorn.

In Colorado, precision of mule deer population estimates from quadrat censuses has varied from ± 17 to 23% of $\bar{x}$ at the 90% confidence level on pinyon-juniper range (Kufeld et al. 1980) and from ± 22 to 35% of $\bar{x}$ at the 90% confidence level on sagebrush range (R. B. Gill, unpubl. data). These precision levels resulted from first-time experiences with quadrat sampling and presumably all could be increased with improved sampling designs based on acquired knowledge. In constrast, establishing accuracy of census estimates with any method is essentially impossible with large free-ranging populations. Procedures must therefore be devised to help infer reasonableness of estimates. This report describes the approach used with mule deer in Piceance Basin, northwestern Colorado, which involved comparing census estimates to population figures generated from other data.

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METHODS

Preliminary Field Testing

Quadrat census procedures were adapted from those of Gill (1969) who counted mule deer on 93 2.59-km^2 quadrats on a sagebrush winter range in Middle Park, Colorado. However, 2 questions had to be addressed prior to establishing a quadrat census in Piceance Basin; could deer be readily seen under pinyon-juniper canopy and what was a practical quadrat size? Intuitively, a 2.59-km^2 quadrat was too large because of overstory vegetation and rough terrain.

To address the first question, 10 to 15 deer were placed in each of 3 deer-proof pastures of 49 to 66 ha on pinyon-juniper range. An observer with previous census experience, but unfamiliar with the pastures and unaware of how many deer in each, counted and missed only 1 of 37 deer present.

To partially resolve the second question, 2 square quadrat sizes were tested: 0.162-km^2 and 0.648-km^2. Twelve quadrats of each size were arbitrarily located in areas with a variety of vegetation and terrain conditions and with expected high deer densities. The above observer counted 1.7 times more deer per unit of area on 0.648-km^2 quadrats than on 0.162-km^2 quadrats, but took 1.7 times longer per unit of area to search them. From 0 to 24 deer were counted on each set of quadrats, but more small quadrats (7) than large (2) had 0 deer. This suggested greater variability could be expected with smaller quadrats. They also required more frequent maneuvering of the helicopter which detracted from searching for deer. Therefore, the larger quadrat was selected for further evaluation.

Next, testing of a quadrat 0.648 km^2 was done on the 1,722-km^2 winter range previously defined in Piceance Basin (Bartmann and Steinert 1981). Sixty 0.648-km^2 quadrats were randomly selected without replacement and without the restrictions placed on contiguous quadrats by Kufeld et al. (1980). Quadrat size was then doubled by randomly selecting a second 0.648-km^2 quadrat on a cardinal side within the same cadastral section as each original quadrat. The resultant 1.295-km^2 rectangular area was flown as a unit and deer counted and assigned to the proper half. Deer density estimates for each size of a quadrat were similar (Table 1). Coefficient of variation was slightly lower with the 1.295-km^2 quadrat, but problems of orientation on the larger unit outweighed this small increase in precision.

Table 1. Counts of mule deer on 2 sizes of quadrats on pinyon-juniper winter range in Piceance Basin, 1973. *N* = 60.

Quad. size (km^2)	Deer/quad.		Deer/ km^2	CV (%)	Precision[a] (%)	No. of quads. with 0 deer
	$\bar{x}$	SE				
0.648	7.40	0.90	11.42	94	20	14
1.295	14.63	1.56	11.30	82	18	4

[a] One-half of the 90% confidence interval expressed as a percentage of the mean.

Actual Field Testing

Estimated sample size based on the above data indicated 110 0.648-km^2 quadrats should allow estimating deer density within ±15% of $\bar{x}$ at the 90% confidence level. I chose 120 for the study which necessitated selecting an additional 60 quadrats. Subsequent quadrat marking and counting procedures were similar to those described by Kufeld et al. (1980). Flights were made with this system each winter from 1973-80 except for 1977.

Optimal time for censusing was considered when essentially all deer were on the winter range sample area and were widely distributed. To determine this condition, fixed-wing airplane flights were made to spot-check areas in the basin. Snow conditions influenced deer distribution and optimal counting times occurred from late December to early February with early to mid-January most typical. There was no census in 1977 as mild weather allowed many deer to remain above the sample area all winter. I served as observer-navigator each year, but there were 3 different main observers.

Results were appraised by comparing the census estimate with a predicted population size. Each year's estimate was the starting base for calculating a predicted population size the following winter. Sex-and-age composition of the starting population was estimated from aerial deer classifications in early December preceding the census (R.M. Bartmann, unpubl. data). The initial population was then adjusted, in sequence, for winter mortality (Bartmann 1984), hunter harvest, and fawn production. A harvest estimate was from the Colorado Division of Wildlife's annual random survey and was arbitrarily inflated 25% to acknowledge wounding loss and illegal kill. Fawn harvest was ignored as the population was not incremented for production until December, after the hunting season. Addition of fawns yielded a predicted population size entering winter. Reasonable agreement between the predicted value and the census estimate boosted confidence in the census. Agreement was considered when the 90% confidence interval about the census estimate included the predicted population size. Each year's comparison was also subjectively evaluated to identify possible major problems.

RESULTS

Conditions in Piceance Basin from 1973 through 1980 were conducive to large fluctuations in size of the deer population. A severe winter in 1973 sharply reduced deer numbers. Increasingly mild winters from 1974 to 1978 were conducive to population increases. Another severe winter occurred in 1979. Population estimates from quadrat censuses during this same period ranged from 18,806 to 34,952 deer (Fig. 1).

The census estimate in 1973, when 2 sizes of quadrats were compared, was considered low for several reasons; it was the first experience with a new technique and the 1.295-km^2 area was difficult to search. A predicted population figure, calculated by working backwards from the 1974 census estimate, suggested 1/3 or more of the deer were missed in the 1973 census. The 1974 estimate was also the base for calculating the predicted population size to compare with the 1975 census.

From 1975 to 1980, the census estimate and predicted population size agreed 3 out of 5 times. The lower estimate in 1975 was attributed to using a Hughes 500C helicopter in lieu of a Bell 47G3B. Visibility was poorer in the Hughes, seating was cramped with 3 people in front, and the main observer sat in the middle which reduced his counting efficiency. Because of this, the predicted figure was considered to better reflect

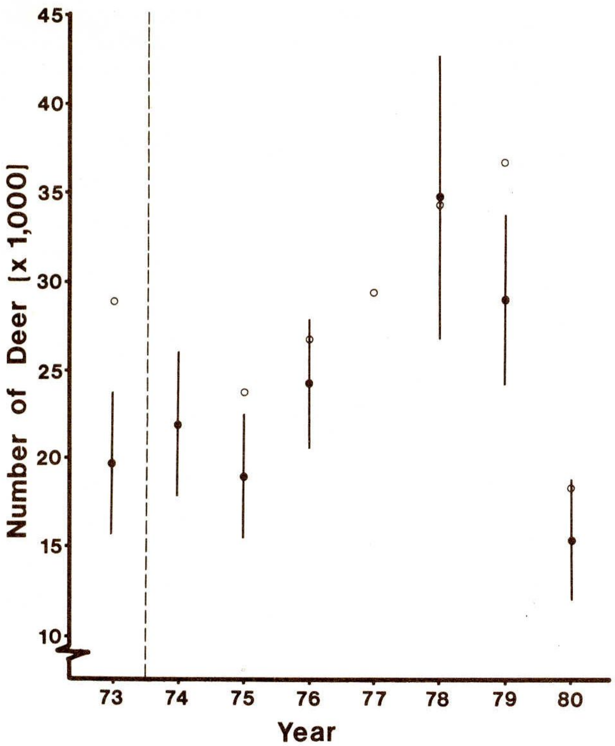

Fig. 1. Population estimates from counts of mule deer on 120 (60 in 1973) 0.648-km^2 quadrats on pinyon-juniper winter range in Piceance Basin, 1973-80. Census estimate means (●) with 90% confidence intervals (vertical lines) are compared with predicted population sizes (o). The 1974 census estimate was the basis for predicted population sizes in 1973 and 1975.

population status and was the base for the 1976 predicted population. The predicted value was used this way again in 1977 when there was no census.

Predicted population size and the census estimate agreed in 1976 and 1978. In 1979, the census estimate was again far below the predicted figure. Type of helicopter, experience of personnel, counting conditions, and deer distribution seemed conducive to a good census and were rejected as major reasons for the difference. The 2 population figures agreed again in 1980, but the count was still considered low. A Bell Jet Ranger was used and the main observer sat in the rear which limited forward visibility and effectiveness. Also, counting conditions were only fair as south aspects had more bare ground than usual. These situations probably had little influence on results of the comparison as, with the same precision, the census estimate could have been about 8,000 deer higher and still contained the predicted value in the confidence interval. Of key significance is that the sharp decline in deer numbers due to the preceding severe winter was reflected to a similar degree with both methods.

DISCUSSION

Comparing census estimates with predicted population values is admittedly not optimum. Since all sources of mortality are not considered, predicted values could be high. Perhaps it is coincidence, but predicted population sizes in Fig. 1 are all higher than corresponding census estimates. Also, mortality and productivity data used to calculate predicted populations are often less precise than census estimates. However, these data are considered adequate to indicate direction of annual population changes. Whenever census and predicted values disagreed, direction of change also disagreed. Those years when both figures did agree, there was a good snow background for counting, a helicopter seating 3 in front was used, and deer were widely distributed. These conditions also existed in 1979 when the 2 population figures disagreed. No explanation is available other than random chance.

Censusing mule deer in pinyon-juniper vegetation is not advised unless chances for success are maximized. Minimally, this means a good snow background and a helicopter providing good visibility and seating 3 in front. Observer experience, although not assessed here, is also assumed critical due to difficult counting conditions in pinyon-juniper habitat. LeResche and Rausch (1974) demonstrated the importance of both snow background and current observer experience for counting moose from the air.

Effects of deer distribution on census results are less obvious. Population estimates should be more precise when deer are widely distributed as fewer quadrats should have 0 deer. This is supported by data in Table 2 where a positive correlation was found between number of quadrats with 0 deer and the CV of the mean estimate of

Table 2. Counts of mule deer on 120 0.648-km^2 quadrats on pinyon-juniper winter range in Piceance Basin, 1973-80.

Year	Deer/quad. $\bar{x}$	Deer/quad. SE	CV (%)	Precision[a] (%)	Most deer on a quad.	No. of quads. with 0 deer
1974	8.24	0.94	124	19	48	42
1975	7.07	0.81	125	19	37	53
1976	9.08	0.82	99	15	39	27
1977	No census					
1978	13.14	1.82	152	23	87	52
1979	10.87	1.09	110	17	54	31
1980	5.76	0.78	149	22	44	56

[a]One-half of the 90% confidence interval expressed as a percent of the mean.

deer density $r = 0.90$, $P < 0.05$). This relationship indicates timing of the census is important due to influence of snow on deer distribution. This was exemplified in 1974 when logistical problems forced rescheduling the census after 20 quadrats were searched. The census was first attempted 1 day after a 10- to 15-cm snowfall. In a recount 9 days later, only 1 of 6 high elevation quadrats had deer, whereas earlier all 6 contained deer. Only 1 of 14 lower elevation quadrats had 0 deer each time.

Precision of deer population estimates in Piceance Basin ranged from ±15 to 23% of $\overline{x}$ at the 90% confidence level. This is similar to that reported by Kufeld et al. (1980) with 193 quadrats and stratified sampling in similar habitat. Such precision is acceptable to managers in Colorado who have implemented the quadrat census on other deer winter ranges. However, the greatest concern is still counting accuracy which should have a high priority in future research.

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