A Comparison of Precision for Three Deer Survey Techniques

Danny L. Rakestraw, *Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843*

Reginald J. Stapper, *Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843*

Daniel B. Fagre, *Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843*

Nova J. Silvy, *Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843*

Abstract: Morning-drive, evening-drive, and night spotlight surveys for deer (*Odicoleus virginianus* and *O. hemionus*) were conducted each quarter on 3 National Park Service (NPS) areas in Texas and New Mexico from January 1987 to March 1988. Spotlight surveys resulted in a larger number of deer seen on all 3 sites. Spotlight surveys had significantly ($P = 0.002$) greater precision than morning or evening surveys. Increasing beyond 3 the number of consecutive days surveys were conducted did not significantly improve the precision of morning surveys ($P = 0.328$) or spotlight surveys ($P = 0.719$). A power analysis, generated for spotlight-survey data, indicated an increased probability of detecting differences in deer densities with increased survey effort. Weekly surveys are recommended.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 52:283–293

Biologists responsible for managing deer populations typically make decisions from indices of population abundance such as browse indices, pellet-group counts, hunter-success ratios, and transect surveys which provide relative abundance and herd-composition counts (Rasmussen and Doman 1943, Connolly 1981, McCullough 1993). Because the accuracy of these indices rarely can be tested or improved, increasing precision of the techniques used to produce the indices is the only area for improvement (McCullough 1982).

Generally, 2 approaches can be used to improve precision. First, factors affecting variability of the parameter can be identified and controlled (Sokal and Rohlf 1981). For most techniques used to produce population indices for deer, behavior has the greatest impact on the variability in the indices. Because only a few factors affecting deer behavior (e.g., season, time of day, weather) have been identified, behavior can only be partially controlled (Progulske and Duerre 1964, McCullough 1982). A second method of improving precision is to increase sample size, either through increasing the number of individuals in the sample or increasing the number of samples (Winter et al. 1991). In theory, with increased sample size, precision will improve.

The primary objective of our study was to compare 3 methods of collecting transect-survey data (i.e., morning-drive counts, evening-drive counts, and night spotlight counts) to identify which method provided the greatest precision for deer counts. A second objective was to evaluate the effect on precision and power to detect population differences by increasing the number of surveys.

Funding for this project was provided by the NPS Cooperative Research Unit, Texas A&M University. Personnel at each of the NPS units provided on-site logistical support and coordination with private landowners. Jerry Dragoo, David Scarborough, Dave Speegle, and students of several wildlife management courses assisted in data collection.

Study Areas

This study was conducted on 3 NPS areas (Lake Amistad National Recreation Area, Carlsbad Caverns NP, and Guadalupe Mountains NP) in western Texas and southern New Mexico. Lake Amistad National Recreation Area is located in Val Verde County in southwest Texas along the Amistad Reservoir on the Rio Grande River. Bow and arrow are used to hunt white-tailed deer within the area. Vegetation on the area was typical of the South Texas Plains as described by Gould (1975). Topography of the area varies from rolling hills to steep washers. Upland vegetation was dominated by honey mesquite (*Prosopis glandulosa*), whitebrush (*Aloysis lycioides*), and numerous forbes. Shoreline areas, which were occasionally flooded, tend to have impenetrable stands of willow baccharis (*Baccharis salicina*) and saltcedar (*Tamarix gallica*).

Carlsbad Caverns NP is located in southern New Mexico, 32 km south of Carlsbad, along the eastern edge of the Guadalupe Mountain Range with 49% of the park in desert-shrub vegetation and 46% in mountain-shrub vegetation (Glass et al. 1974). The desert-shrub type, found in the southern and western portions of the park, was composed of juniper (*Juniperus pinchotti*), lechuguilla (*Agave lechuguilla*), sotol (*Dasylirion leiphyllum*), Roemer's acacia (*Acacia roemeriana*), and Mendora (*Menodora* spp.). The mountain-shrub type was dominated by mountain mahogany (*Cercocarpus breviflorus*) and several species of white oak (*Quercus* spp.) in higher elevations of the park. Other species in the mountain-shrub type include desert ceanothus (*Ceanothus greggii*), skunkbush (*Rhus trilobata*), lechuguilla, century plants (*Agave neomexicana*), and several species of cool-season grasses. Mule deer were not hunted within the park boundary.

Guadalupe Mountains NP is located in the Trans-Pecos Region of Texas in Culberson and Hudspeth counties. Topography of the park was mountainous with steep canyons in the escarpment, and gently rolling flats below, bisected by deep drainages. Mule deer, found within the park, were not hunted. Vegetation of the park was characteristic of both the Chihuahuan Desert and the southern Rocky Mountains. Guadalupe Mountains NP contained 11 vegetation types (Glass et al. 1974) of which mountain shrub (35%), desert shrub (24%), creosotebush (*Larrea tridentata*) (22%), and conifer (11%) were most abundant. The remaining 7 vegetation types covered 8% of the park.

Methods

Deer were surveyed from existing roads on all 3 NPS units. A single road (10.2 km) was used on Lake Amistad National Recreation Area. Roads surveyed on Carlsbad Caverns NP included the Scenic Loop (15.1 km), representing the upper mountains; Walnut Canyon (7.6 km), representing the canyons; and Sewage Pond (7.1 km), representing the flats below the mountains. On Guadalupe Mountains NP, Williams' Ranch (12.1 km) and Dog Canyon (10.2 km) roads were surveyed.

Selected survey roads covered a large representative portion of each unit and minimized overlap of areas surveyed thus reducing likelihood of double-counting individual deer. To minimize the chance of biasing data, we excluded from consideration roads with a history or being seasonally inaccessible due to weather. Roads with moderate to high visitor use were avoided at NPS request to maximize safety and minimize interference with other unit activities.

Road surveys were conducted during mornings (started one-half hour before sunrise), evenings (starting at a time so as to be completed at sunset), and at night (starting 3 hours after sunset) on 3 consecutive days each 3-month quarter from January 1987 through March 1988 on each of the 3 NPS units. Within each unit, the 3 surveys were conducted on the same day and on the same routes to minimize variation resulting from day-to-day changes in animal location or activity patterns. Dog Canyon Road was not surveyed at night, however, because of a request by an adjoining landowner, and Sewage Pond Road was only surveyed during the second quarter when additional student help was available. Because incomplete data were available for these roads, they were not included when comparisons were made of the 3 survey methods. During the second quarter, morning (Scenic Loop, Walnut Canyon, Williams' Ranch, Dog Canyon, and Sewage Pond roads) and spotlight (on Scenic Loop, William's Ranch and Sewage Pond roads) counts were continued for up to 9 consecutive days.

The area surveyed along each route was estimated using a rangefinder to measure the distance observed on each side of the route every 0.8 km along the route. This measurement was taken only once, in the second quarter, which we deemed adequate because visibility changed little between seasons. Distance to each observed deer was not determined. Deer density (ha/deer) was estimated by multiplying the average distance observable by route length then dividing by the number of deer seen per route.

Each of the 3 survey counts was conducted using 2 or 3 people. If a third person was present, the driver did not participate. Vehicle speed was maintained below 24 km/hour. During morning and evening counts, observers scanned areas adjacent to the road with the unaided eye. Upon detecting deer, binoculars were used to identify sex and age of deer, if possible. During spotlight counts, each observer used a 200,000-candlepower spotlight and naked eye to illuminate deer and/or detect eye-shine. Upon detecting deer, observers used binoculars to identify sex and age of the deer, if possible. Movements of deer were monitored to minimize the likelihood of double counting.

Average number of deer seen per kilometer of transect driven, standard deviation, and coefficient of variation (CV) were calculated for each survey count, by quarter, and by unit for 3 days of surveys and then for each cumulative day thereafter. Because means and standard deviations differed among the 3 units, among quarters, and among techniques, we used the CV as the test parameter to compare precision. To compare the 3 survey counts, the CV of the 3 counts were ranked (lowest CV ranked 1) within each quarter and NPS unit. A Quade test (Conover 1980) was used to test differences in rankings of the 3 surveys.

To determine if precision increased or decreased when incorporating additional consecutive days of data, the CV after 4 days of sampling was compared to the CV after 3 days for each route for morning and spotlight survey counts. This process was continued to compare changes in the CV after 5 days with 3 days, and so on up to 9 days compared to 3 days of data. The direction of change in the CV was analyzed using a Sign Test (Conover 1980).

An ANOVA (MINITAB, release 12 for Windows; Minitab, Inc., State College, Pa.) was used to detect if there were significant ($P < 0.05$) differences in deer density (ha/deer) estimates between the 3 census methods for each of the 3 NPS study areas.

Once it was determined which of the 3 census methods had the greatest precision, density (ha/deer) data from the method were subjected to a power analysis using MINITAB statistical software. This analysis determined the probability of detecting differences in deer densities with increased survey effort. Power analyses were generated to represent 3 yearly sampling regimes (quarterly number we ran; monthly; and weekly surveys). These regimes were then used to compare the probability of detecting differences (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% yearly change) in deer densities for the 3 study areas.

Results

On the 10.2-km Lake Amistad National Recreation Area route, 590 deer were sighted; most sightings (324) were recorded during spotlight counts, with morning counts providing the next highest number (159) and evening counts the least (107 sightings). Estimates of deer density for the 1,607 ha surveyed were 9.6, 15.0, and 5.3 ha/deer for morning, evening, and spotlight censuses, respectively. Spotlight counts produced the highest mean deer per kilometer for each of the quarters, and had the lowest CV for 3 of the 5 quarters sampled (Table 1). Evening counts and morning counts had the lowest CVs during the third and fifth quarters, respectively.

Table 1. Mean number of deer surveyed per kilometer ($\bar{x}$ deer/km), standard deviation (SD), and coefficient of variation (CV) after 3 days of counts by period and technique on Carlsbad Caverns National Park (CACA), Amistad National Recreation Area (AMIS), and Guadalupe Mountains National Park (GUMO) from January 1987 through March 1988.

		CACA (22.7 km)			AMIS (10.2 km)			GUMO (12.1 km)		
Period	Technique	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV
Quarter 1										
	Morning	2.07	1.37	0.66	2.47	1.72	0.69	0.19	0.33	1.73
	Evening	1.46	1.55	1.06	1.67	1.61	0.96	0.55	0.54	0.98
	Spotlight	2.52	1.80	0.71	3.58	0.72	0.20	0.91	0.43	0.47
Quarter 2										
	Morning	0.73	0.44	0.60	1.19	0.87	0.73	0.47	0.24	0.51
	Evening	0.77	0.60	0.78	0.93	0.94	1.00	0.25	0.14	0.58
	Spotlight	1.14	0.42	0.37	1.27	0.62	0.49	0.61	0.17	0.28
Quarter 3										
	Morning	0.73	0.86	1.18	0.64	0.76	1.17	0.21	0.29	1.37
	Evening	0.55	0.44	0.81	0.53	0.42	0.79	0.14	0.19	1.14
	Spotlight	1.64	1.00	0.61	1.32	1.32	1.00	0.25	0.05	0.22
Quarter 4										
	Morning	1.42	0.63	0.44	0.89	0.79	0.89	0.81	0.50	0.61
	Evening	2.47	2.08	0.88	0.29	0.43	1.50	0.82	0.27	0.32
	Spotlight	2.33	0.72	0.31	3.49	1.55	0.44	1.13	0.69	0.61
Quarter 5										
	Morning	2.94	1.96	0.94	0.95	0.74	0.78	1.15	0.97	0.84
	Evening	0.91	1.05	1.15	0.46	0.51	1.10	1.11	1.15	1.04
	Spotlight	3.00	2.92	0.98	1.62	1.84	1.13	0.57	0.51	0.90

On Carlsbad Caverns NP, 2 routes (Scenic Loop and Walnut Canyon) totaling 22.7 km yielded 2,631 sightings. A greater number of sightings were recorded during spotlight counts (1,082) than during morning (919) or evening (63) counts. On the 12,628 ha surveyed, deer density estimates were 13.1, 19.5, and 9.9 ha/deer for the morning, evening, and spotlight methods, respectively. Spotlight counts produced the highest mean number of deer per kilometer for all but the fourth quarter, when the evening count was highest (Table 1). Spotlight counts had the lowest CV for 3 of the 5 quarters. During the first and fifth quarters, the CV was lowest for morning counts.

On Guadalupe Mountains NP, the 12.1-km Williams' Ranch Road yielded 323 sightings. A greater number of sightings was recorded during spotlight counts (150) than during morning (107) or evening (66) counts. On the 10,336 ha surveyed the density estimates of deer were 51.3, 67.5, and 32.5 ha/deer for morning, evening, and spotlight surveys, respectively. Spotlight counts produced the highest mean deer per kilometer for all but the fifth quarter, when the morning count was highest (Table 1). Spotlight counts produced the lowest CV in 3 of the 5 quarters. Evening and morning counts produced the lowest CVs during the forth and fifth quarters, respectively.

Using the Quade test, CV rankings for the 3 counts per quarter (Table 2) were significantly (P = 0.002) different. The spotlight count had the greatest precision (average rank 1.5), with morning counts ranking second (average rank 2.0), and evening counts last (average rank 2.5).

Cumulative CVs of morning counts (Table 3) on the 5 routes tended to be larger as additional days were added as did the CV's of spotlight counts (Table 4) on the 3 routes. Increasing the number of survey days from 3 to 4 did not significantly decrease the CV for the morning counts (P = 0.328) or the spotlight counts (P = 0.719). Comparisons between 3 days and 5 through 9 days showed similar results.

For Lake Amistad National Recreation Area, there was a significant (P = 0.041) difference in density estimates for the 3 survey methods with the spotlight having the highest estimate. The spotlight count differed from the evening count but not the morning count. A significant (P = 0.013) difference also was found for Carlsbad Cavern NP. The spotlight survey had a higher density estimate than the evening count but did not differ from the morning estimate. For Guadalupe Mountains NP,

Table 2. Ranked coefficient of variation (CV) by period, area, and technique for deer surveys on Carlsbad Caverns National Park (CACA), Guadalupe Mountains National Park (GUMO), and Amistad National Recreation Area (AMIS) from January 1997 through March 1998.

		Technique		
Period	Area	Morning	Evening	Spotlight
Quarter 1				
	CACA	1	3	2
	GUMO	2	3	1
	AMIS	3	2	1
Quarter 2				
	CACA	2	3	1
	GUMO	2	3	1
	AMIS	2	3	1
Quarter 3				
	CACA	3	2	1
	GUMO	3	1	2
	AMIS	2	3	1
Quarter 4				
	CACA	2	3	1
	GUMO	2	3	1
	AMIS	3	1	2
Quarter 5				
	CACA	1	3	2
	GUMO	1	2	3
	AMIS	1	3	2
Average		2.0	2.5	1.5

Table 3. Cumulative mean number of deer surveyed per kilometer ($\bar{x}$ deer/km), standard deviation (SD), and coefficient of variation (CV) for morning counts for up to 9 days on Carlsbad Caverns National Park (CACA) and Guadalupe Mountains National Park (GUMO) during May 1997.

	Scenic Loop (CACA)			Walnut Canyon (CACA)			Williams Ranch (CACA)			Dog Canyon (GUMO)			Sewage Pond (CACA)		
Days	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV
3	0.72	0.13	0.91	1.20	0.96	0.80	0.47	0.24	0.50	1.63	0.34	0.21	0.28	0.24	0.87
4	0.70	0.11	0.16	1.23	0.78	0.64	0.30	0.31	0.86	1.34	0.64	0.48	0.42	0.03	0.82
5	0.68	0.11	0.16	1.13	0.71	0.63	0.38	0.27	0.71	1.24	0.61	0.49	0.42	0.30	0.71
6	0.70	0.11	0.15	0.99	0.73	0.73	0.35	0.26	0.75	1.10	0.64	0.59	0.38	0.29	0.77
7	0.69	0.10	0.14	0.90	0.70	0.78	0.31	0.26	0.83	1.04	0.61	0.59			
8	0.65	0.14	0.21	0.83	0.69	0.83	0.27	0.26	0.97						
9	0.65	0.13	0.20	0.86	0.65	0.76	0.26	0.25	0.96						

Table 4. Cumulative mean number of deer per surveyed kilometer ($\bar{x}$ deer/km), standard deviation (SD), and coefficient of variation (CV) for spotlight counts for up to 9 days on Carlsbad Caverns National Park (CACA) and Guadalupe Mountains National Park (GUMO) during May 1997.

	Scenic Loop (CACA)			Seward Pond (CACA)			Williams Ranch (GUMO)		
Days	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV	$\bar{x}$ deer/km	SD	CV
3	0.70	0.36	0.52	0.90	0.57	0.63	0.61	0.17	0.28
4	1.18	1.00	0.86	0.88	0.46	0.52	0.52	0.20	0.36
5	1.24	0.88	0.71	0.77	0.52	0.71	0.60	0.22	0.36
6	1.24	0.79	0.64	0.75	0.47	0.62	0.63	0.20	0.32
7	1.24	0.72	0.58						
8	1.28	0.67	0.53						
9	1.25	0.63	0.51						

there was no significant (P = 0.264) difference between density estimates for the 3 survey methods.

Because the spotlight survey had the greatest precision and the highest density estimates, spotlight results were subjected to a power analysis to determine the effect of sample effort on the probability of detecting change in density estimates. For Lake Amistad National Recreation Area, the quarterly-spotlight census (as we ran them) only had a 65% probability of detecting a doubling in population size (Fig. 1). A monthly-spotlight census had a 95% probability to detect a population change of 80%. With weekly-spotlight censuses, a 40% change in population numbers could be detected at the 95% probability level. However, weekly-spotlight censuses had only a 17%, 52% and 86% chance of detecting population changes of 10%, 20%, and 30%, respectively.

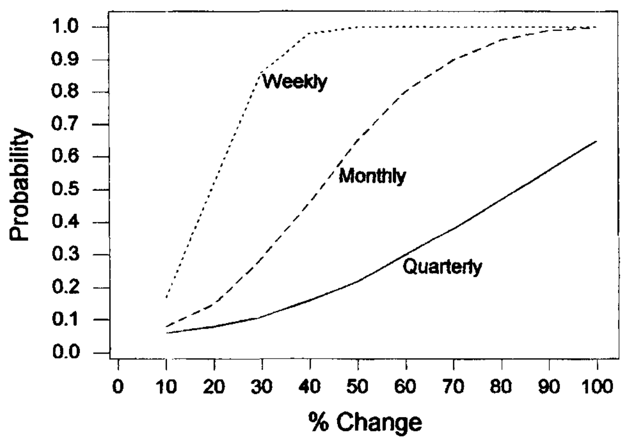

Figure 1. A power analyses estimate of the probability (0.0–1.0) of detecting change (10%–100%) in deer densities if quarterly-, monthly-, and weekly-spotlight censuses were conducted at Lake Amistad National Recreation Area.

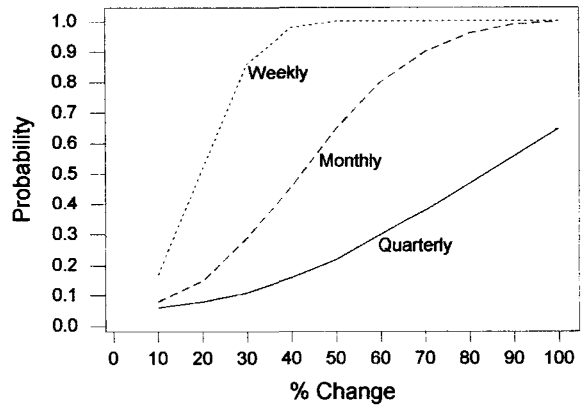

Figure 2. A power analyses estimate of the probability (0.0–1.0) of detecting change (10%–100) in deer densities if quarterly-, monthly-, and weekly-spotlight censuses were conducted at Guadalupe Mountains National Park.

For Carlsbad Caverns NP, a quarterly-spotlight census only had a 7% chance of detecting a 10% change in population numbers and a 94% chance of detecting a doubling of the population (Fig. 2). With monthly-spotlight censuses, there was a 97% chance of detecting a 50% change in the population. A >95% detection rate was observed when the population changed by 30% if weekly-spotlight censuses were conducted. Weekly spotlight censuses had a 39% chance to detect a 10% population change and a 92% chance to detect a 20% change.

At Guadalupe Mountains NP, a quarterly spotlight census had about a 5% chance of detecting a 10% change in the deer population and only a 28% chance if

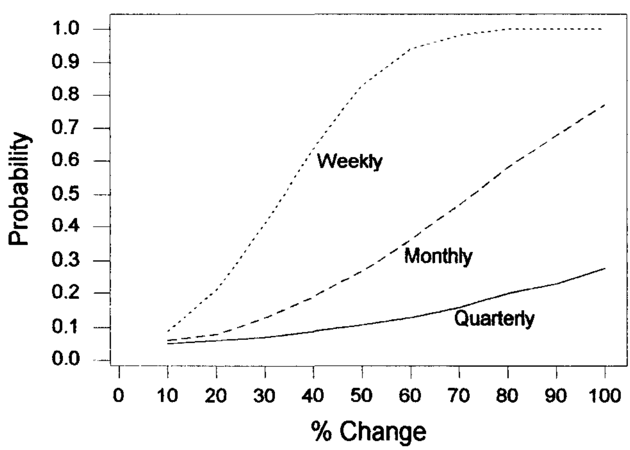

Figure 3. A power analyses estimate of the probability (0.0–1.0) of detecting change (10%–100%) in deer densities if quarterly-, monthly-, and weekly-spotlight censuses were conducted at Carlsbad Cavern National Park.

the population doubled (Fig. 3). With monthly-spotlight surveys, a doubling of the population could be detected at a 77% probability. Weekly-spotlight surveys could detect changes at the 95% probability for a 70% increase in population. Weekly-spotlight surveys had the ability to detect 10%, 20%, 30%, 40%, 50%, and 60% increases in population numbers at 9%, 21%, 41%, 64%, 82%, 94% probabilities, respectively.

Discussion

Precision of spotlight surveys was significantly greater than for other surveys with several possible explanations. First, more deer were seen during spotlight counts than on morning or evening counts, as also observed by McCullough (1993). In theory, the greater number of deer observed during a sampling effort (sample size) would result in reduced variability in the parameter, assuming there were no changes in the actual number of deer present.

A second possible reason was the greater likelihood of seeing all individuals. Deer behavior changes throughout the day and is affected by weather factors such as wind, rain, and temperature (Progulske and Duerre 1964). These behavioral changes can greatly affect detection during daylight hours because the observer during morning or evening count relies on movement or silhouettes of the animal to detect deer. If a deer were to bed down in a heavily vegetated area, an observer would have less likelihood of counting the individual. Observers conducting spotlight surveys do not rely on passive observation of deer. With spotlights, eye shine reflects through vegetation and an observer was more likely to observe deer regardless of behavior.

Incorporating additional survey days into the analyses gave mixed results. Extending the sample period should result in improved precision if the number of deer and the deer behavior in an area were similar throughout the sample period. Because deer behavior is influenced by so many environmental factors, deer behavior often changes over an extended period of time (Progulske and Duerre 1964, McCullough 1993). These changes in deer behavior over time and between areas are likely the cause of the lack of improvement in precision over time and the differences between the areas. Because deer were hunted on Lake Amistad National Recreation Area and on lands surrounding the other 2 parks, human disturbance may have contributed to changes in deer behavior and differences between the areas.

Density estimates for the spotlight survey were higher than for the other 2 methods. This would be expected as more deer were seen with this method and density is a function of number of deer seen per unit area. However, it is impossible to tell which method is most accurate without knowing the true deer density.

If deer biologists determine that some understanding of the relative abundance of deer in an area is necessary, spotlight counts are recommended because they provided the most precise information for the 3 methods we evaluated. Conducting more than 3 consecutive days of counts did not increase precision and therefore is not recommended.

Increasing the number of surveys from quarterly to weekly would improve the probability to detect population change and is highly recommended. At all 3 NPS areas, the use of weekly-spotlight surveys would have increased the probability to detect a change in population numbers (Figs. 1–3). The weekly-spotlight survey was the only survey method that could detect with 100% probability the doubling of the deer population at each of the 3 NPS areas.

However, as with all techniques that are indices of the actual population, biologists should treat the numbers produced by spotlight counts with adequate skepticism. The abundance data must be coupled with such other information as habitat condition, condition of individual animals, and the objectives of the management before making management decisions.

Literature Cited

Connolly, G. E. 1981. Assessing populations. Pages 287–345 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Neb. Press, Lincoln.

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons, Inc., New York, N.Y. 493 pp.

Glass, M. R., R. E. Reisch, and G. M. Ahlstrand. 1974. Range condition survey and wildlife browse analysis, Carlsbad Caverns and Guadalupe Mountains National Parks. Natl. Park Serv. 57 pp.

Gould, F. W. 1962. Texas plants—A checklist and ecological summary. Texas Agric. Exp. Sta., College Station. Bull. No. 591. 121 pp.

McCullough, D. R. 1982. Evaluation of night spotlighting as a deer study technique. J. Wildl. Manage. 46:963–973.

———. 1993. Variation in black-tailed deer herd composition counts. J. Wildl. Manage. 57:890–897.

Progulske, D. R. and D. C. Duerre. 1964. Factors influencing spotlighting counts for deer. J. Wildl. Manage. 28:27–34.

Rasmussen, D. I. and E. R. Doman. 1943. Census methods and their application in the management of mule deer. Trans. North Am. Wildl. Conf. 8:369–380.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co. New York, N.Y. 859 pp.

Winer, B. J., D. R. Brown, and K. M. Michels. 1991. Statistical principles in experimental design. McGraw-Hill, Inc., New York, N.Y. 1,057 pp.