California Fish and Game 104(1): 19-27; 2018

Comparison of rabbit abundance survey techniques in arid habitats

Brian L. Cypher,* Curtis D. Bjurlin, and Julia L. Nelson

California State University-Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA (BLC, CDB, JLN)

** Correspondent: bcypher@esrp.csustan.edu*

We evaluated the strengths, weaknesses, relative effort, and cost of four survey techniques for indexing black-tailed jackrabbit (*Lepus californicus)* and desert cottontail (*Sylvilagus audubonii*) abundance in arid scrub habitats in the San Joaquin Valley of California in April 2004. The four survey techniques were aerial, spotlight, track station, and visual encounters along foot transects. Rabbit abundance indices in areas with and without shrubs were 5.79/km and 0.04/km for aerial surveys, 0.5/km and 2.94/km for spotlight surveys, 1.53/km and 0.27/km for visual encounter surveys, and 52% and 40% visitation rates for track station surveys. Visual encounter, spotlight, and aerial surveys all provided species-specific counts of individuals that can be used to estimate an index of abundance (e.g., number/km) or density using distance methods. Track stations provided a visitation rate but the number of individuals and species could not always be determined. Visual encounter and aerial surveys measured diurnal habitat use, spotlight surveys measured nocturnal habitat use, and track stations measured both. For visual encounter and spotlight surveys, rabbit observability was reduced in areas with shrubs compared to areas without shrubs resulting in a habitat bias. Road availability can limit access for visual encounter, spotlight, and track station surveys but not aerial surveys. For two biologists working two 8-hour days, estimated number of sampling units and costs (labor, materials, travel) for each technique were 24 track stations ($27.05/station), 40 km of visual encounter transects ($16.36/km), 140 km of aerial transects ($16.00/km), and 100 km of spotlight transects ($6.80/km). Project objectives, study site attributes, and budgets will determine which survey technique might yield the best results and be most cost-effective for a given project.

Key words: Abundance indices, aerial surveys, arid scrub habitat, black-tailed jackrabbits, desert cottontails, spotlight surveys, track station surveys, visual encounter surveys

---

A variety of techniques have been used to measure the abundance of rabbits. These techniques include track counts (on transects or plots), fecal pellet counts (on transects or plots), visual counts (on driving routes, walking transects, or spotlight routes), and mark-recapture methods involving live-trapping, among others (Wywialowski and Stoddart 1988, Murray 2003, Mitchell and Balogh 2007). All techniques have advantages and disadvantages with regards to labor requirements, ease of application, data quality, and costs. Thus, the technique used varies among projects depending on objectives, study site attributes, and staff time or funding limitations.

We assessed the relative merits and costs of four techniques to index the abundance of black-tailed jackrabbits (*Lepus californicus*) and desert cottontails (*Sylvilagus audubonii*) in arid scrub habitat. Rabbit abundance was indexed to assess spatial and temporal patterns in prey availability for endangered San Joaquin kit foxes (*Vulpes macrotis mutica*; Nelson et al. 2007, Cypher et al. 2009). The four techniques were visual encounter surveys along walking transects, spotlight surveys, aerial transects, and track stations. We compared rabbit detection rates, labor and time requirements, and costs among techniques and also summarized biases and limitations associated with each technique and the resulting data.

Materials and Methods

Study area.—We indexed rabbit abundance in the Lokern Natural Area (LNA) located approximately 10 km west of the town of Buttonwillow in Kern County, California (Figure 1; 35° 22' N, 119° 34' W). The LNA encompassed approximately 140 km^2 and comprised a mix of public and privately owned lands. Much of the region was alluvial with flat to gently sloping terrain and elevation was approximately 100 m. The region has a Mediterranean climate characterized by hot, dry summers, and cool, wet winters with frequent fog. Mean maximum and minimum temperatures were 35°C and 18°C in summer, and 17°C and 5°C in winter. Annual precipitation averaged approximately 15 cm and occurred primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 2002).

The vegetation community was characterized as Lower Sonoran Grassland (Twisselman 1967) or Allscale Scrub Alliance (Sawyer et al. 2009). The community consisted of arid shrublands with a sometimes dense herbaceous cover dominated by non-native grasses and forbs. Desert saltbush (*Atriplex polycarpa*) and spiny saltbush (*A. spinifera*) were the dominant shrubs while cheesebush (*Ambrosia salsola*) and bladderpod (*Peritoma arborea*) also were common. Ground cover consisted primarily of annual grasses and forbs, and was dominated by red brome (*Bromus madritensis*) and red-stemmed filaree (*Erodium cicutarium*). Large portions of the area were devoid of shrubs due to repeated wildfires; saltbush is not fire-adapted and fire frequency has increased due to the non-native grasses (Sawyer et al. 2009). The LNA is within a region considered to be important habitat for the conservation of a variety of rare animal and plant species (U.S. Fish and Wildlife Service 1998).

Indices compared.—We indexed rabbit abundance using four survey methods: visual encounter, spotlight, aerial, and track station. All surveys were conducted in April 2004 to control for temporal variation in rabbit abundance. Four field biologists were used to conduct all of the surveys with a pair of biologists conducting each individual survey.

Visual encounter surveys consisted of an observer slowly walking along a 1-km transect and counting all rabbits observed. The surveys were conducted between mid-morning and mid-afternoon when rabbits typically were resting. The transects were triangular in shape (~0.33 km per side such that the observer ended back at the starting point. Starting points were randomly selected and with the restrictions that they needed to be within

1 km of a road (to facilitate access) and separated by at least 1 km. A GPS unit was used to navigate the transect and each required approximately 15-20 minutes to complete. Fifteen transects were in areas with shrubs and 15 were in areas without shrubs (Figure 1).

Spotlight surveys were conducted at night and consisted of two observers (one driving) shining spotlights from a vehicle while slowly driving along a route. All routes were along existing gravel roads and all surveys were conducted from pickup trucks. Routes were driven at approximately 10-15 km/h while two observers shined two-million candle-power spotlights out of opposite sides of the vehicle. When an animal or eye-shine was observed, the vehicle was stopped and binoculars were used to determine whether the animal was a rabbit. Spotlight routes totaled approximately 29.6 km with 11.7 km in areas with shrubs and 17.9 km being in areas without shrubs (Figure 1).

Aerial surveys were conducted during the day from a 4-seat Bell Ranger helicopter with one observer in the front passenger seat and one observer on the opposite side in a back seat. The helicopter was flown at approximately 35 km/h at altitudes of 50-100 m above the ground along transects and flushed rabbits were counted. Eleven transects were flown with 22.8 km in areas with shrubs and 16.0 km in areas without shrubs (Figure 1). Transects varied in length were subjectively chosen to traverse large blocks of habitat.

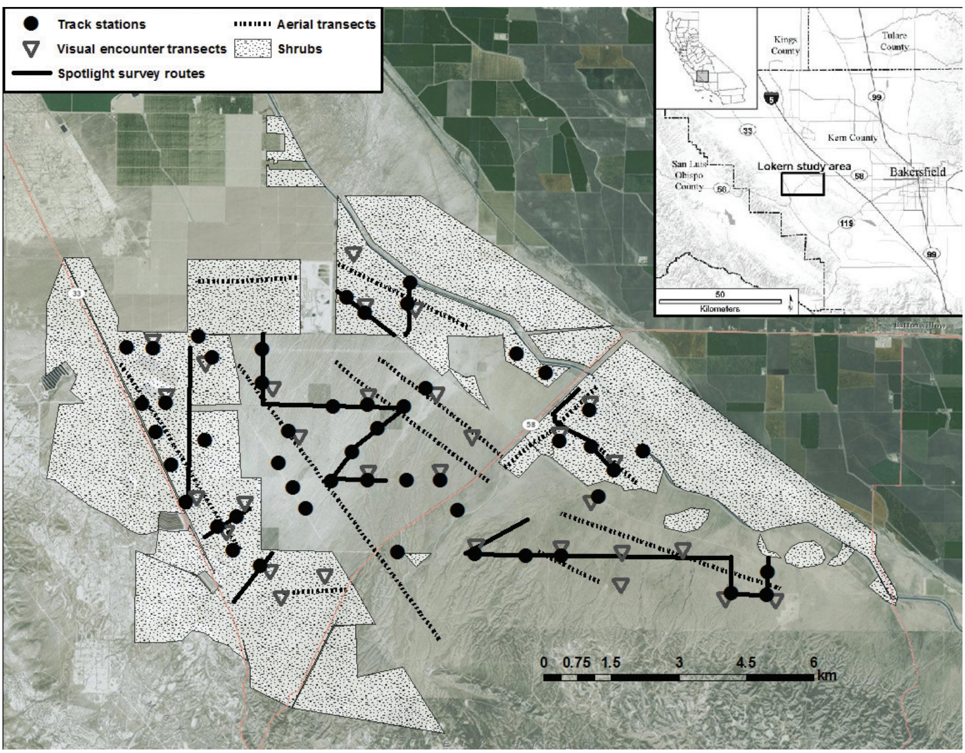

FIGURE 1.—Locations of aerial transects, visual encounter transects, spotlight transects, and track stations for rabbit surveys conducted in April 2004 on the Lokern Natural Area, Kern County, California.

We established track stations throughout the study area and individual stations were separated by a minimum of 0.5 km (Figure 1). This spacing was based on the diameter (~0.2 km^2) of typical home range sizes for black-tailed jackrabbits (Lechleitner 1958, French et al. 1965) and was used to reduce the likelihood that individual rabbits visited multiple stations in one night. Of 50 stations created, 25 were in areas with shrubs and 25 were in areas without shrubs. The stations were located on the edge of the road to avoid disturbance by vehicles. Each station was created by removing vegetation, rocks, and debris from an approximate 1-m^2 area. Dry, powdery dirt collected from the study site was sifted over the area to create a smooth layer at least 0.5 cm thick. A handful of commercial alfalfa pellets was placed in the center of each station along with a 2.5-cm^2 plaster of Paris square infused with carrot oil (J.R. and Sons, Monroeville, Ohio, USA). The stations were created one day and then checked the next day. Visits by rabbits were determined by identifying tracks recorded in the soft dirt of the stations. Generally, we could not identify tracks to species. Also, the actual number of rabbits that visited a station could not be determined from the tracks, and therefore the station was recorded as "visited" if any rabbit tracks were present.

We determined the number of rabbits detected for each technique in areas with and without shrubs. For visual encounter, spotlight, and aerial surveys, we used a 2-way analysis-of-variance to compare mean number of rabbits among techniques and between habitats, and to examine interactions between these two factors. Fisher's least-significant-difference test was used to conduct pair-wise comparisons among technique x habitat combinations. We also used contingency table analysis with a chi-square statistic and a Yate's correction-for-continuity (Zar 1984) to compare proportions of track stations visited by rabbits between habitats. P-values < 0.05 were considered significant.

To compare productivity and costs between techniques, we estimated the number of sampling units (e.g., kilometer of transect, track station) that could be comfortably completed by two field biologists working two 8-hour days. We used two days as a standard because that is the minimum number of days required to conduct a track station survey because the stations need to be created one day and then checked the next day. For comparison purposes, we estimated the cost for completing all work using standardized rates of $20/h for labor and $0.40/km for vehicle use, and also added any other costs associated with employing each technique.

Results

Among visual encounter, spotlight, and aerial surveys, the mean number of rabbits/km was highest for aerial surveys conducted in areas with shrubs and the lowest was for aerial surveys conducted in areas without shrubs (Table 1). The difference in mean rabbits/km among techniques approached significance ($F_{2,47}$=3.141, P=0.052) and was higher in areas with shrubs compared to areas without shrubs ($F_{1,47}$=4.766, P=0.034). Interactions between technique and habitat were significant ($F_{2,47}$=9.068, $P \leq 0.001$). In areas with shrubs, mean rabbits/km was highest for aerial surveys and lowest for spotlight surveys (Table 1). However, in areas without shrubs, mean rabbits/km was highest for spotlight surveys and lowest for aerial surveys. The proportions of track stations visited (Table 1) were similar between stations in areas with and without shrubs (χ_1^2=0.725, P=0.395).

Among the survey techniques, aerial surveys were the most expensive ($2,240) due to the cost of chartering a helicopter and pilot (Table 2). The total cost for two days of surveys for the other three techniques was comparable ($654.40-$689.20). Track station surveys were the most expensive technique per sampling unit while spotlight surveys were the least expensive (Table 2).

Table 1.—Results for four survey techniques used to index rabbit abundance in the Lokern Natural Area, California during April 2004.

	Survey techniques							
	Visual encounter (rabbits/km)		Spotlight (rabbits/km)		Aerial (rabbits/km)		Track station (visitation rate)	
	Mean ± SE	*Range*	*Mean ± SE*	*Range*	*Mean ± SE*	*Range*	*Visited*	*Rate*
Shrubs present	1.53±0.69	0-10	0.50±0.37	0-2.7	5.79±1.80	2.2-12.9	13	0.52
Shrubs absent	0.27±0.21	0-3	2.94±1.14	0-6.67	0.04±0.04	0-0.19	10	0.40
Sample units	15 1-km transects with shrubs = 15 km		6 transects (1.2-3.5 km) with shrubs = 11.7 km		6 transects (1.5-4.9 km) with shrubs = 22.8 km		25 stations with shrubs	
	15 1-km transects without shrubs = 15 km		6 transects (2.4-4.5 km) without shrubs = 17.9 km		5 transects (1.6-7.7 km) without shrubs = 16.0 km		25 stations without shrubs	

Table 2.—Comparison of costs for four survey techniques used to index rabbit abundance in the Lokern Natural Area, California during April 2004. The number of sampling units and costs are based on two 8-hour days by two biologists.

	Survey technique			
Survey parameter	**Visual encounter**	**Spotlight**	**Aerial**	**Track station**
Sampling units	40 1-km transects	100 km of routes	140 km of transects	24 track stations
Labor	32 h	32 h	32 h	32 h
Labor costs ($20/h)	$640	$640	$640	$640
Driving distance[a]	36 km	100 km	0 km	23 km
Driving cost ($0.40/km)	$14.40	$40.00	$0	$9.20
Other costs	$0	$0[b]	Helicopter charter: 2 h x 2 d @$400/h = $1,600	Alfalfa pellets: $10
				Carrot oil lure: $30
Total costs	$654.40	$680.00	$2,240.00	$689.20
Cost per sample unit	$16.36/km	$6.80/km	$16.00/km	$28.72/station

[a] Only includes travel while conducting the work; does not include travel to and from the study site.

[b] Assumes that all spotlighting equipment was already available and did not need to be purchased.

Discussion

All of the survey techniques we employed were successful at detecting a sufficient number of rabbits to produce a useful index of abundance. Visual encounter, spotlight, and aerial surveys provided a count of individuals. In track station surveys, it usually was not possible to determine whether a single or multiple rabbits visited a station, and therefore the counts derived are a minimum number. Each technique has further advantages and disadvantages, which we summarize below. The importance of these depends upon study site attributes, project objectives, available funding, and staff and time constraints.

Data biases.—Habitat conditions may reduce the efficacy of some survey techniques and produce inherent biases in the data. In particular, shrubs can substantially reduce visibility. This was particularly evident for spotlight surveys, which was the only technique where indices were lower for areas with shrubs. Rabbits generally are more abundant in areas with shrubs, which provide cover from predators and thermal cover (Brown and Krausman 2003, Flinders and Chapman 2003), and this was reflected in the indices for the other techniques. However, visibility also likely was reduced in shrub areas during visual encounter and aerial surveys. In aerial surveys, the vantage point of observers above the shrubs and the tendency for rabbits to flush from cover due to the noise of the helicopter probably helped to largely overcome visibility issues. In shrub habitats in Utah, higher jackrabbit density estimates from surveys conducted on horseback compared to surveys on foot were attributed to the elevated position of the observer (Wywialowski and Stoddart 1988). Rugged or undulating terrain also can cause a reduction in visibility. This was not a significant factor on our study site as the terrain was mostly flat except for occasional dry washes. Track stations were the one technique in which visibility was not a factor.

Related to visibility, visual encounter, spotlight, and aerial surveys allow for species identification in areas where multiple species occur and in situations where such data are relevant. Although we did not report species numbers, we were easily able to distinguish between black-tailed jackrabbits and desert cottontails during visual encounter and aerial surveys. Species identification was sometimes difficult during spotlight surveys when animals were on the edge of the range of illumination. For track stations, species identification is possible from tracks, mostly based on size differences, but requires good quality tracks.

Another inherent bias on our study site resulted from the diel timing for each technique. Black-tailed jackrabbits and desert cottontails are primarily nocturnal (Fitch 1947, Lechleitner 1958, Flinders and Hansen 1973, Costa et al. 1976). Consequently, visual encounter and aerial surveys primarily reflect diurnal habitat use when rabbits may largely be in resting cover. Spotlight surveys primarily reflect nocturnal habitat use when rabbits are usually foraging and more active. In heterogeneous landscapes such as the LNA, these techniques would produce biased habitat-specific indices because rabbits tended to be in shrub areas during the day and then were observed venturing out into areas without shrubs at night. Track stations avoid this bias as long as they are operated for 24 hours. If the objective is to produce a site-wide index of abundance and habitat-specific indices are not needed, then a diel-associated bias is avoided as long as habitat types are surveyed in proportion to their representation on the study site. This bias would not be a factor in more homogeneous landscapes.

One final bias is that false-negatives could occur in track station surveys because they require that rabbits come to a specific, relatively small location and leave evidence. Also, a visit to a station may not be recorded if track quality is poor or tracks are misidentified. Additionally, high visitation by rabbits or other species, especially by rodents, can obliterate tracks and result in rabbit visits being missed.

Data analyses.—Data from some of the techniques lend themselves well to more in-depth analyses. For visual encounter, spotlight, and aerial transects, the effective width of the area being surveyed can be determined by measuring the distance from the transect to each rabbit observed (we did not do this in our study). This information can then be analyzed using distance techniques to calculate a density estimate (Smith and Nydegger 1985, Harris 1986, Wywialowski and Stoddart 1988), which can then be extrapolated to the entire study site to produce a total population estimate. Determining belt width and calculating densities also standardizes the abundance estimates facilitating comparisons between habitats and study sites. Because of their higher vantage point, aerial surveys likely survey the widest belt. Density and population estimates cannot be derived from track station surveys because the effective area sampled is unknown. Also, as mentioned previously, it may not be possible to determine when multiple rabbits are visiting a station.

Effort and costs.—Track station surveys required the most time to complete. Two days are required to obtain data because stations are created one day and then checked the next. Other logistical challenges for track stations are that sudden changes in weather, such as rain or strong winds, can obfuscate tracks before data are collected. For all of the techniques except aerial surveys, decent road access throughout the study area is required to adequately sample rabbit abundance.

Per sampling unit, spotlight surveys were the least expensive technique and might be the favored option on projects with small budgets. Aerial surveys probably sampled the greatest area per unit time due to the distance covered.

Risks.—Regarding risks, visual encounter, spotlight, and track station surveys all involve operating vehicles to travel around the study site. On our study site, the roads were unpaved and unmaintained, and therefore travel speeds were low, as was the risk. Aerial surveys involve inherent risks associated with flying, but the risk was considered low due to a relative lack of obstacles and slow flying speeds and low altitude. Rattlesnakes (*Crotalus oreganus*) were observed during both visual encounter and track station surveys. Finally, valley fever (also known as coccidioidomycosis) can be a significant concern depending upon the study site location and whether soil from the study site is used as the tracking medium. Our study site was in an area where spores from the *Coccidioides* fungus are extremely prevalent in the soils and valley fever is considered to be "highly endemic" (Center for Disease Control and Prevention, http://www.cdc.gov/fungal/diseases/coccidioidomycosis/causes.html). This risk can be reduced through use of protective equipment (e.g., dust masks) or by using another tracking medium (e.g., diatomaceous earth, fire clay).

Other techniques.—Other common techniques used to index rabbit abundance include pellet counts and live-trapping (Murray 2003, Mitchell and Balogh 2007). Pellet counts can be conducted on plots or in belt transects. Counts involving plots might incur labor costs similar to track station surveys, particularly if the plots are visited initially to clear existing pellets. Counts involving belt transects might incur costs similar to our visual encounter surveys. Particularly in arid environments, challenges can include distinguishing between recently deposited versus old pellets if sampling units are not cleared first. Pellet persistence can vary among habitats and microsites (Iborra and Lumaret 1997). Also, pellet deposition rates likely vary with diet, and this could complicate comparisons between habitat types or seasons (Murray 2003). Finally, pellet counts may not be useful if counts of individuals or species identification are important. Live-trapping entails setting traps and checking the next day. Obtaining a sufficient sample size to make valid temporal or spatial comparisons could require a number of days of trapping, depending on the number of traps deployed and capture rates. Initial costs for trapping and handling equipment could be high. Also, trapping methods could be restricted in areas such as our study site where listed species are present. Finally, handling animals requires a level of expertise, and live-trapping always involves some risk to the animals.

In summary, the choice of survey technique will depend upon project objectives, available funding, study site attributes (e.g., habitat types, road access), and time and staff constraints. In relatively sparsely vegetated arid habitats such as our study site, we recommend the use of aerial surveys (assuming the availability of sufficient funding) to index rabbit abundance because large quantities of data can be collected in just one day, and these suffer fewer of the biases that affect the other techniques. For more limited budgets, automated field cameras are being used increasingly to survey for a variety of species and may constitute an effective strategy for surveying for rabbits with the development of an appropriate methodology.

Acknowledgments

Funding for this project was provided by the California Department of Transportation, and the U.S. Fish and Wildlife Service. We thank A. Brown for field assistance and T. Westall for graphics assistance. We thank D. Houghton of San Joaquin Helicopter, Delano, California for piloting services. We thank E. Tennant, R. Burton, and an anonymous reviewer for many helpful suggestions to improve the manuscript.

Literature Cited

Brown, C. F., and P. R. Krausman. 2003. Habitat characteristics of 3 leporid species in southeastern Arizona. Journal of Wildlife Management 67:83-89.

Costa, W. R., K. A. Nagy, and V. H. Shoemaker. 1976. Observations of the behavior of jackrabbits (*Lepus californicus*) in the Mojave Desert. Journal of Mammalogy 57:399-402.

Cypher, B. L., C. D. Bjurlin, and J. L. Nelson. 2009. Effects of roads on endangered San Joaquin kit foxes. Journal of Wildlife Management 73:885-893.

Fitch, H. S. 1947. Ecology of a cottontail rabbit (*Sylvilagus audubonii*) population in central California. California Fish and Game 33:159-184.

Flinders, J. T., and J. A. Chapman. 2003. *Lepus californicus* and allies. Pages 126-146 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Flinders, J. T., and R. M. Hansen. 1973. Abundance and dispersion of leporids within a shortgrass ecosystem. Journal of Mammalogy 54:287-291.

French, N. R., R. McBride, and J. Detmer. 1965. Fertility and population density of the black-tailed jackrabbit. Journal of Wildlife Management 29:14-26.

Harris, C. E. 1986. Comparison of line transects and road surveys to monitor lagomorph populations on Naval Petroleum Reserve #1. U.S. Department of Energy Report EGG 10282-2098, National Technical Information Service, Springfield, Virginia USA.

Iborra, O., and J. P. Lumaret. 1997. Validity limits of the pellet group counts in wild rabbit (*Oryctolagus cuniculus*). Mammalia 61:205-218.

Lechleitner, R. R. 1958. Movements, density, and mortality in a black-tailed jackrabbit population. Journal of Wildlife Management 22:371-384.

Mitchell, B., and S. Balogh. 2007. Monitoring techniques for vertebrate pests – rabbits. New South Wales Department of Primary Industries, Bureau of Rural Sciences, Canberra, Australia.

Murray, D. L. 2003. Snowshoe hare and other hares (*Lepus americanus* and allies). Pages 147-175 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. The Johns Hopkins University Press, Baltimore, Maryland, USA.

National Oceanic and Atmospheric Administration. 2002. Local climatological data, Bakersfield, California. National Climatological Data Center, Ashville, North Carolina, USA.

Nelson, J. L., B. L. Cypher, C. D. Bjurlin, and S. Creel. 2007. Effects of habitat on competition between kit foxes and coyotes. Journal of Wildlife Management 71:1467-1475.

Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. A manual of California vegetation. Second edition. California Native Plant Society, Sacramento, California, USA.

Smith, G. W., and N. C. Nydegger. 1985. A spotlight, line-transect method for surveying jackrabbits. Journal of Wildlife Management 49:699-702.

Twisselmann, E. C. 1967. A flora of Kern County, California. Wasmann Journal of Biology 25:1-395.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

Wywialowski, A. P., and L. C. Stoddart. 1988. Estimation of jack rabbit density: methodology makes a difference. Journal of Wildlife Management 52:57-59.

Zar, J. H. 1984. Biostatistical analysis. Second edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Submitted 01 January 2018
Accepted 14 March 2018
Associate Editor was S. Osborn