A MOUNTING TECHNIQUE FOR TRAILMASTER CAMERA SYSTEMS TO MONITOR DEER

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ABSTRACT: Since 1994, we have used Trailmaster™ Model TM1500 camera systems to monitor mule deer (*Odocoileus hemionus*) populations and habitat use in the central Sierra Nevada. Factory-provided mounts, 1-m tall wooden stakes, and an infrared pulse length of 0.25 sec (5 pulses) were used with the systems during the winters of 1994-95 and 1995-96. We used three plywood boxes, 1.5-m tall steel t-posts, and an infrared pulse length of 0.75 sec (15 pulses) during the winters of 1996-97 and 1997-98. Different mounts and pulse settings were used from 1996-1998 to minimize problems we encountered with factory mounts, stakes, and shorter pulse from 1994-1996. The number of pictures with deer increased ($P < 0.001$), while the number of pictures without deer decreased ($P < 0.001$) with the boxes, t-posts, and longer pulse used in 1996-98. The boxes and t-posts protected the units from inclement weather, and provided a stable platform for the transmitter and receiver. Lengthening the pulse made the units less sensitive to rain, snow, and fog and leaves, twigs, and vegetation blowing in the wind that might break the infrared beam and trigger the camera to take photographs of non-animal events.

Key words: mule deer; *Odocoileus hemionus*; cameras; remotely triggered cameras; monitoring; wildlife photography.

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Within the last few years, Trailmaster camera systems have become widely used in wildlife investigations (Kucera and Barrett 1993, Franzreb and Hanula 1995, Hernandez et al. 1997*a*, Jones et al. 1997), and the use of these and other remotely triggered camera units (Jacobson et al. 1997) is increasing. These studies have generally reported successful use of the camera systems, but problems occur due to vegetation, unstable mounting, animal interference, and inclement weather (Rice 1995, Hernandez et al. 1997*b*). Kucera and Barrett (1995) discussed some of the possible reasons for the problems reported by Rice (1995) and how these problems might be avoided or minimized, while Hernandez et al. (1997*b*) discussed how they modified camera setups to rectify some problems.

We have used Trailmaster Model TM1500 camera systems since November 1994 to monitor mule deer populations and habitat use in the central Sierra Nevada. While the camera systems initially performed relatively well, we had many of the same problems reported by Rice (1995) and Hernandez et al. (1997*b*), particularly with inclement weather, non-animal objects, and unstable mounts during 1994-96. Because of the weather resistance, data gathering, and photographic abilities of Trailmaster systems, we needed to improve performance so that we could continue monitoring deer using this system. Therefore, we designed and constructed numerous modifications to the housing and mounting of the camera system and adjusted the pulse, and this paper describes how these modifications and adjustments improved Trailmaster system performance.

STUDY AREA

We conducted this study on four 20.3-ha study stands in southern Placer County, California. Elevations ranged from 1240-1450 m, and the stands were located on the plateaus and upper portions of steep river canyons which characterized the study area. Study stands were located in larger size, homogeneous forest stands with a tree layer dominated by large diameter (>40 cm diameter breast height) California black oak (*Quercus kelloggii*) and ponderosa pine (*Pinus ponderosa*). Other tree species included interior live oak (*Q. wislizenii*), Douglas-fir (*Psuedotsuga menziesii*), white fir (*Abies concolor*), sugar pine (*P. lambertiana*), and incense cedar (*Calocedrus decurrens*). Seedling and sapling California black oak and ponderosa pine dominated the subcanopy at one stand, while the other stands had little subcanopy. The shrub layer was generally sparse, and deerbrush (*Ceanothus integerrimus*) and manzanita (*Arctostaphylos* spp.) were the most common shrubs. The herbaceous layer was dominated by a sparse to dense cover of mountain misery (*Chamaebatia foliolosa*).

METHODS

Camera System Field Arrangement

The four stands each contained two adjacent 10.1-ha subplots. Two camera systems each were placed in the 10.1-ha subplots, so four camera systems each were placed in the 20.3-ha stands. Camera locations were selected at random from a subset of 31-32 25-m^2 plots where deer pellet groups counted in 1994 exceeded the median number (range 400-1200 pellets/ha, n = 60-62 plots/stand) of pellet groups for the stand. Thus, the camera systems were located in places where deer use was relatively great compared to other locations in the stand. The camera, transmitter, and receiver were located in open areas in the plot where trees and shrubs would not interfere with the system. Camera locations remained the same during the study period.

The Trailmaster Model TM1500 (Goodson and Associates, Incorporated, Lenexa, Kansas 66215) consists of an active infrared transmitter and receiver, and a weather-resistant automatic 35-mm camera (Trailmaster Model TM35-1). The camera is triggered when an infrared beam is broken. When the beam is broken, a photograph is taken and the receiver's event counter records the event's date and time. The operation of the Trailmaster Model TM1500 is discussed by Kucera and Barrett (1993) and Hernandez (1997*b*). We placed the systems in the field in early November and removed them in mid-May, a 6-month period when the stands received the greatest use by wintering deer. We checked the units every 1-4 wks depending on weather and road access. The datum of interest was the photograph taken during the event triggered when a deer crossed the beam, and photographs with and without deer were recorded as such. Photographs without deer included: (1) pictures of habitat without deer; (2) camera malfunctions when no picture was taken; (3) flash malfunctions when a dark picture was taken; and (4) pictures of heavy snow, rain, or fog where deer could not be seen.

1994-96 Camera System Mounting

We used the mounting components provided by the factory during the winters of 1994-95 and 1995-96. The camera was mounted in a metal bracket on a plastic tripod using a plastic ball-and-head screw. The tripod was mounted to the top of a 1-m tall wooden surveyor's stake using the tripod's velcro straps and reenforced with duct tape. On the same stake below the camera, the receiver was mounted approximately 45-50 cm above the ground using the straps attached to the receiver bracket. On a second 1-m tall wooden surveyor's stake 10-m away, the transmitter was mounted approximately the same height above the ground such that the infrared beam was properly aligned using the unit's sight lines. The 10-m distance between transmitter and receiver was used because of the uneven ground, ground-level vegetation, and the need for space large enough to allow deer to move unimpeded between the two stakes yet keep the distance narrow enough to minimize false events (see Hernandez et al. 1997*b*). The 45-50-cm height above ground for the transmitter and receiver was used to maximize the likelihood that deer would break the beam, while reducing the likelihood that smaller, non-target animals would. The stakes were hammered into the ground approximately 15-20 cm deep depending on ground hardness. The transmitter was also attached using the straps that were part of the transmitter's metal bracket. At one site, the camera and receiver were mounted to a 25-cm diameter California black oak using duct tape. The camera systems were placed on relatively flat ground that had few shrubs, seedlings, and saplings to interfere with the beam. Some cutting of grasses, shrubs, seedlings, and saplings was done to remove interfering vegetation. Open areas were used to place the camera systems because we needed clear areas to take photographs of deer, and vegetation might interfere with the beam.

The camera was programmed to take pictures anytime during a 24-hr period when the infrared beam was broken, and the pulse was set to 0.25 sec (5 pulses of beam). The camera delay (time interval between interrupted pulse and camera taking picture) was set at 0.1 min (6 seconds). The cable connecting the receiver to the camera was bundled and attached to the stake using duct tape.

1996-98 Camera System Mounting

Beginning in November 1996, we designed and used a new mounting technique because of the large number of photographs taken without deer and several problems encountered with the factory mounts. The camera was mounted in a plywood box to protect it from inclement weather and stabilize it (Table 1, Figure 1). The camera box was mounted to a 1.5-m tall steel t-post approximately 1 m above the ground using a single U-bolt (Figures 1 and 2).

The receiver was mounted in a plywood box, and the box was mounted using two U-bolts to a second t-post approximately 1 m from the camera (Table 1, Figures 1 and 2). The box was open for the receiver's face so that the event display could be read and the settings adjusted. The box extended approximately 7-10 cm from the front of the receiver to shield the beam from inclement weather. The unit's beam sensitivity was increased to 0.75 sec (15 pulses) to reduce the likelihood that non-animal events would trigger an event. The camera delay was set to 0.1 min, and the camera was set to take photographs over a 24-hr period.

The cable from the camera to the receiver ran down the camera's t-post and underground to the receiver's t-post through PVC pipe (Table 1, Figures 1 and 2). The PVC pipe was cut into sections and taped to the two t-posts using duct tape. A hole was drilled into the bottom of the box so the cable could be connected to the receiver through the PVC pipe. The cable ran through another section of PVC pipe that was joined to the PVC pipe on the t-post and run underground to prevent animal and weather damage. The PVC pipe was 1.3 cm in diameter for the underground, camera t-post, and lower half of the receiver t-post sections. The PVC pipe for the upper half of the receiver t-post section was 2.5 cm in diameter to accommodate surplus camera cable. The receiver was mounted to the t-post such that the beam was 45-50 cm above the ground.

The transmitter was mounted in a plywood box and placed on a third t-post 10-m away from the receiver's t-post (Figure 2). The box was open in the front, and the top, bottom, and sides extended beyond the receiver's face 3-5 cm to shield the beam (Table 1, Figure 1). The transmitter was mounted at a height of 45-50 cm so that the beam was aligned with the receiver using the unit's sight lines.

T-posts were hammered to depths of 15-25 cm depending on ground hardness. The sides and bottoms of the plywood boxes were connected using either nails or wood screws. The boxes were painted in a black-green-brown camouflage pattern, but the t-posts were not painted to hide their forest green and white paint.

Statistical Analysis

Photographs with and without deer were totaled for

Table 1. Material list corresponding to numbered parts shown in Figure 1.

Part No.	Description
1	Camera box top, 1.6-cm thick plywood, 23 cm x 13 cm
2	Camera box bottom, 1.6-cm thick plywood, 23 cm x 6 cm
3	Camera box side, 1.6-cm thick plywood, 15 cm x 10 cm
4	Camera box back, 3.8-cm thick wood, 11 cm x 7.5 cm, 1-cm x 1-cm groove cut lengthwise (11 cm face) down middle of back; back has a single U-bolt, 4.7-cm wide opening (inside width), bolt 0.5-cm thick, through hole drilled 2 cm below top of Part No. 3; used to mount unit to t-post
5	3-cm long, 0.5-cm thick nut with washer on outside and nut on inside of Part No. 2; through hole drilled 2.5 cm from front and 8 cm from end where Part No. 2 attached to Part No. 3
6	Receiver top and bottom, 1.6-cm thick plywood, 18 cm x 11-cm
7	Receiver sides, 1.6-cm plywood, 28 cm x 10 cm, mounted at last 10 cm of Part No. 6
8	Receiver back, 3.8-cm thick wood, 25 cm x 8.5 cm, 1-cm x 1-cm groove cut lengthwise (25 cm face) down middle of back
9	Two U-bolts same size as Part No. 4, but through holes drilled 1.5 cm below top and 1.5 cm above bottom of Part No. 8; used to mount unit to t-post
10	Four 1-cm long, 3 mm-wide wood screws with Phillips head to mount receiver bracket to Part No. 8; same size screws used to mount Transmitter to Part No. 14
11	Two wood screws per piece, 3-cm long x 3-mm wide to attach top, sides, and bottom pieces together
12	Transmitter top and bottom, 1.6-cm thick plywood, 12 cm x 12 cm
13	Transmitter sides, 1.6-cm thick plywood, 23 cm x 8.5 cm, mounted at last 8.5 cm of Part No. 12
14	Transmitter back, 3.8-cm thick wood, 20 cm x 7.5 cm, 1-cm x 1-cm groove cut lengthwise (20 cm face) down middle of back
15	Two U-bolts same size as Part No. 4 but holes drilled 1.5 cm below top and 1.5 cm above bottom of Part No. 14; used to mount unit to t-post
16	T-post, 1.5-m tall

each roll of film taken from each camera each winter. Square-root transformations were used because data had Poisson distributions and variances were proportional to means (Zar 1996) (Figure 3). Analysis of variance was used with Bonferroni pairwise comparisons to test for significant differences among years for the number

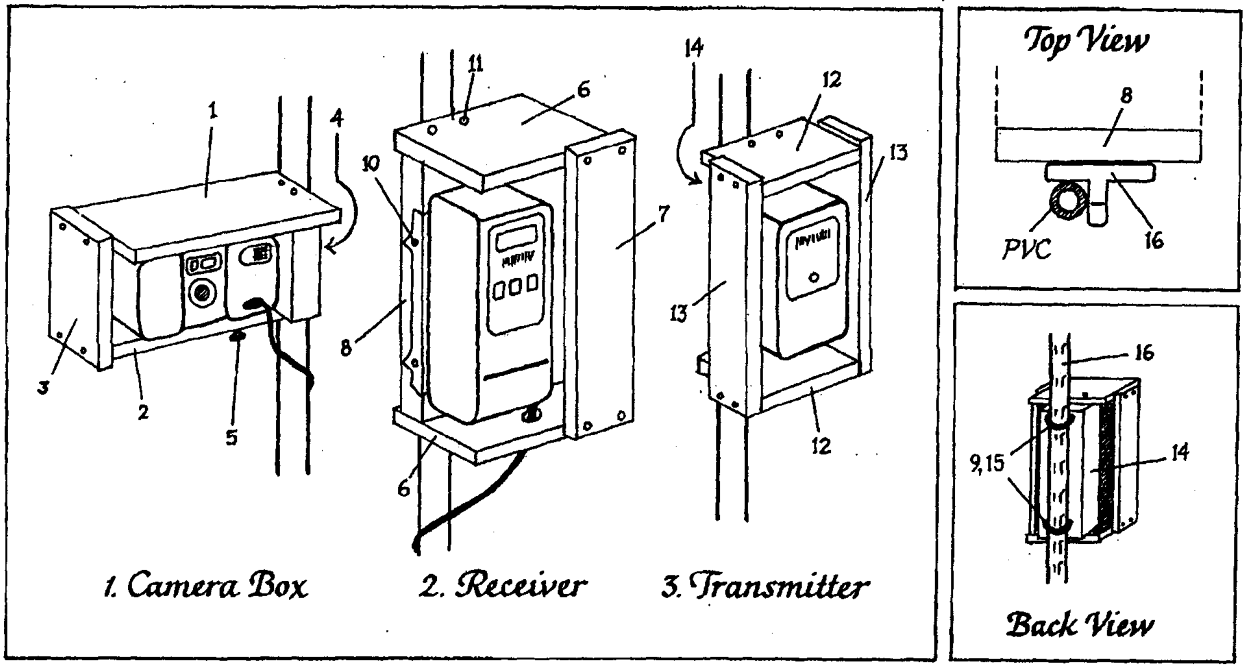

Figure 1. Schematic diagram of the Trailmaster Model TM1500 camera system wooden boxes.

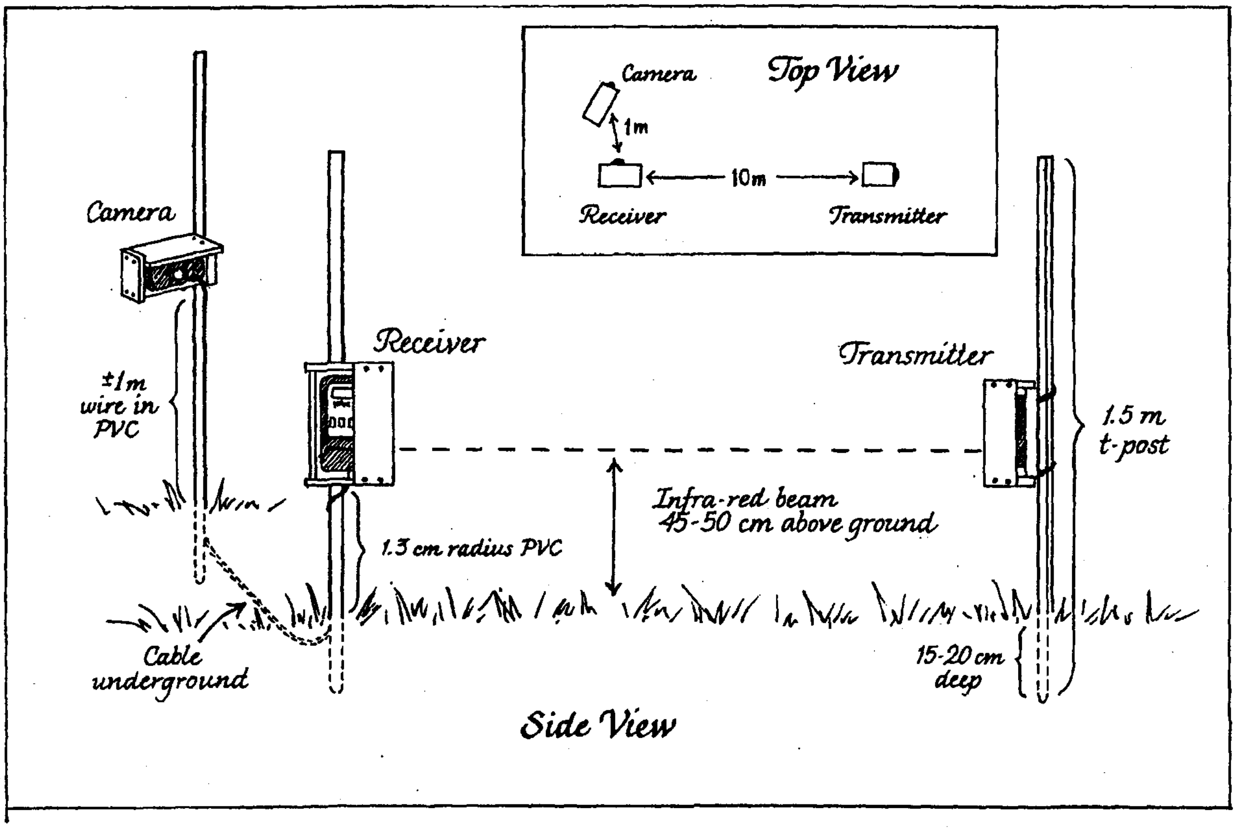

Figure 2. Schematic diagram of the field arrangement of the Trailmaster Model TM1500 camera system.

of pictures with and without deer (SPSS Incorporated 1998). One-tailed P-values were used to determine direction of differences between the data.

RESULTS

The number of pictures with deer increased, while the number of pictures without deer decreased with the new mounts and lengthened pulses (Table 2). The number of pictures with and without deer were equivalent between the two years (Bonferroni comparisons, $P < 0.122$) with the factory-provided mounts and shorter pulse (1994-95 and 1995-96) and the two years (Bonferroni comparisons, $P = 1.000$) with the mounting boxes and longer pulse (1996-97 and 1997-98) (Table 2). In addition, during 1996-98 there was a greater frequency of rolls with fewer pictures (≤ 5 pictures) without deer ($X^2 = 50.94$, $df = 8$, $P = 0.000$) and a greater frequency of rolls with greater numbers of pictures (> 5 pictures) with deer ($X^2 = 39.75$, df = 6, $P = 0.000$) (Figure 3).

DISCUSSION

The plywood boxes, t-posts, and longer pulses used during 1996-98 clearly improved the performance of the Trailmaster Model TM-1500 cameras in monitoring wintering mule deer in the central Sierra Nevada. Improvement occurred by increasing the number of photographs with deer by 1.6-3.7 times and decreasing the number of photographs without deer by 1.7-2.3 times between 1994-96 and 1996-98. These improvements greatly increased the data gathering ability of the Trailmaster units during winter at mid-elevations in the central Sierra Nevada. Over the 4-yr study period, the camera systems were in the same locations and the

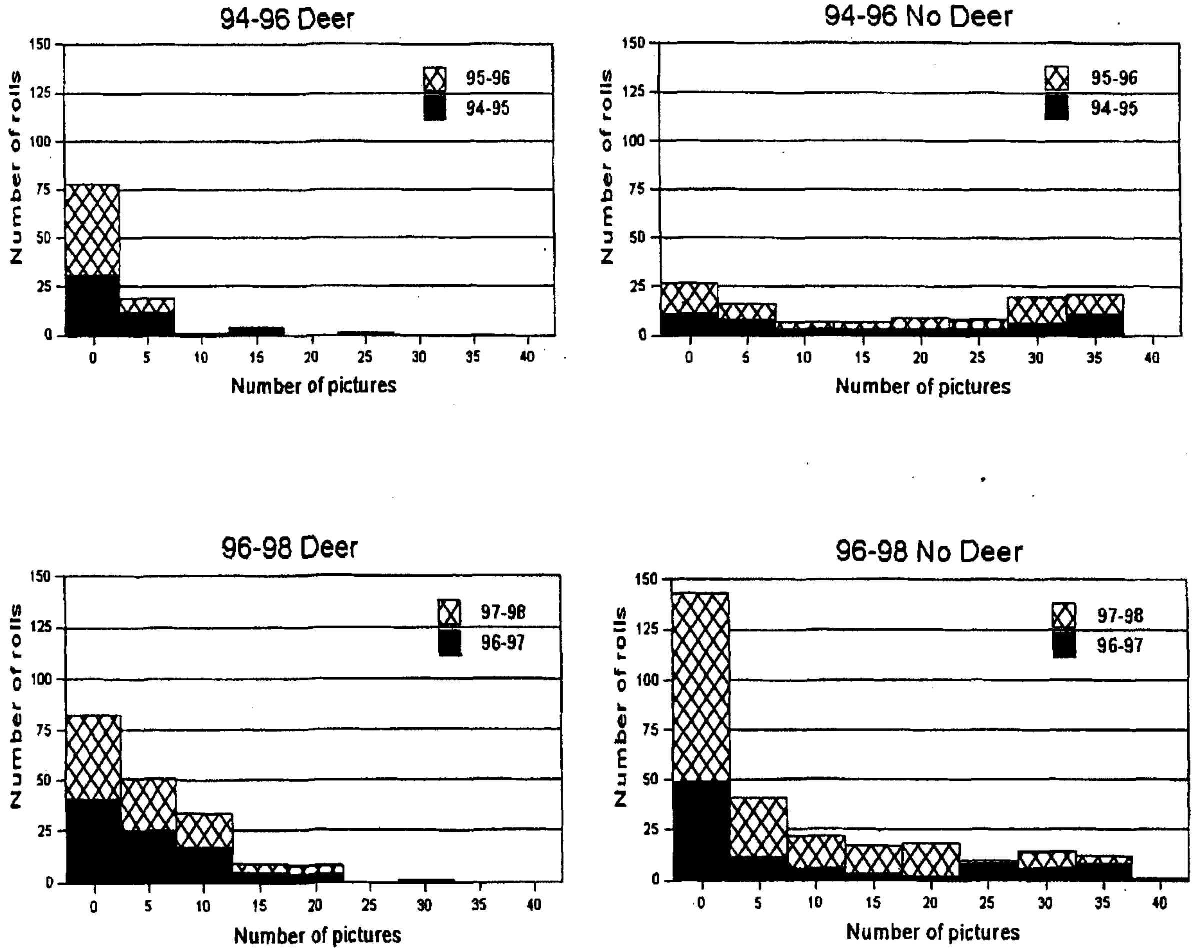

Figure 3. Frequency histogram of the number of pictures with and without deer taken using Trailmaster Model TM-1500 camera systems. Photographs were taken in 1994-95 and 1995-96 using factory mounts, wooden stakes, and 5 pulses, while photographs were taken in 1996-97 and 1997-98 using wooden boxes, steel t-posts, and 15 pulses.

number of extreme weather events (defined as 24-hr periods with ≥5 cm of precipitation) was equivalent (California Department of Water Resources, California Data Exchange Center, Sacramento, unpublished information). We conclude, therefore, that the boxes, t-posts, and longer pulses were responsible for improved camera system performance.

Deer populations (measured by pellet group densities) were greatest during 1994-96 and lowest during 1996-98 (Garrison et al. 1998), yet the number of pictures with deer was greatest in 1996-98. Disagreement between deer population indices derived from pellet group densities and the camera systems indicates that the mounting arrangement used during 1994-96 did not adequately quantify deer populations.

We had many problems with the factory-provided mounting brackets. The plastic ball-and-socket head used to mount the camera to the tripod became stripped from repeated tightening using pliers, and we continually replaced the turning knobs during 1994-96. The metal bracket covering the camera collected snow which caused the camera to tip and take photographs of the ground instead of the beam's field of view. Also, we felt that the openness of the camera's metal bracket and the infrared transmitter and receiver may have been overly sensitive which caused many non-animal events and photographs triggered with inclement weather. The velcro strap on the plastic tripod would loosen when wet from snow and rain causing the tripod and camera to move such that the desired field was not being photographed.

Mounting the camera with the receiver limited the camera's field of view such that deer breaking the beam within 1-2 m of the camera were not photographed effectively; the photographs often had only the deer's body without showing the animal's head which is needed for age and sex determination. The entire system was susceptible to animal damage; we had to replace a camera and several cables due to damage from black bear (*Ursus americanus*) and gray foxes (*Urocyon cinereoargenteus*).

Snow, heavy rain, wind, fog, blowing leaves and twigs, and blowing ground vegetation would sometimes break the beam causing blank photographs and triggering many spontaneous events, sometimes exposing the entire roll of film and triggering the maximum number of events that could be stored in the receiver over several minutes. These events were very costly in terms of field effort, film and development expenses, and lost information. The spontaneous events and resulting blank photographs were caused by several factors including: (1) the 0.25 sec (5 pulses) setting used in 1994-96 was too short and overly sensitive to non-animal events; (2) the 1-m tall wooden stakes would move in the wind, especially when the ground was wet, causing the beam to break as the transmitter and receiver moved out of alignment; and (3) the nylon straps used to mount the transmitter and receiver would stretch when they became wet and slip down the wooden stakes thereby breaking the beam.

Photographs without deer still were taken with the 0.75 sec (15 pulses) setting during severe snow and rain storms. Decreasing sensitivity by increasing pulses to >0.75 sec (>15 pulses) might reduce weather-induced events and blank photographs, but this may not be sensitive enough to detect target animals. We found that 15 pulses was almost too long to trigger the system when we walked at a moderate pace through the beam, but a deer moving at a normal pace triggered the system. A fast-moving deer might not be detected at ≥15 pulses, but we found that fewer pulses were too sensitive to weather-induced events. Large piles of snow falling from trees also triggered the unit, and snow occasionally piled up inside the transmitter and/or receiver boxes which would break the beam and cause non-animal events.

Table 2. Statistics (mean ± SD) from Trailmaster Model TM-1500 camera systems used to monitor mule deer (*Odocoileus hemionus*) in the central Sierra Nevada, 1994-1998. Factory mounts, wooden stakes, and 5 pulses were used during 1994-95 and 1995-96, while plywood boxes, steel t-posts, and 15 pulses were used during 1996-97 and 1997-98.

Year	*n*	Number of pictures with deer per roll		Number of pictures without deer per roll	
1994-95	48	4.06 + 5.62	A[a]	18.71 + 13.88	A
1995-96	54	1.80 + 2.86	A	19.78 + 13.36	A
1996-97	93	6.62 + 6.59	B	11.14 + 13.08	B
1997-98	92	6.52 + 5.62	B	8.60 + 9.89	B

[a] Years with differing letters are significantly ($P < 0.05$) different using Bonferroni pairwise comparisons in ANOVA. Number of pictures with deer: $F_{3,283} = 14.52$, $P < 0.0005$; number of pictures without deer: $F_{3,283} = 12.95$, $P < 0.0005$.

Mounting the camera on a separate t-post 1 m away from the receiver resulted in more complete photographs of the head and body of deer when the animals were within 1-2 m of the receiver. The t-posts were very stable and did not move with wind, and Hernandez et al. (1997*b*) also recommended the use of t-posts with Trailmaster units for this reason. The t-posts remained in field locations after the monitoring period was completed allowing for quick and easy placement of the boxes and camera systems in subsequent years, as well as continuous placement of the same system configuration over time. The plywood boxes are still intact after three winters of continuous use so they can be used for long study periods. The boxes and t-posts are heavy, however, so they more difficult to get into remote field sites than the factory mounts.

The improved mounting and longer pulse worked reasonably well for deer and probably will also for other large-bodied wildlife such as black bear and mountain lions (*Felis concolor*) that are moving through the infrared beam without being attracted to bait. Our monitoring efforts will continue into the near future using the Trailmaster camera systems, plywood boxes, steel t-posts, and 15-pulse settings. Other configurations may work better for studies that differ from ours in terms of habitat, season, length of monitoring period, target species, and use of attractants.

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