J. Field Ornithol., 66(2):199–211

A 24-HOUR REMOTE SURVEILLANCE SYSTEM FOR TERRESTRIAL WILDLIFE STUDIES

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Abstract.—The configuration, components, specifications and costs of a state-of-the-art closed-circuit television system with wide application for wildlife research and management are described. The principal system components consist of color CCTV camera with zoom lens, pan/tilt system, infrared illuminator, heavy duty tripod, coaxial cable, coaxitron system, half-duplex equalizing video/control amplifier, time-lapse video cassette recorder, color video monitor, VHS video cassettes, portable generator, fuel tank and power cable. This system was developed and used in a study of Mississippi Sandhill Crane (*Grus canadensis pratensis*) behaviors during incubation, hatching and fledging. The main advantages of the system are minimal downtime where a complete record of every event, its time of occurrence and duration, are permanently recorded and can be replayed as many times as necessary thereafter to retrieve the data. The system is particularly applicable for studies of behavior and predation, for counting individuals, or recording difficult to observe activities. The system can be run continuously for several weeks by two people, reducing personnel costs. This paper is intended to provide biologists who have little knowledge of electronics with a system that might be useful to their specific needs. The disadvantages of this system are the initial costs (about $9800 basic, 1990–1991 U.S. dollars) and the time required to playback video cassette tapes for data retrieval, but the playback can be sped up when little or no activity of interest is taking place. In our study, the positive aspects of the system far outweighed the negative.

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UN SISTEMA REMOTO DE OBSERVACIÓN DE 24 HORAS PARA ESTUDIOS DE VIDA SILVESTRE

Sinopsis.—Se describen la configuración, los componentes, las especificaciones y los costos de un circuito cerrado de televisión (CCTV) con adelantos técnicos de gran utilidad para el estudio y manejo de la vida silvestre. Los componentes principales del sistema incluyen cámaras CCTV a color con lentes zoom, sistemas de bandejas reclinable, iluminadores infrarojos, tripodes fuertes, cables coaxiales, un sistema coaxitrón, un amplificador con control a distancia para grabar y duplicar en video, una grabadora de videocassette con control y registro del tiempo, una pantalla de televisión a colores, cintas VHS, generador portátil, tanques de combustible y cables de potencia. Este sistema se desarrolló y usó en un estudio sobre los comportamientos durante la incubación, la eclosión, y el emplumaje de *Grus canadensis pratensis.* Las ventajas del sistema incluyen un registro completo y permanente de cada evento, cuando ocurrió y su duración el cual puede ser revisado cuantas veces sea necesario para anotar los detalles. El sistema es particularmente útil en estudios de comportamiento y depredación, para contar individuos o para registrar comportamientos difíciles de observar. Se puede correr el sistema continuamente durante semanas por dos personas lo que reduce costos de personal. Este trabajo interesa ofrecerle los detalles del sistema a biólogos con poco conocimiento de la electrónica que pueden darle uso a este equipo para sus proyectos. Las desventajas del sistema incluyen costos iniciales (cerca de $9800 el equipo básico según los costos en los E.U.A. entre 1990 y 1991) y el tiempo requerido para revisar las cintas de videocassette para retraer los datos. No obstante, la velocidad de revisión de las cintas puede acelerarse cuando no hay actividad o cuando ésta es de poco interés. En nuestro estudio, los méritos del sistema sobrepesan las desventajas.

Closed-circuit television (CCTV) was first applied to studies of wildlife in the early 1970s (Pulliainen 1971). A variety of videographic systems have since been used in wildlife research, both in the field and in the lab (Escobar et al. 1988; Pulliainen 1971, 1975; Reed et al. 1973; Wisniewski 1982).

We used a specially configured, state-of-the-art (1990) CCTV system to observe and record the nesting activities of the endangered Mississippi Sandhill Crane (*Grus canadensis pratensis*) during incubation, hatching and fledging at the Mississippi Sandhill Crane National Wildlife Refuge (30°25′N, 88°40′W), Jackson County, Mississippi. The small relic flock has not been producing sufficient numbers of young to sustain the population. We were interested in behaviors of nesting pairs and all events that took place at or near nests that might be related to nesting success. This CCTV system has a broad range of potential uses in wildlife studies and is described in detail to aid biologists who have little knowledge of electronics to develop a CCTV system to meet their research or management needs. As CCTV technology continues to improve, the costs of systems should drop significantly.

FEATURES OF THE CCTV SYSTEM

We constructed our CCTV system from high performance components, capable of continual operation for several years, rather than from home video equipment. Industrial-grade components are necessary for wildlife studies in which equipment must operate with minimal maintenance and under all weather conditions. A portable power source provided the flexibility necessary to operate anywhere. The closed-circuit television system used to study crane nests (Figs. 1–6) was designed to operate 24 h per

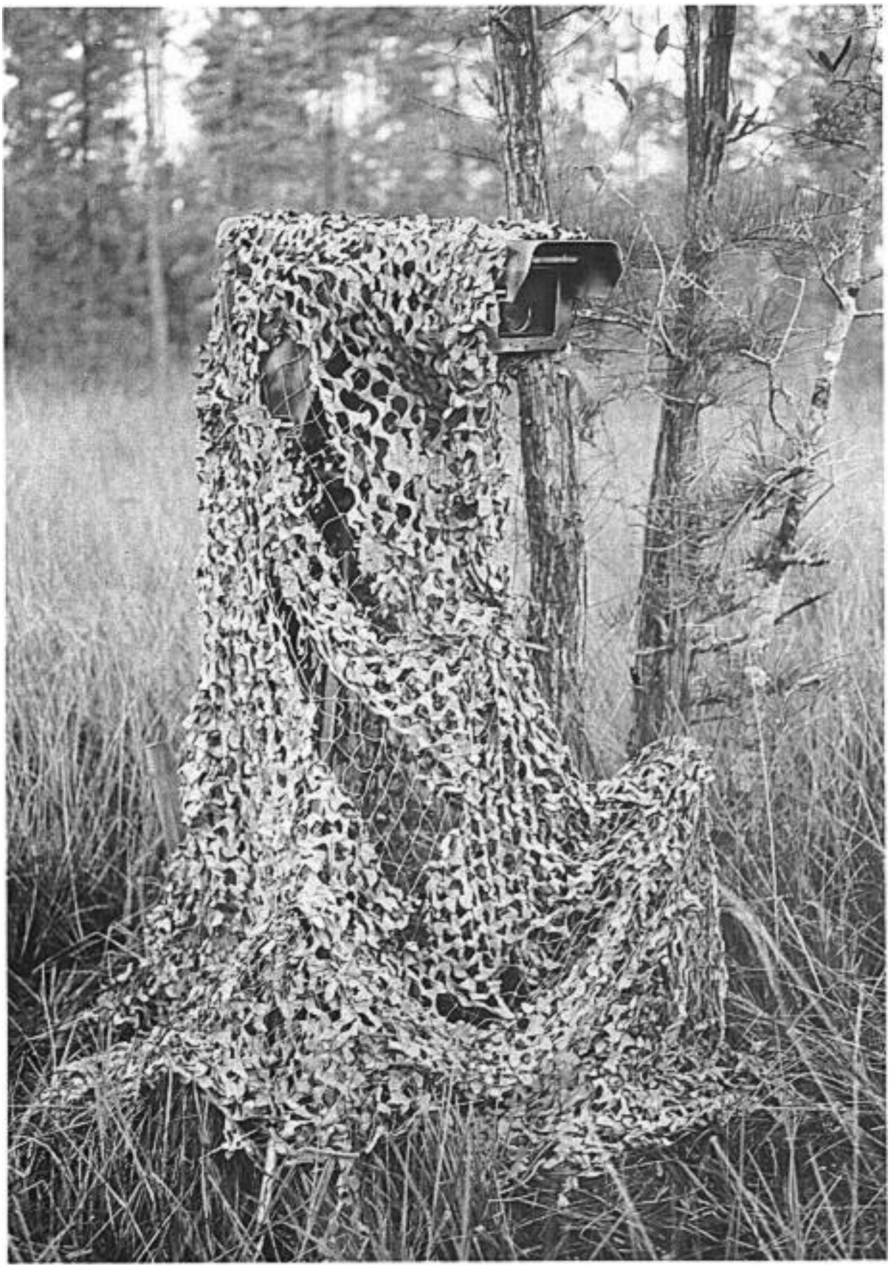

FIGURE 1. CCTV camera setup in the field at a Mississippi Sandhill Crane nest (before installation of infrared illuminator). The unit is draped with camouflage netting and placed near existing trees and shrubs wherever possible to make it less conspicuous.

FIGURE 2. The control, monitoring and recording equipment for the CCTV system consists of: (1) color video monitor with incubating crane displayed on screen, (2) half-duplex equalizing amplifier, (3) Coaxitron System 2000 transmitter-controller and (4) time-lapse video cassette recorder.

day under all weather conditions. All activity at a nest was video taped for later data retrieval and analysis. Industrial-grade T120 VHS video tapes were used while recording on the VHS video cassette recorder (VCR) in 6-h mode. Hence, only four tapes were needed per 24-h period. The VCR was equipped with a date-time generator that permitted the time, date and duration of each event to be overlayed onto the recorded video image. The system can also be programmed for extended time-lapse modes. Daylight coverage was in full color and night coverage in subdued color or black and white. Night coverage was accomplished using an infrared illuminator.

We were limited in placement of the system only by security considerations for the equipment during brief periods when personnel were not in attendance. Down time of the system was about 15–20 s while changing tapes, and 2–3 min twice daily while shifting from one power unit to another. We decided that sound recording was not necessary for our study, but CCTV systems with audio are available.

The principal components for a CCTV system, manufacturers, model numbers, dimensions, masses and 1990–1991 costs are given in Table 1. The cost for the basic video system was approximately $9800 (US), and the coaxial cable, power cable, video cassettes, control center shed and

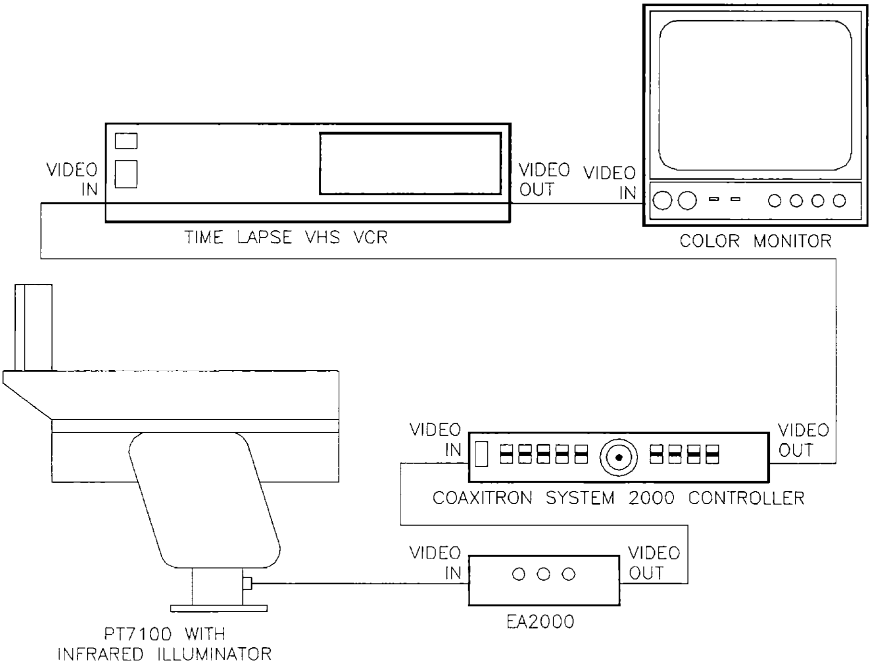

FIGURE 3. Schematic of CCTV system components showing direction of video signal transmission.

small equipment trailer added another $5200. The configuration of the components is shown in Figure 3, while their features are presented below. We use standard abbreviations and notations widely used in the electronics industry. The electrical and operating specifications are given in Table 2.

Color CCTV camera.—The camera (Figs. 4 and 5) is an integrated high-performance solid-state color unit, with a charge coupled device image sensor and a horizontal resolution of 430 lines. The camera's integrated features include electronic zoom, sensitivity control and variable shutter speed. The integrated features can be controlled through a single coaxial cable or selected switches on the camera. The variable-speed electronic shutter operates at 1/250, 1/500 or 1/1000 s. The camera has a composite video as well as separate luminance and chrominance output for direct S-VHS compatibility and high-quality picture playback performance. The minimum scene illumination is 10 lux at F1.4 with automatic gain control. In addition, electronic sensitivity can be selected on or off. Automatic sensitivity selection is a maximum of 10×. Using the optional controller, automatic sensitivity can go up to 32×. Automatic or manual sensitivity selection is with the camera control unit. Automatic sensitivity is 2×, 4×, 6× and 10× and manual sensitivity is 1× (normal), 2×, 4×, 6×, 10×, 16× and 32× on this camera.

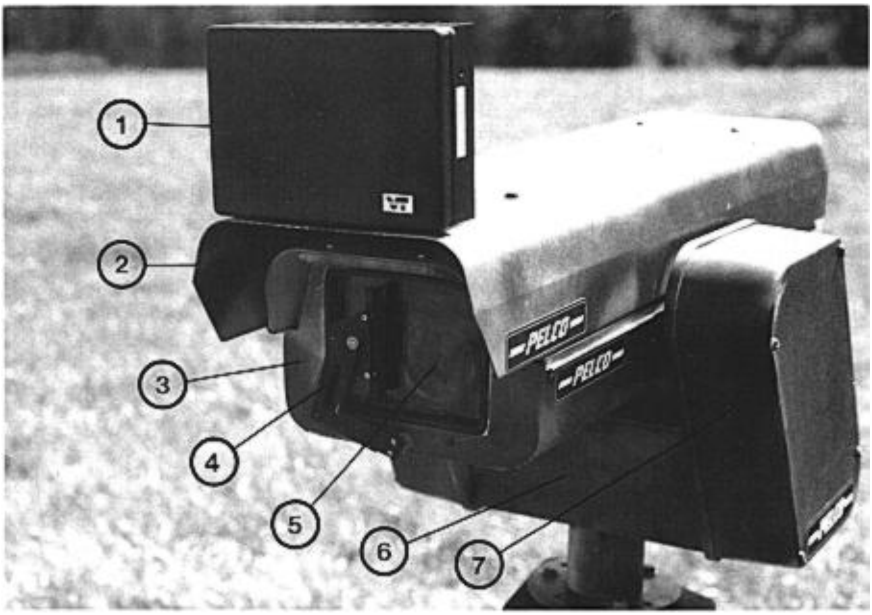

FIGURE 4. External left front quarter view of camera apparatus: (1) infrared illuminator, (2) sun shroud with camouflage pattern, (3) body of environmental enclosure with camouflage pattern, (4) window wiper, (5) zoom camera lens as seen through front window, (6) housing containing pan system and (7) left housing of tilt system.

Zoom camera lens.—The 10× zoom lens (Figs. 4 and 5) has a focal length of 11–110 mm. The auto iris is F1.8 to approximately F560, the motorized focus is 1.3 m to infinity, and motorized zoom 11 to approximately 110 mm.

Pan/tilt system.—The pan/tilt assembly (Figs. 4 and 5), the aluminum environmental camera enclosure, and a control receiver/driver are factory-delivered as a self-contained package. The system is designed for indoor and outdoor operation. The mechanical braking of the motors provides instant stopping with near zero coasting. The system comes factory prewired for motorized zoom lens, camera power, enclosure power and video. All operating functions are integrated into a single printed circuit board. Pan movement in the horizontal plane is 0–355° and speed 9° per second. Tilt movement in the vertical plane from horizon is +15° (tripod legs can be adjusted for additional tilt) to −90°, and speed 4.5° per second.

The enclosure provides a weatherproof chamber for the camera system and is designed for camera-lens assemblies up to 61 cm long, 18.4 cm wide and 14.7 cm high. The enclosure is available in 51, 66 and 81 cm lengths. We used the 66-cm model with a 7.6-cm overhang above the plate glass window. Opening is assisted by a gas spring, which securely holds

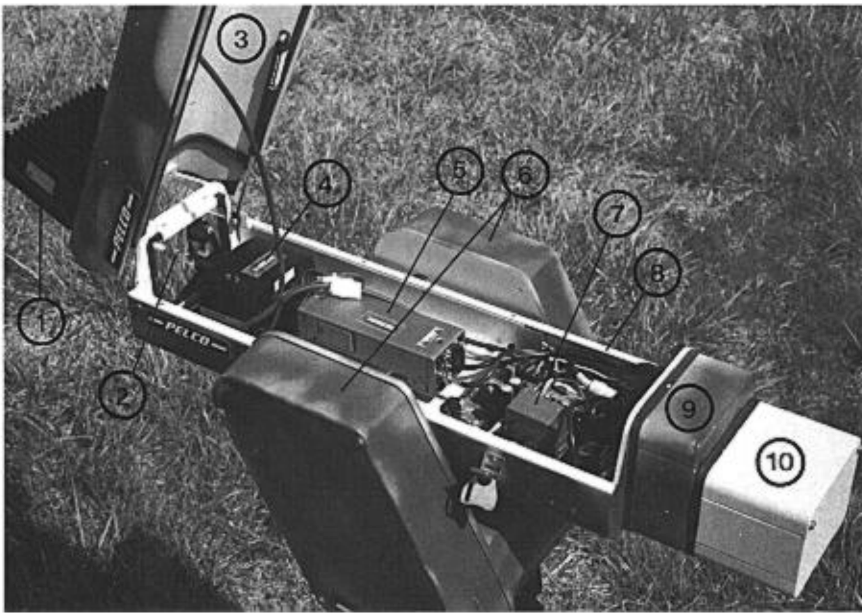

FIGURE 5. Top left lateral view of camera apparatus with cover of environmental enclosure in open position to show components: (1) infrared illuminator, (2) front window, (3) cover of environmental enclosure, (4) zoom camera lens, (5) color CCTV camera, (6) left and right housings containing tilt system, (7) 12V DC transformer for the infrared illuminator, (8) body of environmental enclosure, (9) blower housing and (10) motor unit for window wiper.

the lid in the open position. An adjustable camera sled has a removable elevation block and can be inverted depending on the camera and lens used. Optional accessories on our enclosure include a thermostatically controlled heater and blower, a manually controllable window wiper and sun shroud. The sun shroud protects the enclosure from direct rays of the sun and can reduce internal temperature approximately 5–8 C when temperature in sun is 27 C and higher. The forward overhang of the sun shroud shields the plate glass window of the enclosure from sun glare and precipitation. The heater is set to cut in at 7 C and out at 13 C, and the blower in at 35 C and out at 30 C. The wiper is used to remove condensation that builds up on the outside of the enclosure plate glass window during evening and early morning.

Infrared illuminator.—The infrared illuminator (Figs. 4 and 5) is a solid-state device designed for indoor and outdoor use. The spectral emission has an infrared wave length (maximum) of 880 nm. No ventilation or maintenance is required, and the service life is greater than 100,000 h. We mounted the illuminator on the top front end of the sun shroud. The illuminator was on and functioning whenever the camera was operating.

FIGURE 6. Video monitor display showing an adult crane incubating. The camera lens is zoomed in approximately one half for the picture shown. The date (month-day-year) is in the top upper left with time (24-h clock) below. The date and time are recorded continually on the video tapes exactly as shown. The image on the monitor screen is actually much sharper than shown by a photograph of the screen.

A 12-V DC transformer with regulator converted AC to DC for operation of the unit.

Tripod.—The tripod is a heavy-duty commercial-grade model with a capacity of at least 45 kg. The pan head of the tripod was modified to mate with the base plate of the pan/tilt system.

Coaxial cable.—The coax cable is 95% copper shielded type standard RG59/U with a polyvinyl chloride jacket. We have a total of 762 m of coax cable in two pieces to provide flexibility in a variety of field conditions. This length of cable provided adequate signal between camera and receiving equipment.

Coaxitron system 2000.—System 2000 is an outdoor desk-top remote control system (Figs. 2 and 3) for the camera, zoom lens and pan/tilt system integrated into a single printed circuit board for reliability and ease of operation. The coaxitron system consists of transmitter/controller and receiver. The transmitter/controller are combined into a single unit. The receiver is combined with the PT 7100 pan/tilt unit and protected in a weatherproof enclosure. All functions are controlled through a single coaxial cable that provides simultaneous transmission of the control and video signals. Up to 16 remote control functions are possible (10 simul-

TABLE 1. Closed-circuit television (CCTV) system components.

General function	Component	Manufacturer[1]	Model	Dimensions[2] (cm) W	H	L	Mass (kg)	Approximate 1990–1991 costs[3]
Camera apparatus	Color CCTV camera	Panasonic	WV-CL700	7.0	7.1	21.5	1.2	$1500.00
	Zoom camera lens	Computar	MIOZ1118AMS	12.9	9.3	14.6	1.2	840.00
	Pan/tilt system	Pelco	PT7100-1	39.4	38.1	35.6	17.2	1940.00[4]
	Environmental enclosure	Pelco	EH5526-1	22.3	15.9	66.0	4.6	—[4]
	Sun shroud	Pelco	SS5526	23.0	10.0	81.0	1.5	60.00
	Window wiper	Pelco	WW5526-1	—	—	—	<0.05	300.00
	Infrared illuminator	Videor Technical	MFL-I/LED-30W	6.7	12.8	18.2	1.2	659.00
	Tripod	Innovative Television Equipment	ITE-T2 (closed)	19.0	100.0	—	4.3	250.00
			(max. extension)	146.5	156.0	—		
	Coaxial cable[5]	Belden	8241 RG59/U AWM 1354	0.242	—	—	0.04/m	4.30/m
		Alpha	07P/N9059B RG59B/U				0.04/m	4.30/m
		West Penn Wire	4815[6]	0.292	—	—	0.04/m	5.58/m
Controls, monitor, and record	Coaxitron system 2000	Pelco	MPT9000CZ (transmitter)	26.7	4.4	44.7	5.7	400.00
			and CX9115RX (receiver)	—	—	—		
	Half-duplex equalizing amplifier	Pelco	EA 2000	14.0	4.4	26.6	1.4	230.00
	S-VHS/VHS time-lapse video cassette recorder	Panasonic	AG-6720-P	42.1	11.2	43.0	8.8	2100.00
	Color video monitor	Panasonic	CT-1030M	28.4	26.6	32.2	8.5	500.00
	Video cassette	Sony	T-120	10.3	2.4	18.7	0.3	3.65
Power unit	Portable generator	Kubota	AV2500	41.0	49.0	53.5	38.0	1000.00
	Steel fuel drum	—	208-liter	58.4	—	88.9	7.5 (empty)	20.00 (new)
	Power cable	Triangle	N-A PCC Type TC Sun Res. 3/C #10	1.0	—	—	2.0/m	2.63/m

[1] Use of trade names does not imply U.S. Government endorsement of commercial products.
[2] Maximum outside dimensions: W = width or diameter, H = height, L = length.
[3] Costs do not include labor to adapt some components to the system or small miscellaneous items (i.e., plugs, relay module, 3-A power supply).
[4] Costs for pan/tilt system and environmental enclosure are combined.
[5] Three options of cable; we used the Belden and Apha types.
[6] Recommended for those applications where cable will be submerged or installed for extended periods of time.

TABLE 2. CCTV system electrical specifications and operating temperatures.

Component	Power				Ambient temperature (C)
	Source (V)	Frequency (hz)	Consumption (W or VA[2])	Current (A)	
CCTV camera	120 AC	60	8.5 W		−10–50
Camera lens					
Iris	8.5~16 DC	NA	≤0.64 VA	≤0.040	−10–50
Focus	8 DC	NA	≤0.36 VA	≤0.045	−10–50
Zoom	8 DC	NA	≤0.32 VA	≤0.040	−10–50
Pan/tilt system[1]	120 AC	60	195 VA	—	−23–60
Window wiper	120 AC	60	86 VA	—	−23–60
Infrared illuminator	12.5 DC	NA	31.25 VA	2.5	−6–50
Coaxitron System 2000 transmitter	120 AC	10	2.5 VA	—	−20–60
Half-duplex equalizing amplifier	120 AC	60	1.5 VA	—	0–50
VCR	120 AC	60	33 W	—	5–40
Video monitor	120 AC	60	40 W	—	5–40

[1] Includes receiver, pan/tilt unit and heater/blower.
[2] VA = volt amperes.

taneously) for CCTV equipment. We used only one camera in our study, but the basic coaxitron system can be expanded to control multiple camera sites by adding switching devices. The coaxitron system can also be set to do automatic random scanning as an option.

Half-duplex equalizing video/control amplifier (EA 2000).—The amplifier (Figs. 2 and 3) is compatible with the Coaxitron System 2000 control system. It provides an effective means of maintaining a CCTV picture quality in runs of up to 914 m of RG59/U coaxial cable and at the same time maintains the quality of the coaxitron control system. Without this amplifier, the distance between the camera and the coaxitron control system is limited to 229 m. Operating environment is 0–90% relative humidity.

S-VHS/VHS time-lapse video cassette recorder.—The time-lapse video cassette recorder (VCR) (Figs. 2 and 3) format delivers 400-line horizontal high resolution in both color and black-and-white for S-VHS and 240 lines color and 300 lines black-and-white for VHS. Besides the 2-h and 6-h S-VHS/VHS recording modes, this VCR can record in time-lapse modes of 24, 48, 72, 120, 180, 240 and 480 h. It also can record in single-shot mode. The unit can be set to "stand by" so it will begin recording in 2-h mode when triggered by an external alarm or sensor.

The VCR has a built-in time/date generator that records the time and date continually on the cassette tape. The time is in the 24-h format, listing hour, minutes and seconds, and the date is the month in numerals followed by day and year (Fig. 6). An internal battery provides a back-up lasting approximately 1 mo for the timer so the time and date do not have to be reset when the CCTV system is shut down for short periods or in case of power failures.

The video recording system has two helical scanning rotary heads. Tape speed for standard play is 33.35 mm/s and for standard long play 11.12 mm/s with S-VHS and VHS tapes. This unit is fully equipped for audio. Tape width is 12.7 mm. Fast-forward and rewind time is approximately 3.5 min. The television system of the video has Engineering Institute of America standard of 525 lines and 60 fields.

Color video monitor.—The monitor is a 335.5-cm^2 diagonal color video unit (Figs. 2, 3 and 6) with audio and full front-panel access. It is light in weight and durably constructed and small enough for desk-top operation. Hook-up to the VCR is with an eight-pin connector. A 75-Ω termination is selected automatically for line inputs, so no impedance switches are required. Resolution is 300 television lines on the horizontal.

Video cassette.—The video tapes are professional VHS video cassettes of the T-120 premier grade 12.7-mm tape. Recording time for standard play is 2 h, long play 4 h, and extended play 6 h. Dust jackets were retained for storage and protection of the cassettes.

Portable generator.—The power source for the CCTV system is a 2500-W, 60-Hz portable generator. The unit has a maximum output of 2500 W, a rated output of 2200 W, 120 V AC, rated power of 18.3 A, power factor of 100%, capacitor load compensating voltage regulator, and over-current-protector circuit breaker. The generator has an air-cooled four-cycle 169-cm^3 overhead valve engine that operates on unleaded 87 or higher octane gasoline. The engine has a recoil starting system and transistor-controlled ignition. The engine lubricating oil capacity is 0.6 l. The generator system features a pilot light, AC voltage meter and emergency stop mechanism in case of abnormal oil level. Engine oil should be checked daily and changed every 50 h of operation. The air cleaner element should be cleaned every 50 h and the spark plug cleaned and gap checked and spark arrester serviced every 100 h. Clean the fuel filter every 200 h.

Steel fuel drum.—A 208-l fuel drum is used instead of the 14-l fuel tank on the generator to supply fuel to the carburetor. The drum is placed in a cradle on its side and gasoline is gravity-fed to the carburetor through the 3-m long fuel line. The fuel line must be shaded for its entire length to prevent airlocks. The fuel line from the tank on the generator is plugged and the fuel line from the drum is attached to the carburetor fuel intake.

Power cable.—The power cable is tray type, direct burial, dual rated, three conductor, 600-V, 10-gauge wire with nylon jacket. This cable provides power without a drop from source to equipment for at least 0.8 km. The jacket is tough enough to be dragged along the ground and through dense brush without damage.

Control center.—A portable shed 1.8 m wide, 2.4 m long and 2.4 m high was used to house the control, monitoring and recording equipment. The shed was secured on a flatbed small equipment trailer with chains so it could be quickly and easily moved from site to site. The shed was air conditioned to protect the electronic gear from high temperatures, humidity, dust and direct sunlight, and at the same time afford a degree of comfort to persons operating the system continually on daily shifts of up to 12 h. The power source for the CCTV system also ran the air conditioner. The shed was wired for electricity with a circuit breaker panel and electric lighting. There were electric outlets to operate the various system components and additional equipment as needed. The shed was located at a distance of 400 m or more from, and usually out of sight of, crane nests so that activity such as shift changes by personnel, talking, motorized vehicles and shifting generators did not affect the behavior of the cranes.

DISCUSSION

Once the system was set up in the field and minor adjustments were made, we found it easy to operate and relatively maintenance free. A series of detailed protocols covering all system components, safety and record keeping were developed so that all personnel involved were well aware of standardized operating procedures. Equipment manuals for each major system component were available in case further details were required during system operation. In our study of four crane nests, once the equipment was in place and put into operation, the system was not shut down until the conclusion of data recording at a given nest (4–22 d).

There are several advantages of a remote video system over the more conventional methods of recording data while observing an animal. First, continuous taping, with minimal down time to change video cassettes and shift generators, is the only way to obtain a complete record of each and every event that takes place. This is not possible using direct observation of a non-recording monitor, time-lapse TV recording, or observers using notebooks, laptop computers, or recording directly into a tape recorder. Observer attention-span is very limited (3 h or less), particularly if the activity being observed is infrequent. Some events can take place in seconds, such as predation, and can easily be missed by time-lapse recording or lack of concentration by an observer. We felt continuous recording on video tape was the best method for our purposes. The time-date generator in the VCR enables one to determine the exact time and duration of events. Tape can be replayed as many times as required to obtain the desired data or to double check a given event. On playback the tape can be paused or fast-forwarded during periods of inactivity or when seeking certain types of data at any point at the command of the person recording the data. For recording data on playback, additional VCRs and monitors of the household variety can be used to speed along data retrieval. Two people can operate the CCTV system continually for several weeks in the field, thus reducing personnel costs. This system is particularly applicable for behavioral studies, documenting predation, recording numbers of individuals passing a given point, or recording other difficult-to-observe activities.

There are a few negative aspects to the CCTV system. Among these are the initial costs of the system, the disturbance created when setting the camera in place, the limited area that can be covered from a fixed point, the jerky motion resulting when panning with the camera lens at close focus and on time lapse, and the time required to replay the tapes for data retrieval. We found in our study of the Mississippi Sandhill Cranes that the positive aspects of the CCTV system far outweighed the negative. Given the continuing advances in the electronic field, equipment will be improved and costs will go down.

There was a minor problem encountered using the camera with the infrared illuminator at night with frequent high humidity or light fog. The light from the infrared illuminator was reflected by the moisture in the air causing reduced sharpness of the images. The illuminator was rated to have an effective range of 28 m, which it did when we tested inside a building in total darkness with low humidity. Under field conditions with 90–100% humidity, however, the distance from the camera to a crane nest could be no more than 20 m to provide an acceptable image on the video system. At closer distances the image was further enhanced.

ACKNOWLEDGMENTS

We wish to thank the staff of the Mississippi Sandhill Crane National Wildlife Refuge for their assistance in locating Sandhill Crane nests, building the control shed, furnishing the flatbed trailer, providing many suggestions, helping set up the CCTV system at each crane nest studied and manning the control center on occasion. In particular we express appreciation to J. D. Bates, C. D. Cooley, W. S. Davis, A. C. Harden, W. T. Harper, S. G. Hereford, R. P. Ingram, G. A. Noble, J. E. Noble, P. G. Range and C. A. Wilder. Special thanks are extended to T. D. Chisolm, R. C. Southern, and J. T. Seginak for assistance manning the control center. At Tech Systems, Inc., Norcross, GA, we thank B. C. Hitt, D. W. Keeler, S. Stephens, and D. Savage. J. R. Belthoff, D. K. Cairns, M. R. Fuller, D. W. Keeler, O. H. Pattee, C. S. Robbins and M. Wallace made helpful suggestions for improvement of this paper, and B. J. Fancher typed the manuscript.

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Received 8 Feb. 1994; accepted 25 Jul. 1994.