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A solar-powered transmitting video camera for monitoring cliff-nesting raptors

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ABSTRACT. We designed a system of solar-powered video cameras that transmitted images via telemetry to a monitor. This system allowed us to study the breeding behavior of the Bearded Vulture (*Gypaetus barbatus*) in the Pyrenees (northeastern Spain). From 2000 to 2004, 12 nests in seven territories were equipped with video cameras. To avoid disturbing the birds, equipment was installed 3–8 weeks before egg-laying. The acceptance rate was 75%. No decline in productivity was observed for nests monitored with video cameras compared to control nests. The cameras enabled us to document egg-laying, hatching asynchrony, the nestlings' diet, and the parents' breeding behavior from distances of 2–3 km, although technical problems temporarily interrupted the transmission of images. Video cameras can be used successfully to study the Bearded Vultures, and probably other cliff-nesting raptors, without reducing productivity.

SINOPSIS. **Videocámara emisora alimentada por energía solar para el monitoreo de rapaces rupícolas**

Diseñamos un sistema de cámaras de vídeo alimentado por energía solar que transmite imágenes por telemetría a un monitor. Este sistema permitió estudiar el comportamiento reproductor del Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos (NE España). Durante el periodo de 2000–2004 se equiparon con cámaras de video 12 nidos en siete territorios. Los equipos se instalaron entre 3 y 8 semanas antes de la puesta, para reducir las molestias a las aves. El éxito de aceptación fue del 75%. No se observó un descenso en la productividad de los nidos estudiados con las cámaras con respecto a los no equipados con dicho sistema. El sistema permitió documentar a una distancia de 2–3 kms, la asincronía de puesta y eclosión, la dieta del pollo y el comportamiento de los adultos en el nido, aunque se detectaron algunos problemas técnicos que temporalmente interrumpieron la emisión de las imágenes. Las cámaras de vídeo pueden ser utilizadas para estudiar a otras aves rupícolas sin afectar la productividad.

Key words: Bearded Vulture, breeding biology, cliff-nesting, *Gypaetus barbatus*, solar powered, video camera

Remote monitoring systems can be used to study birds sensitive to human disturbance. Several studies have been carried out using still cameras (Major 1991, Major and Gowing 1994, Franzreb and Hanula 1995, Hernández et al. 1997, Cutler and Swann 1999) and video cameras (Brown et al. 1998, Thompson et al. 1999, McQuillen and Brewer 2000, Pietz and Granfors 2000, Stake and Cimprich 2003). The use of video cameras to study raptors has increased over the last decade (Kristan et al. 1996, Delaney et al. 1998, Grønnesby and Nygård 2000, Dykstra et al. 2002, Booms and Fuller 2003). In most studies, equipment is installed during the breeding period (incubation or nestling; Kristan et al. 1996, Delaney et al. 1998, Booms and Fuller 2003) when human activity near a nest may cause abandonment (Cain 1985). In threatened species, the risk of abandonment or breeding failure makes the installation of equipment during the incubation or nestling periods inadvisable (Margalida et al. 2002).

Obtaining data on the breeding biology of cliff-nesting raptors can be difficult if nests are difficult to reach and adults are sensitive to disturbance (Richardson and Miller 1997). For threatened species, conservation is the highest priority and activity near active nests should be avoided (Steidl and Anthony 2000). Such is the case for the Bearded Vulture (*Gypaetus barbatus*), an endangered species that inhabits European mountain ranges, including the Pyrenees and the Alps (after their reintroduction in 1986) and the islands of Corsica and Crete. There are 122 breeding pairs in the European Union, with 80% of those pairs in the Pyrenees (Heredia and Margalida 2003).

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We developed a camera system for documenting lesser known aspects of the breeding biology of Bearded Vultures and tested the system during four consecutive breeding seasons at 12 Bearded Vulture nests. Here we describe the monitoring system and analyze its advantages and disadvantages.

METHODS

The Bearded Vulture is a cliff-nesting vulture characterized by late sexual maturity and a prolonged breeding cycle that begins in September–October with the rebuilding of the nests (Margalida and Bertran 2000a) and ends in June–July when young fledge (Margalida and Bertran 2000b, Margalida et al. 2003). Egg-laying takes place in December–February and the incubation period is 54 days. The nestling period lasts about 4 months (Margalida et al. 2003).

Our study was conducted in the Catalan Pyrenees mountains of northeastern Spain where there are 31 Bearded Vulture territories, including 22 breeding territories. The terrain is rugged, and access to nests is difficult. The mean distance from roads to nests was >500 m.

Nests were located and monitored when nest building began during September and October. Each year during the pre-laying period (October–December), we installed video camera systems in three different territories. Cameras were installed on the roofs of cavities to provide a view of the inside of the nest and sufficiently high so as not to disturb the birds (Fig. 1). Transmission systems were installed either on top ($N = 9$) or at the bottom ($N = 3$) of the cliff. The average distance between nests and transmission systems was 36.7 ± 21.1 (SD) m (range 15–80 m, $N = 12$).

The camera system (Fig. 1) included transmitting equipment (video camera, transmitting antenna, and battery; Fig. 2) and receiving equipment (receiving antenna and video recorder; Fig. 3). The video camera (Panasonic model YK 2739) used a 12-volt power source (all components were 12 volt unless otherwise noted) and operated on a current of 100 mA. The camera was connected to a 2.4 GHz, water-resistant radio transmitter (AV-24-PP). The radio transmitter operated on a current of 180 mA. A small microphone was connected to the transmitter. Cameras and transmitters were held in place using rock-climbing materials (bolts; Fig. 1), and transmitter antennas were supported by 1-m aluminum rods that allowed us to point them in the required direction (Fig. 1). Cam-

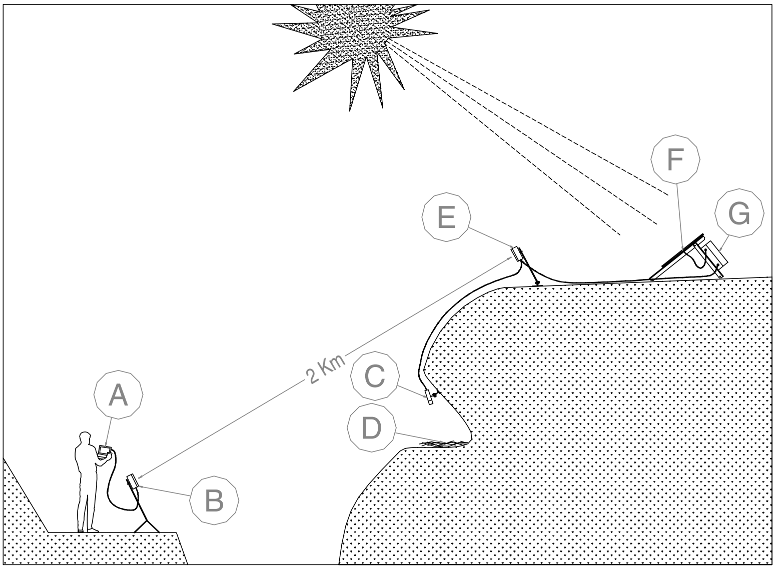

Fig. 1. Drawing of the video-monitoring system used to study Bearded Vulture breeding behavior. (A) Video recorder with a color monitor and battery, (B) Receiving antenna, (C) Camera, (D) Nest, (E) Transmitting antenna, (F) Solar panel, and (G) Power unit.

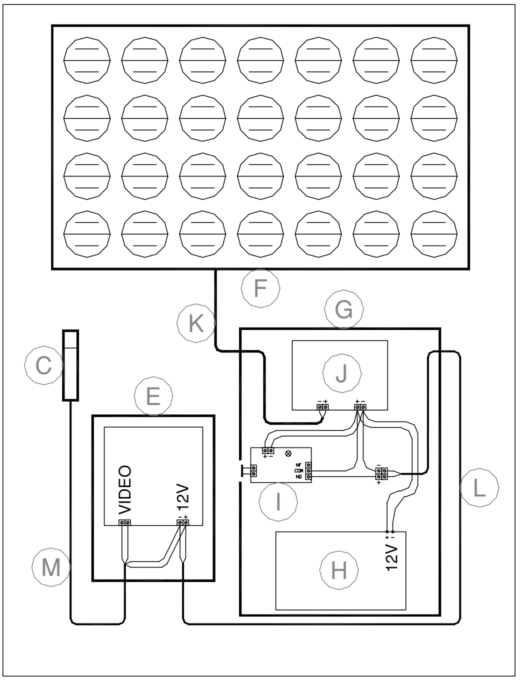

Fig. 2. Drawing of the transmitting equipment used to study Bearded Vulture breeding behavior. (C) Waterlight color microcamera (12 volts), (E) video transmitter (12 volts), (F) 75 W solar panel, (G) Battery charge control unit, (H) 12 volt, 12 amp battery, (I) Twilight switch (12 v), (J) Charge regulator, (K) Charge regulator power cable, (L) Video transmitter power cable, and (M) Power cable and video camera.

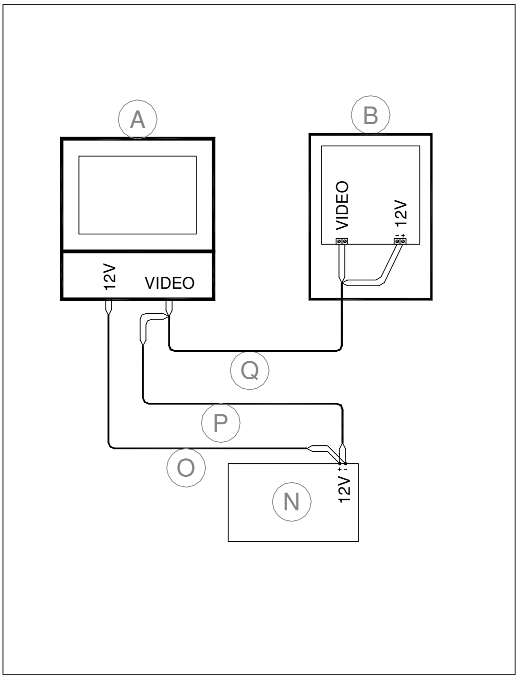

Fig. 3. Drawing of the receiving equipment. (A) Portable digital color recorder monitor (12 volts), (B) video receiver (12 volts), (N) 12 v battery, (O) Video recorder/monitor power cable, (P) Video receiver power cable, and (Q) Video transmission cable.

eras were connected to the transmitting antenna (AV-24 PP Societé Française d'Emetteurs model E-24-PP) using a coaxial audiovisual cable, and the transmitters were connected to a power unit located either above or below the cliff using the coaxial cable.

Batteries were attached to the support frame of the solar panels, which supplied the energy required by the transmission system. This power unit (Fig. 2) was a 12-volt light sensor operated using a current of 5-60 mA. The light sensor (65 × 45 × 30 mm) was connected to a solar regulator (CBE P262-2) that operated on a current of about 0.1 mA, and was connected to the solar panel (Siemens model SP75) with a nominal voltage of 15.5 volts. This device charged the lead battery (Yuasa NP 12-12). Batteries lasted 3–4 days without sunlight and, if discharged, took 3 hours of sunlight to recharge completely. At one nest, we used a wind-powered battery charger (Rutland WG 913) with an adapted volt regulator (Conrad SR 2000). Images were received at distances up to 1 km by an antenna (Societé Française d'Emetteurs AV-24-PP model R-24 P) programmed using the same frequency as the 2.4 GHz transmitter. The receiver was powered using an audiovisual cable connected to a video recorder (Sony model GV-D900E) either with its own battery or connected to a 12-volt lead battery (Fig. 3).

At each site where a camera system was installed, we noted the distance between the nest and the transmission system and the time spent installing the system. We also noted the response of the breeding pair (i.e., number of days between installation and the first observation of an adult at the site and whether the pair initiated breeding or not), and the fate of nests (successful or not and, if successful, the number of fledged young).

RESULTS

From 2000 to 2004, we installed camera systems at 16 potential nest sites, and adults were observed at 12 of those sites. For those sites, mean installation time (once we had reached the nest cliff) was 3.4 ± 1.2 (SD) h (range = 2.2–6.4 h; $N = 12$). The mean time between camera installation and the first observation of adults at those sites was 3.2 ± 0.98 days (range = 2–5 days; $N = 12$).

To monitor the 12 breeding attempts, a total of 16 camera systems were installed, which implies an acceptance rate of 75%. This was a result of some pairs changing nests (four cases) and the cameras were reinstalled. Because the same two pairs were monitored in different years, the average acceptance rate per pair was 68 ± 34.6%. (range 0–100%, $N = 7$). We documented successful breeding at nine (56.3%) of 16 nest sites where the camera systems had been installed. Because two pairs of Bearded Vultures were observed at nest sites in different years, the total number of pairs observed during our study was seven. At four of our 16 sites, no adults were ever observed. In addition, at two sites, pairs were observed, but no eggs were laid. At another site, a pair was observed, but they moved to other nest sites (changing sites a total of four times) and finally bred successfully. This move was probably not related to the presence of the camera system because this pair generally built several nests before egg-laying (Margalida, pers. observ.).

Of the 16 cameras installed, 10 were camouflaged with natural materials present at the nest site (e.g., wool) and no camouflage was used with the remaining six. Vultures nested at eight of the 10 sites (80%) where cameras were camouflaged, and at three of the six sites (50%) where cameras were not camouflaged.

Differences in productivity at camera and control nests. The mean number of young for Bearded Vultures at nests with cameras was 0.78 per breeding attempt ($N = 9$). During the same period, the mean number of young for vultures at control (undisturbed) nests was 0.40 per breeding attempt ($N = 53$). For all the nests where camera systems were installed ($N = 12$), the mean number of young fledged per breeding attempt was 0.67. Thus, the presence of cameras did not appear to negatively affect reproductive success.

System performance and problems. The camera system allowed us to document egg-laying intervals, incubation behavior, hatching asynchrony, sibling aggression, and diet (Margalida et al. 2004, 2005). This system also allowed us to document the hatching interval (time between the first observation of a hole in an egg and when a chick was completely free of the shell). In addition, for three focal pairs, 309 of 352 (87.8%) prey items delivered to nests were identified.

Temperature fluctuation or precipitation caused condensation on two camera lenses during December, January, and March. Because this coincided with incubation, it was not possible to replace cameras. At another site, a mammal chewed through the camera cable and disrupted the video signal for 2 mo. At five sites, cameras were moved so than they no longer focused directly on nest sites. At one site, adults collecting wool placed on the camera to make it less conspicuous caused a slight movement of the camera. At the other four sites, the cause of the movement was unknown. In one case, the movement was slight and did not prevent data from being collected. At the other sites, we were able to correct the problem by visiting the sites when adults were not present.

Although designed to permit reception of a signal within a 1-km radius, our system was tested successfully at 3.5 km. Although image quality was lower at that distance, we were still able to document laying intervals and hatching asynchrony and identify prey.

DISCUSSION

Our results indicate that Bearded Vultures, a species sensitive to human disturbance (Layna and Rico 1991, Donázar et al. 1993), will tolerate the presence of a camera system. Although some pairs changed nest sites, this behavior has also been observed in undisturbed Bearded Vultures, suggesting that our cameras may not have been a factor. We also found that females did not lay eggs at two of our sites. However, Margalida et al. (2003) studied Bearded Vultures in the same area and found that about 25% of paired females did not lay eggs.

The effects of installing cameras near raptor nests during the incubation or nestling periods vary among species. For Bald Eagles, for example, Cain (1985) reported a high rate of nest abandonment after installation of cameras, while Dykstra et al. (2002) reported that nesting success was similar to that at undisturbed nests (72% vs. 75%, respectively). The response of Bald Eagles to cameras is apparently related to a pair's breeding stage when cameras are installed, distance of cameras from nests, or whether eagles are habituated to humans (Cain 1985). In other species, such as Peregrine Falcons (*Falco peregrinus*; Enderson et al. 1972) and Ospreys (*Pandion haliaaetus*; Steidl et al. 1991, Kristan et al. 1996), no negative reactions to cameras were observed. Possible negative impacts may be avoided or reduced by installing camera systems during the pre-laying period. In addition, installing camera systems during the pre-laying period (1) may allow the birds to become accustomed to the system and accept its presence before breeding begins, (2) provides time to check the system and correct technical problems, and (3) leaves time to move systems if pairs change nest sites. Our system also allows a study to be carried out without having to visit nest sites after installation (except when technical problems arise). This reduces the potential negative effects the presence of a researcher would have on the breeding effort.

Our camera systems permitted us to study the breeding biology of Bearded Vultures (Margalida et al. 2002, 2004, 2005) without causing a decrease in productivity. For example, we were able to identify 81.5% of the prey remains at nest sites and 88% of prey delivered by adults, a higher percentage than that obtained using telescopes (55.1% and 88.2%, respectively; Margalida et al. 2005). Similarly, Booms and Fuller (2003), using a time-lapse video system, were able to identify 95% of the prey delivered to nest sites by Gyrfalcons (*Falco rusticolus*). Additional advantages of our system include: (1) the receiving system is easily transported for use at different nests, and (2) the ability to observe interactions in the vicinity of the nest (<500 m) while nest sites are being videotaped.

One disadvantage of our camera system is that someone must be present when recording (to change tapes). Other potential disadvantages include mechanical failure and the cost and time invested in monitoring. Chances of mechanical failure can be reduced by increasing the capacity of the batteries, the size of the solar panels, the use of wind-powered battery chargers, and the use of repellents to keep mammals away from the equipment. Also, to permit access to equipment that fails without disturbing the birds, transmission and power systems should, if possible, be placed where they cannot be seen from the nest.

Using solar power to charge batteries may not be as reliable in non-arctic climates or in seasons when less sunlight is available (Booms and Fuller 2003). One possible solution to this problem would be the use of wind-powered battery chargers. These devices can replace the solar panels and can be especially effective in cliffs facing the north that receive little sunlight. In addition, wind-powered battery chargers would permit the use of infrared cameras because batteries could be recharged at night.

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