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Use of digital trail cameras to study Bonelli's eagle diet during the nestling period

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Abstract
The study of avian diet is one of the most commonly discussed topics in Ornithology. Different methods such as direct observations of hunting, analysis of pellets and collection of prey remains have usually been employed to study avian diet. Fortunately, digital technologies have rapidly advanced in recent years, allowing researchers to increase our understanding of avian behaviour. Here we report the outcomes of a pilot project to study the diet of Bonelli's eagle (*Aquila fasciata*, Syn = *Hieraaetus fasciatus*) during the nestling period using digital trail cameras. We describe the monitoring system, provide results on dietary composition and discuss advantages and shortcomings of the method employed. Our results show that the main prey delivered to nests were pigeons (*Columba* spp.) and common rabbits (*Oryctolagus cuniculus*). One advantage of the method is the relative low cost of the material employed in contrast to digital video cameras. Disadvantages were the limited duration of power supply of the units and, because recordings can only be obtained at the end of the breeding season, it is not possible to fix the device if a problem arises. Nevertheless, in the light of our results, we recommend the use of digital trail cameras as an efficient, non-intrusive method to study the diet of cliff-nesting raptors, given that, in combination with traditional methods, it facilitates estimation of dietary composition in an objective, economic, contrastable and unbiased manner.

Keywords: Aquila fasciata*, behaviour, dietary composition,* Hieraaetus fasciatus*, pellets*

Introduction

The study of avian diet is one of the most commonly discussed topics in Ornithology. Direct observations of hunting, analysis of pellets and collection of prey remains are methods usually employed to study avian diet (e.g. Martí 1987; Simmons et al. 1991; Mersmann et al. 1992; Oro & Tella 1995; Lewis et al. 2004; López-López et al. 2009). However, in many cases data are difficult to obtain because of the endangered status of the species, nesting habitat (e.g. birds nesting on cliffs), or because birds are prone to disturbance due to human presence (for a complete review see Rosenberg & Cooper 1990). This is the case for Bonelli's eagle (*Aquila fasciata*, Syn = *Hieraaetus fasciatus*), an endangered species distributed across the Paleartic, Indomalayan and marginally Afrotropical region (Ferguson-Lees & Christie 2001), with its main stronghold in the European Mediterranean region, mostly in Spain. The species, previously named *Hieraaetus fasciatus*, has been recently reclassified to *Aquila fasciata* (Sangster et al. 2005; Cadahía et al. 2009).

Digital technologies have rapidly advanced in recent years, allowing researchers to increase our understanding of avian behaviour. The use of automatic devices to record diet or nesting behaviour of birds goes back 40 years (e.g. Enderson et al. 1972; Rosenberg & Cooper 1990; reviews in Cutler & Swann 1999; and Booms & Fuller 2003). Recent examples of raptor studies are the time-lapse video monitoring of nests (reviewed in Reif & Tornberg 2006). In Spain, solar-powered video cameras were used to monitor Bearded Vultures (*Gypaetus barbatus*; Margalida et al. 2006) and Bonelli's eagle, as part of an educational and recreational program in the

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Garraf Natural Park (www.diba.es/parcsn/parcs/plana.asp?parc=10&m=192&o=5).

Preliminary results on distribution pattern (López-López et al. 2004), habitat selection (López-López et al. 2006), demography (López-López et al. 2007b; Soutullo et al. 2008), and conservation (López-López et al. 2007a) of Bonelli's eagle have been previously reported in eastern Spain. In addition, several studies have tried to assess the diet of this species across its range, both during the breeding (Jordano 1981; Palma et al. 1984, 2006; Simeon & Wilhelm 1988; Real 1991; Martínez et al. 1994; Gil-Sánchez 1998; Gil-Sánchez et al. 2000, 2004) and the non-breeding season (Cheylan 1977; Iezekiel et al. 2004; Moleón et al. 2007). However, these studies were based on traditional methodologies, mainly pellet analysis and collection of prey remains, and thus are all sensitive to bias depending on the method employed in each case and prey species-specific biology (see Rosenberg & Cooper 1990 for a review; see also Real 1996 for the specific case of Bonelli's eagle).

Here we report the outcomes of a pilot project to study the diet of Bonelli's eagle during the nestling period using digital trail cameras. As far as we know, this is the first time that digital trail cameras have been used for a dietary analysis of this raptor species. We describe the monitoring system, provide some results on dietary composition and also discuss the advantages and shortcomings of the method employed.

Materials and methods

Study species

The Bonelli's eagle is a medium-size cliff-nesting raptor whose breeding season starts in December–January and ends in May–June when the young fledge (Ferguson-Lees & Christie 2001). Egg-laying takes place from January to March, with a mean incubation period of 39 days (Arroyo et al. 1995). Usually the clutch size varies from 1–3 eggs with a modal breeding performance of 1–2 fledglings (rarely 3) (López-López et al. 2007a). Eighty percent of the European population breeds in Spain, where the species is catalogued as Endangered according to the IUCN (Real 2004). We applied digital trail cameras to study the diet of three pairs located in Alicante province, southeastern Spain (Figure 1), during the 2007 breeding season. Breeding pairs were located in the municipalities of Albatera (pair A), Monòver (pair B) and Finestrat (pair C). All pairs were also monitored during the breeding season using spotting scopes with a magnification of 20–60 × Leica Televid 77®. Nests were monitored at a distance larger than 300 m to avoid disturbing eagles.

Photographic material

We employed digital trail cameras (Bushnell Trail Scout®) with 2.1 Mega pixels of resolution. This device is currently available at hunting stores, and

Figure 1. Iberian Peninsula (including Spain and Portugal). The Alicante province (study area) is shaded in grey.

was originally designed to remotely capture animal activity, mainly game mammals, at a maximum distance of 30 m by means of an infrared sensor. This sensor is activated by means of animal movement, which prevents its activation by rain or vegetation blown by the wind. The photographic equipment is assembled in a stagnate plastic box equipped with security measures to avoid manipulation or even theft. The unit is powered with four D-cell alkaline batteries (1.5 V) and images are stored on an SD card (1 GB). It can take pictures or even videos up to 15 s, but not both at the same time. When a picture is taken, the device is stopped automatically for an interval of 30 s, 1 min or 2 min. Given that the trade-off between the number of images captured and power supply, we programmed them to take a picture at 2 min intervals to make the power supply last as long as possible. The camera is equipped with a conventional flash to take pictures during the night at a maximum distance of 10 m.

Camera set up and installation

We programmed the camera to initiate activity just before dawn and to finish recording after sunset, to avoid disturbing the eagles during the night. The sound level, although not stated by the manufacturer, was almost imperceptible to human hearing, and given that this type of device is designed to capture fauna in the wild it is estimated not to disturb eagles. We did not manipulate the photographic equipment to install an external power source (solar, wind) to avoid installing electronic material (batteries, cables) on the cliffs where eagles nested, thus avoiding disturbance during the breeding period.

Bonelli's eagles usually have several nests in a breeding territory and normally change breeding nest every breeding season. Thus, cameras were not installed until the active nest with the breeding pair was found. We installed cameras when eagles had small chicks of about 15–25 days based on our own experience in tagging juvenile Bonelli's eagles with satellite transmitters and in obtaining samples for parasites in chicks. The first camera was installed on 23 March 2007, the second on 11 April 2007 and the third on 8 May 2007. Nestlings' age was estimated from feather development by observations with a spotting scope according to the figures given by Gil-Sánchez (2000). We selected nestlings' age for two main reasons: (1) in this period, the chance of abandoning the brood is lower than during the incubation period, the most sensitive phase of the breeding cycle; (2) eaglets are not small enough to suffer from hypothermia due to absence of the parents and they are still too young to fall off the cliff. The installation was conducted by three people experienced in handling raptors; two of them, rock-climbers, went to the top of the cliff and the other stayed below the cliff to supervise the operation. Photographic devices were fixed in a hole drilled in the cliff at a minimum distance of 1 m from the nest (the minimum focal distance of the camera). In all cases the installation procedure was performed in the early hours of the morning when parents are both hunting and are out of the immediate vicinity of the nest. After installing the units, we conducted follow-up surveys to ensure that parents returned to the nest and fed the chicks.

Fledging performance (chicks fledged per nest) was recorded as well as the characteristics of the nest site (cave, open ledge or sheltered ledge) and the age of parents (adults or subadults or the combination of adult/subadult) as described in López-López et al. (2007a).

Prey identification

Prey were identified by comparing with field guides of Spanish birds (Jutglar & Masó 1999) and mammals (Blanco et al. 1998). Average prey biomass was also recorded from the bibliography. In all cases, prey were determined and recorded by both authors in accordance with the observations of the photographic material.

Results

Three cameras were installed in the 2007 breeding season. Mean installation time was 77 ± 10 min (range = 66–85 min; n = 3). The average time between camera installation and the first observation of the parents was 49 ± 32 min (range = 19–82 min; n = 3) and between device installation and first entry of parents in the nest was 146 ± 128 min (range = 45–290 min; n = 3).

Pairs were formed by two adults in all cases and all chicks fledged in all nests (a successful fledgling rate of 100%): two chicks in pairs A and B and one chick in pair C. One nest was placed on an open ledge and two on a sheltered ledge.

We only obtained pictures of two nests (pairs B and C), due to a failure in power supply since batteries were moved during installation and the camera installed in pair A could not initiate recording. From the two remaining cameras, we obtained 3074 pictures, 1546 from one camera and 1528 from the other. Of these, 1128 and 1190 pictures were valid, respectively (73% and 78%), while the remainder were completely black. Cameras operated continuously during 17 and 16 days with the programmed duty cycle.

Table I. Prey items recorded on the two Bonelli's eagle's nests using digital trail photographic cameras during the 2007 breeding season.

Nest B	Date	Prey	Nest C	Date	Prey
	11 April	*Cavia tschudii**		12 May	Undetermined bird
	11 April	*Columba* sp.		14 May	*Oryctolagus cuniculus*
	13 April	*Columba* sp.		16 May	*Oryctolagus cuniculus*
	14 April	*Lepus granatensis*		21 May	*Columba* sp.
	15 April	*Alectoris rufa*		22 May	*Oryctolagus cuniculus*
	16 April	*Columba* sp.			
	18 April	*Dendrocopos major*			
	18 April	*Accipiter nissus*			
	19 April	*Columba* sp.			
	22 April	*Oryctolagus cuniculus*			
	23 April	*Oryctolagus cuniculus*			
	24 April	*Alectoris rufa*			
	26 April	*Columba* sp.			

*Delivered by the climbers.

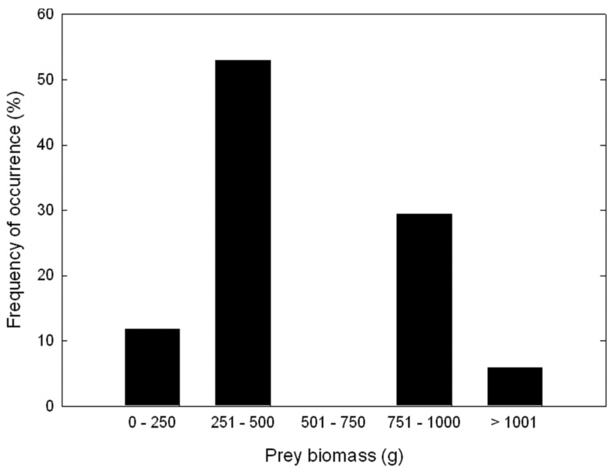

Figure 2. Prey delivered by adult Bonelli's eagles during the nestling period recorded with digital trail photographic cameras according to average prey biomass.

We recorded a total of 17 prey items brought to nests, 12 from nest B and 5 from nest C. Diet was mainly composed of pigeons (*Columba* spp.) and rabbits (*Oryctolagus cuniculus*) (Table I). Of prey delivered to nests, 94.12% were identified. Average prey biomass was recorded in the intervals between 251 and 500 g and between 751 and 1000 g (Figure 2). An example of two pictures recorded at nest B is shown in Figure 3.

Figure 3. Example of two pictures taken with digital trail cameras to study Bonelli's eagle diet during the nestling period. In both cases the female is present at the nest and the prey delivered are (**A**) Iberian hare (*Lepus granatensis*), and (**B**) pigeon (*Columba* sp.).

Discussion

The use of electronic devices has provided new insights in the study of poorly known stages of avian biology; for example, the use of satellite transmitters to study bird movements (e.g. Cadahía et al. 2005, 2008). A number of papers have recently been published in relation to the study of breeding ecology by means of digital equipment (see Reif & Tornberg 2006 for a review; e.g. Bolton et al. 2007). These papers have shown non-negative effects on breeding behaviour due to the installation of cameras in most raptor species such as Bald Eagle (*Haliaeetus leucocephalus*) (Dykstra et al. 2002), Peregrine Falcon (*Falco peregrinus*) (Enderson et al. 1972), Ospreys (*Pandion haliaetus*) (Kristan et al. 1996) or Bearded Vulture (Margalida et al. 2006), amongst others. This is an important issue, as disturbance caused by researchers on raptors is subject to debate, and obtaining permission to access the nests is not always easy. Disturbance may vary in relation to the habituation of raptors to human presence as well as with regard to the technical equipment to be installed, or even the stage of the breeding season in which electronic devices are installed into the nest (Cutler & Swann 1999; Mcquillen & Brewer 2000; Reif & Tornberg 2006).

One of the advantages of our method is that it is non-invasive once the camera is set up. In addition, unlike traditional methods for studying diet, it allows data to be obtained continuously without much field effort, and it is the least biased method for estimating diet composition (Rosenberg & Cooper 1990). Also, images are the most objective material and allow repeated analysis by several experts and various uses in future studies with different objectives (Reif & Tornberg 2006). Indeed, this is not a secondary question, as reliability of data is unfortunately not always guaranteed in dietary studies.

As mentioned above, this is a pilot project, and a small quantity of cameras could be installed. In this sense, our results do not allow us to obtain conclusive results about feeding ecology of Bonelli's eagle. Given that it was out of our scope and because of the small sample size, we did not perform any statistical comparison because it would lack biological and statistical meaning. Even so, diet composition between the two monitored pairs was variable and interesting data were obtained. Both Bonelli's eagle breeding pairs delivered prey to chicks mainly in the early hours of the morning. The feeding rate was higher in the pair with two chicks (pair B) than in the pair with only one chick (pair C), as initially expected. In addition, pair B showed a much varied dietary composition, mostly avian-based. According to the camera records, the main delivered prey were pigeons (*Columba* spp.) and rabbits (*Oryctolagus cuniculus*), but the presence of other less-reported prey items such as Great Spotted Woodpecker (*Dendrocopos major*) and Sparrow Hawk (*Accipiter nisus*) is also interesting (Table I). We also collected remains of Red Partridge (*Alectoris rufa*), pigeons (*Columba* spp.), Ocellated Lizard (*Timon lepidus*) and Yellow-legged Gull (*Larus cachinnans*) in the base of usual roosting places in the vicinity of nests. Although some of these prey were not reported to be delivered to nestlings, their presence could be explained due to different composition of the diet of adults and nestlings during the breeding period. In contrast, pair C delivered mostly rabbits (*Oryctolagus cuniculus*), although some pigeons and an undetermined bird were also reported (Table I). The contribution of bigger prey as well as the existence of only one nestling could also explain the lower feeding rate of this pair.

We noted two main disadvantages of this method: (1) the limited duration of power supply of the cameras; and (2) because recordings can only be obtained at the end of the breeding season, it is not possible to fix the equipment if a problem arises. In contrast, using less electronic material (e.g. batteries, solar cells, wiring, etc.) and not using external power supplies reduces the chances of mechanical failure, as reported in other more complex monitoring devices like digital video cameras (Margalida et al. 2006). In addition, more advanced units require the participation of field crews experienced in both climbing and electronics, which is not always available. The presence of mammals that could chew the cables should also be taken into account (Margalida et al. 2006).

This system has several advantages over traditional methods and some other cameras. One advantage of the method is the relative low cost of the material employed ($400 per camera), in contrast to digital video cameras (usually more than $3000 per camera). Moreover, the installation procedure is simple and quick if performed by experienced climbers. It is important to note that there is a trade-off between power supply duration and the number of pictures that can be taken. In our case, although we programmed the devices for lasting as long as possible, only data on 16–17 days could be gathered. Therefore, it is difficult to obtain pictures of the entire nesting period, and most invalid pictures were taken at the end of the recording period. However, there were no differences between duration of the cameras between the nest with one chick and the nest with two chicks. Cameras are activated by means of bird movement, so nests with more activity should be expected to run down batteries quicker than those with less activity. Nevertheless, power supply duration could vary in relation to external temperature, the use of a flash and the quality of the batteries (Reif & Tornberg 2006) and the employed equipment. Depending on manufacturers, there are different models on the market with nominal average duration varying from 15 to 150 days. The use of long-life batteries would improve the expected life of the digital device. We also recommend the use of adhesive tape to hold batteries in place, avoiding a failure in power supply during installation. In our case, one camera was reset, the duty cycle was lost and no images could be obtained because of this problem.

In conclusion, we recommend the use of digital trail cameras as an efficient non-intrusive method to study diet of cliff-nesting raptors. This method, in combination with pellet and prey remains collection, would lead to estimate dietary composition in an objective, economic, contrastable and unbiased manner (Oro & Tella 1995; Lewis et al. 2004; López-López et al. 2009). We recommend installing the cameras cautiously by experienced climbers, and preferably in nests of pairs habituated to human presence to some extent. Furthermore, this method enables interesting information to be obtained, not only about diet but also about nesting ecology and behaviour of birds that, otherwise, would be costly both in personal and economic terms. On this subject, the use of digital automatic devices can potentially provide new insights on other aspects of breeding ecology such as cainism, self- and allopreening times/activities, times of mating, times of prey deliverance, site guarding and chicks attending, among others.

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