J. Field Ornithol. 76(1):40–45, 2005

Assessing the diet of nestling Bearded Vultures: a comparison between direct observation methods

Antoni Margalida,[1] Joan Bertran, and Jennifer Boudet

Bearded Vulture Study and Protection Group, Apdo 43, E-25520 El Pont de Suert, Lleida, Spain

Received 29 October 2003; accepted 29 March 2004

ABSTRACT. We compared direct observation methods to assess the diet of nestling Bearded Vultures in the Pyrenees northeastern Spain. Using video cameras and telescopes, diet was determined from observations of food items delivered to, and prey remains in, nests. Using video cameras, the proportion of prey identified in remains in nests was significantly greater than that identified using telescopes, but no differences were found in food items delivered to the nest and in the species composition of the diet. Data suggest that the proportion of prey identified in food items delivered was greater than that identified in prey remains. Prey remains and food items delivered grouped by taxa showed significant differences, with the remains underrepresenting small prey. By combining data on prey remains and food items delivered, these biases can be reduced or eliminated. The results suggest that the combination of prey remains and food items delivered allow one to increase sample size without biases and thus to optimize the considerable investment in time that this method of direct observation involves.

SINOPSIS. **Dieta de los pollos de *Gypaetus barbatus*: comparación entre métodos de observación directa**

Comparamos métodos de observación directa para determinar la dieta de los pollos de Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos (NE España). Utilizando videocámaras y telescopios, la dieta fue determinada directamente a través de los restos aportados al nido y la observación de restos presentes en él. Con las videocámaras, la proporción de restos identificados presentes en el nido fue significativamente mayor que utilizando telescopios, aunque no se encontraron diferencias en la composición de especies presentes en la dieta. Los datos sugieren que en los restos aportados, la proporción de restos identificados fue mayor que en los restos presentes. Los restos presentes y los restos aportados agrupados por taxones mostraron diferencias significativas: los restos presentes infravaloraron las presas pequeñas. Combinando los datos de restos presentes y aportados, los sesgos pueden ser reducidos o eliminados. Los resultados sugieren que la combinación de los restos presentes y los aportados permite incrementar el tamaño de muestra sin sesgos y por tanto optimizar la importante inversión de tiempo que supone la utilización de este método de observación directa.

Key words: Bearded Vulture, diet, food, *Gypaetus barbatus*, prey remains, telescope, video camera

The Bearded Vulture (*Gypaetus barbatus*) is a solitary and territorial bone-eating vulture (Hiraldo et al. 1979). Unlike most vulture species that deliver food to the nest in their crop, the Bearded Vulture carries prey remains to the nest in its talons and bill and does not feed its young by regurgitation (Brown and Plug 1990; Margalida and Bertran 2000). Nevertheless, detailed information on the Bearded Vulture's diet is scarce (Brown and Plug 1990; Thibault et al. 1993; Margalida and Bertran 1997; Margalida et al. 2001), and a better understanding of the composition of its diet may have significant implications for the conservation of this endangered species.

The main problems in studying the Bearded Vulture's diet compared with those of other raptors are (i) it feeds on the remains of dead animals, especially their bones, that are difficult to identify and can be fully digested by the birds (Houston and Copsey 1994; Robert et al. 2002); (ii) pellets are not abundant and are occasionally recycled, i.e., the birds eat remains that were not fully digested the first time (Margalida and Bertran 1996); and (iii) this species uses caches, especially larger bones that are first broken up by dropping them onto rocks from a height (Heredia 1991a; Bertran and Margalida 1996; Margalida and Bertran 2001). No study has tested for biases in diet determination of this species.

Biases associated with different methods used in the study of raptor diets have been analyzed in several species (e.g., Collopy 1983; Simmons et al. 1991; Mersmann et al. 1992; Real 1996; Redpath et al. 2001). Of the different methods used, direct observation provides the most com-

[1] Corresponding author. Email: margalida@gauss.entorno.es

plete and accurate estimate of the diet. Because this method requires a great deal of time (Marti 1987), the use of video cameras (e.g., Delaney et al. 1998; Booms and Fuller 2003) can optimize the time invested and reduce disturbance to breeding birds (Margalida et al. 2002a).

Recently, video cameras were installed in six Bearded Vulture nests, allowing the collection of detailed information on the food provisioning of nestlings (Margalida et al. 2002a,b). The aims of this paper are to describe the type of food provided to Bearded Vulture nestlings using telescopes and video cameras, and to compare the use of prey remains with the method of using delivered prey; to evaluate the diet of nestling vultures by using both methods separately and together; and to propose management recommendations that can be applied to the conservation of this endangered species.

METHODS

Study area. The study was carried out in the Catalonian Pyrenees in northeastern Spain. The area contains 29 territories of Bearded Vultures. Breeding regularly occurs in 20 of those territories, all of which have been monitored intensively. The mean (± SD) productivity in 1992–1999 was 0.43 (±0.28) fledglings/breeding pair/year (N = 119 breeding attempts; Margalida et al. 2003). Nests are generally situated in caves on inaccessible cliffs (Heredia 1991b), so the collection of data is difficult.

In this area, Bearded Vultures feed mainly on dead domestic and wild ungulates (Margalida et al. 2001). Calculations of food availability suggest that pairs have sufficient food to cover their annual energy requirements during the breeding season, estimated at 223 kg/pair/breeding attempt (Margalida et al. 1997). There are also seven feeding stations that supplement the birds' food in winter.

Data collection. Seven breeding pairs were intensively monitored during 1931 h of observations. Four of these pairs were monitored with telescopes (N = 51, 154, 207 and 148 food items observed respectively) and three with video cameras (N = 83, 301 and 292 food items, respectively). We observed prey brought to the nest by vultures from mid-February to late July in 1996–2002. The frequency of observations was minimally two visits per week per nest, from hatching until fledging. The observations were carried out between 06:00 and 21:00 h, covering all hours of daylight. Observations in nests monitored with telescopes were done with a 60–90× Questar telescopes from blinds at a distance of 100 m. Light conditions at these nests were good, and they were in open locations (cornices and overhangs), allowing the activity in the nests to be observed in great detail. In the other three nests, we installed cameras connected to 2.4 GHz-10 mW radio receivers by a coaxial audiovisual cable. The transmission system was powered by solar panels. The image was received at <3 km via a Sony mini DV receiver with an LCD screen programmed at the same frequency as the 2.4 GHz transmitter (Margalida et al. 2002a,b).

With both monitoring systems (video cameras and telescopes), we were able to identify the food items delivered to the nest (N = 25, 63, 95 and 51 food items observed with telescopes, respectively and N = 68, 145 and 139 food items observed with video cameras, respectively), and the prey remains present in the nest (N = 26, 91, 112 and 97 food items with telescopes, respectively, and N = 15, 156 and 153 food items with video cameras, respectively). Food items delivered to the nest were considered to have been brought after foraging. Prey remains were considered to have been in the nest before the day's observation. The identification of the two categories of prey (remains and delivered items) was possible during the adults' manipulation of the food for their own consumption or to feed their young. Food items were separated into six categories: large mammals (e.g., cow [*Bos taurus*], horse [*Equus caballus*]); medium-size mammals (e.g., sheep [*Ovis aries*], wild boar [*Sus scrofa*], southern chamois [*Rupicapra pyrenaica*]); small mammals (e.g., rabbit [*Oryctolagus cuniculus*], beech marten [*Martes foina*], red fox [*Vulpes vulpes*]); other small mammals categorized as micro-animals (e.g., common mole [*Talpa europaea*], wood mouse [*Apodemus sylvaticus*]); birds, and reptiles. Because most of the remains were parts of dead animals, prey biomass was not estimated. Comparisons between taxa and prey categories obtained by both methods of diet assessment (telescopes vs. video cameras and prey remains vs. food items delivered) were performed by means of chi-square contingency tables, and statistical significance was set at $P < 0.05$ (Sokal and Rohlf 1995).

Table 1. Diet of nestling Bearded Vultures determined from prey remains in the nest (PR) and food items delivered to the nest (FID) using video cameras (*N* = 3 nests) and telescopes (*N* = 4 nests).

	Video camera			Telescope		
	PR (%)	FID (%)	PR + FID (%)	PR (%)	FID (%)	PR + FID (%)
Mammals						
Large mammals	1.9	2.6	2.3	10.2	5.2	7.9
Medium mammals	90.5	80.9	85.3	70.2	61.1	66
Small mammals	4.9	12.3	8.9	13.3	17.6	15.3
Micro-animals	0	1.95	1	0.9	7.8	4.1
Birds	2.7	1.95	2.3	4.5	6.7	5.5
Reptiles	0	0.3	0.2	0.9	1.6	1.2
Total (*N*)	264	309	573	225	193	418

RESULTS

Camera vs. telescope in prey identification. The proportion of prey identified in prey remains present in the nest using cameras was greater than the proportion of remains identified with telescopes (81.5 vs. 55.1%, $\chi^2_1 = 12.98$, $P = 0.001$), but no differences were found in the identification of prey delivered to the nest (12.2 vs. 17.5%, $\chi^2_1 = 2.8$, $P = 0.094$).

Dietary differences between food items delivered and prey remains using video cameras. Of 352 food items delivered to the nests, 309 (87.8%) were identified by video camera, representing 19 species. Of these, 97.8% were mammals, 1.9% birds, and 0.3% reptiles. Considering the mammals alone (*N* = 302), 82.8% were medium-sized, 12.6% small, 2.6% large, and 2% micro-animals. Of 324 prey remains observed in the nest, 264 (81.5%) were identified, representing to 14 species. The proportion of prey identified in food items delivered to the nest was greater than the proportion identified in the prey remains present in the nest ($\chi^2_1 = 4.7$, $P = 0.03$). Of these, 97.3% were mammals and 2.7% birds. Considering mammals alone (*N* = 257), 93% were medium-sized, 5% small, and 2% large (Table 1). Comparing methods, no differences were found in species composition of the diet ($\chi^2_2 = 1.2$, $P = 0.55$).

In total, eight species (three birds, three small mammals and two micro-animals) were identified from food items delivered to the nest that were not identified in prey remains in the nest. Four species (two birds and two small mammals) were identified in the prey remains in the nest but not observed being delivered to the nest. No differences were found in the number of species identified ($\chi^2_1 = 1.2$, $P = 0.27$).

Comparison of prey remains observed in the nest and food items delivered to the nest grouped by taxa (Table 1) showed significant differences among the six categories of prey ($\chi^2_5 = 16.9$, $P = 0.005$). The number of small mammals was underestimated in prey remains observed in the nest. The number of food items delivered to the nest, and the latter plus prey remains present, did not differ among the six prey categories ($\chi^2_5 = 4.3$, $P = 0.50$).

Differences between prey remains and food items delivered using telescopes. Of 234 food items delivered to the nest, 193 (82.5%) were identified, representing 25 species. Of these, 91.7% were mammals, 6.7% birds, and 1.6% reptiles. Considering mammals alone (*N* = 177), 66.7% were medium-sized, 19.2% small, 8.5% micro-animals, and 0.5% large. Of 326 prey remains observed in the nest, 225 (69%) were identified, representing to 24 species. The proportion of prey identified in food items delivered to the nest was greater than the proportion identified in the prey remains in the nest ($\chi^2_1 = 12.3$, $P < 0.001$). Of these, 94.7% were mammals, 4.4% birds, and 0.9% reptiles. Considering mammals alone (*N* = 213), 74.2% were medium-sized, 14.1% small, 10.8 large, and 0.9% micro-animals (Table 1). Comparing methods, no differences were found in species composition of the diet ($\chi^2_2 = 1.5$, $P = 0.48$).

In total, 10 species were identified from food items delivered to the nest (five birds, three small mammals, and two micro-animals) that were not identified in prey remains observed in the nest, whereas eight species (five birds, two small mammals, and one medium-sized mammal) were identified as prey remains in, but were not observed being delivered to, the nest. No significant difference was found in the number of species identified ($\chi^2_1 = 0.04$, $P = 0.84$).

Results of prey remains observed in the nest and food items delivered to the nest grouped by taxa (Table 1) showed differences between the six categories of prey ($\chi^2_5 = 19.4$, $P = 0.0012$). The number of micro-animals was underestimated in prey remains observed in the nest. The number of food items delivered to the nest, and the latter plus remains present, did not differ among the six prey categories ($\chi^2_5 = 6.2$, $P = 0.28$).

DISCUSSION

Video cameras provided more information on the identification of prey remains present in the nest but not for delivered prey. Different pairs were studied with each system, and this could produce some of the variation because of the availability of prey in each of territory. However, the individual analysis with each method showed similar results, suggesting that the proportion of prey identified in food items delivered was greater than the proportion identified in prey remains, prey remains and food items delivered showed significant differences grouped by taxa, the combination of food items delivered plus prey remains compared with food items delivered was not significant. This suggests that when determining the diet of this species, the combination of both methodologies would allow for an increase in sample size and the number of species identified, thus optimizing the time invested in this lengthy procedure (Marti 1987).

The results show that the identification of food items delivered to the nest provides significantly more information than the prey remains present in the nest. In our study, 12% (cameras, $N = 352$) and 17.5% (telescopes, $N = 234$) of the food items delivered were not identified, a similar percentage (17%, $N = 104$) to that obtained with 40× telescopes by Brown and Plug (1990) working on Bearded Vultures in South Africa. In addition, the percentages of non-identified remains were 18.5% with cameras ($N = 324$) and 31% with telescopes ($N = 321$). This was due to the food items delivered being more intact and the presence of fur or feathers making them easier to identify. The greater proportion of remains and food items delivered that were identified with video cameras probably resulted because images can be viewed at slow speeds and reviewed by experts.

The determination of diet through the analysis of remains alone could result in a lower measure of prey diversity because most of the unidentified remains were small food items, such as small birds or parts of small mammals. These food items are generally delivered in the bill, and directly consumed by the chick or rapidly torn into pieces as soon as the adult arrives at the nest, and the observation time for their identification thus is limited. To avoid these biases, it has been suggested for other species that a combination of direct observations and pellet analysis would give the best representation of prey diversity (e.g., Redpath et al. 2001). However, in the Bearded Vulture, pellets are scarce and occasionally recycled (Margalida and Bertran 1996), making it difficult to use this method.

The prey-remains method did not show any significant differences from delivered prey in a study of eagles (Real 1996). In contrast, our study revealed differences when food items were grouped by taxa. The number of micro-animals was underestimated in prey remains, probably because of their size and hence differential detectability. Small food items such as micro-animals were either directly or partly consumed, and dismembered items were not always identifiable. However, this is a minor issue because micro-animals are not an important part of the Bearded Vulture's diet. One would also expect that large mammals would be overestimated in prey remains. However, this was not the case, probably because most of the individuals taken were very young and whose remains were small and easily carried (Robert et al. 2002), thus remaining in the nest for shorter periods.

The biases associated with other diet-determination methods, such as collections made after the breeding season, are unknown. However, there is seasonal variation in the Bearded Vulture's diet (Margalida and Bertran 2001), which would make periodic collections during the breeding season necessary. Because this would require disturbance to this endangered species, this methodology is not advisable. If remains are collected after the breeding season, large mammals and birds would probably be overestimated because they are easy to detect. In addition, the removal of prey remains by scavengers (red fox, beech marten), as suggested in other species, may also reduce detection (Oro and Tella 1995). The use of video cameras appears to solve many of the problems with other methods.

While medium-sized mammals (principally wild and domestic ungulates) are the most important species in the Bearded Vulture's diet (Hiraldo et al. 1979; Margalida and Bertran 1997), it must be recognized that small food items are also important (17.5% of the total), probably because of the large proportion of meat (as opposed to just bone) they provide (Margalida and Bertran 1997, 2001). Most breeding failures in this species take place during hatching, and food quality may be a limiting factor for breeding success (Margalida et al. 2003). The provisioning of food, via feeding stations, with a higher meat content during February–April may increase breeding success in Bearded Vultures.

ACKNOWLEDGMENTS

We thank M. Arilla, P. Arilla, J. Canut, S. Ecolan, D. García, R. Heredia, J. M. Martínez, and P. Romero for help with field work. The comments of M. A. Anderson, G. R. Bortolotti, S. Mañosa, and an anonymous reviewer improved the manuscript. S. Hardie translated the text into English. This study was supported by the Dirección General de Conservación de la Naturaleza of the Ministerio de Medio Ambiente and Departament de Medi Ambient of the Generalitat de Catalunya.

LITERATURE CITED

BERTRAN, J., AND A. MARGALIDA. 1996. Patrón anual de observaciones de Quebrantahuesos (*Gypaetus barbatus*) de diferentes grupos de edad en los sectores de nidificación. Alauda 64: 171–178.

BOOMS, T. L., AND M. R. FULLER. 2003. Time-lapse video system used to study nesting Gyrfalcons. Journal of Field Ornithology 74: 416–422.

BROWN, C. J., AND I. PLUG. 1990. Food choice and diet of the Bearded Vulture *Gypaetus barbatus* in southern Africa. South African Journal of Zoology 25: 169–177.

COLLOPY, M. W. 1983. A comparison of direct observations and collections of prey remains in determining the diet of Golden Eagles. Journal of Wildlife Management 47: 360–368.

DELANEY, D. K., T. G. GRUBB, AND D. K. GARCELON. 1998. An infrared video camera system for monitoring diurnal and nocturnal raptors. Journal of Raptor Research 32: 290–296.

HEREDIA, R. 1991a. Alimentación y recursos alimenticios. In: El Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos (R. Heredia, and B. Heredia, eds.), pp. 79–89. ICONA, Colección Técnica, Madrid, Spain.

———. 1991b. Biología de la reproducción. In: El Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos (R. Heredia, and B. Heredia, eds.), pp. 27–38. ICONA, Colección Técnica, Madrid, Spain.

HIRALDO, F., M. DELIBES, AND J. CALDERÓN. 1979. El Quebrantahuesos *Gypaetus barbatus* (*L.*). ICONA, Madrid, Spain.

HOUSTON, D. C., AND J. A. COPSEY. 1994. Bone digestion and intestinal morphology of the Bearded Vulture. Journal of Raptor Research 28: 73–78.

MARGALIDA, A., AND J. BERTRAN. 1996. Quebrantahuesos (*Gypaetus barbatus*) ingiriendo sus propias egagrópilas. Butlletí del Grup Català d'Anellament 13: 49–51.

———, AND ———. 1997. Dieta y selección de alimento de una pareja de Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos durante la crianza. Ardeola 44: 191–197.

———, AND ———. 2000. Breeding behaviour of the Bearded Vulture *Gypaetus barbatus*: minimal sexual differences in parental activities. Ibis 142: 225–234.

———, AND ———. 2001. Function and temporal variation in use of ossuaries by Bearded Vultures (*Gypaetus barbatus*) during the nestling period. Auk 118: 785–789.

———, ———, R. HEREDIA, J. BOUDET, AND R. PELAYO. 2001. Preliminary results of the diet of Bearded Vultures (*Gypaetus barbatus*) during the nestling period and applications in conservation and management measures. In: Proceedings of the 4th Workshop of Bearded Vulture (A. Sakoulis, M. Probonas, and S. Xirouchakis, eds.), pp. 59–62. Natural History Museum of Crete and University of Crete, Irakleio, Greece.

———, J. BOUDET, R. HEREDIA, AND J. BERTRAN. 2002a. Videocámaras para la monitorización de la nidificación del Quebrantahuesos (*Gypaetus barbatus*). Ecología 16: 25–333.

———, D. GARCÍA, J. BERTRAN, AND R. HEREDIA. 2003. Breeding biology and success of the Bearded Vulture *Gypaetus barbatus* in the eastern Pyrenees. Ibis 145: 244–252.

———, ———, AND R. HEREDIA. 1997. Estimación de la disponibilidad trófica para el Quebrantahuesos (*Gypaetus barbatus*) en Cataluña (NE España) e implicaciones sobre su conservación. Doñana Acta Vertebrata 24: 235–243.

———, R. HEREDIA, AND J. BOUDET. 2002b. Caméras vidéo pour l'étude de la biologie de la reproduction du Gypaète barbu (*Gypaetus barbatus*): un premier bilan. In: Proceedings of the International Conference "Conservation of Bearded Vulture Populations" (LPO Fir, eds.), pp. 115–121. Paris, France.

MARTI, C. D. 1987. Raptor food habits studies. In: Raptor management techniques manual (B. A. G. Pendleton, B. A. Millsap, K. W. Cline, and D. M.

Bird, eds.), pp. 67–80. National Wildlife Federation, Washington, D.C.

MERSMANN, T. J., D. A. BUEHLER, J. D. FRASER, AND J. K. D. SEEGAR. 1992. Assessing bias in studies of Bald Eagle food habits. Journal of Wildlife Management 56: 73–78.

ORO, D., AND J. L. TELLA. 1995. A comparison of two methods for studing the diet of the Peregrine Falcon. Journal of Raptor Research 29: 207–210.

REAL, J. 1996. Biases in diet study methods in the Bonelli's Eagle. Journal of Wildlife Management 60: 632–638.

REDPATH, S. M., R. CLARKE, M. MADDERS, AND S. J. THIRGOOD. 2001. Assessing raptor diet: comparing pellets, prey remains, and observational data at Hen Harrier nests. Condor 103: 184–188.

ROBERT, I., A. MARGALIDA, AND J. F. SEGUIN. 2002. Contribution à l'étude du régime alimentaire du Gypaète Barbu (*Gypaetus barbatus*): analyse comparée des restes alimentaires prélevés dans les nids et les aires de cassage en Corse et en Espagne. In: Proceedings of the International Conference "Conservation of Bearded Vulture Populations" (LPO Fir, eds.), pp. 75–82. Paris, France.

SIMMONS, R. E., D. M. AVERY, AND G. AVERY. 1991. Biases in diets determined from pellets and remains: correction factors for a mammal and bird-eating raptor. Journal of Raptor Research 25: 63–67.

SOKAL, R. R., AND F. J. ROHLF. 1995. Biometry, 3rd ed. Freeman, New York, N.Y.

THIBAULT, J. C., J. D. VIGNE, AND J. TORRE. 1993. The diet of young Lammergeiers *Gypaetus barbatus* in Corsica: its dependence on extensive grazing. Ibis 135: 42–48.