Supplementary feeding during the chick-rearing period is ineffective in increasing the breeding success in the bearded vulture ()

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ORIGINAL PAPER

Supplementary feeding during the chick-rearing period is ineffective in increasing the breeding success in the bearded vulture (*Gypaetus barbatus*)

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Abstract One of the most widespread tools in the conservation of scavenger species is the provision of supplementary food. However, scientific studies on its effectiveness have been rarely conducted. Here, we present the first results of an experimental specific supplementary feeding programme applied from hatching to 45–60 days, aimed at increasing the breeding success of an obligate brood reducer, the threatened bearded vulture *Gypaetus barbatus*. We tested its effectiveness in the Spanish Pyrenees, the locale of the most important population of this species in the European Union, in which a regressive trend in breeding parameters has been observed in recent years. We compared the breeding success in nests with supplementary food to non-supplemented control nests. Supplementary food did not significantly increase global breeding success (supplemented nests, 0.793±0.193 chicks per pair with eggs hatched vs non-supplemented nests, 0.771±0.185) or the individual breeding performance of the territories (supplemented period, 0.712±0.307 vs non-supplemented period, 0.642±0.311). The similar values obtained suggest that the specific supplementary feeding programme applied during the chick-rearing period is apparently ineffective at increasing breeding success. The results suggest that, at least in the study area, factors that provoke breeding failure after hatching continue to operate independently of the supplementary feeding programme. Although more research on this subject is required, these preliminary conclusions should be taken into account by managers in order to optimise the investment of economic resources and to better prioritise the future establishment of alternative conservation actions.

Keywords Bearded vulture · Breeding success · *Gypaetus barbatus* · Supplementary feeding

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Introduction

In several facultatively siblicidal species, supplementary feeding during the nestling period increases fledging success, suggesting that food requirements of nestlings limit the number of offspring that can be raised (Lack 1947, 1954; Wiehn and Korpimaki 1997; González et al. 2006). However, in obligately siblicidal species, it has been proposed that aggressiveness is not related to food availability (Forbes and Mock 1996). Thus, although in obligate brood reducers it is not possible to increase the fledgling success through supplementary feeding, this management technique may help ensure the rearing of the only brood and increase the global breeding success of a population. Until now, there have been no empirical data on the effectiveness of supplementary feeding in increasing breeding success in an obligately siblicidal species. To test this, we applied an experimental supplementary feeding programme during the chick-rearing period in the bearded vulture *Gypaetus barbatus*, a typical obligate brood reducer (Simmons 1988; Margalida et al. 2004). This species is considered endangered in Europe with 160 territories in the European Union in 2009 and with Spain holding, the most important population with 98 territories (63% of the European population; Donázar et al. 2009b). One of the management measures proposed by the National

Strategy for the Conservation of the Bearded Vulture in Spain (CNPN 2002) is to 'utilize specific food for breeding pairs through the application of a program that delivers meat remains during the critical period of hatching and first weeks of life of the chick'. In this sense, taking into account that most breeding failures take place during hatching and chick-rearing periods, the quality of food and the breeding experience are considered possible factors that influence breeding failures (see Margalida et al. 2003).

One of the most widespread tools in the conservation of this and other vulture species is the creation of feeding stations or vulture restaurants (Brown 1990; Mundy et al. 1992; Gilbert et al. 2007; Donázar et al. 2009b). Although feeding stations (FS) for the non-breeding population of bearded vultures have proven useful in increasing pre-adult survival (Oro et al. 2008), the effectiveness of specific supplementary feeding sites (SSFS) close to nesting sites for the breeding population has not been tested. Thus, managers and policy-makers must have objective data to implement priority conservation measures successfully, based on experimental studies that show the utility or lack thereof of specific conservation tools. In this sense, it has been hypothesised that if food quality (as a consequence of its spatial and temporal unpredictability) is a limiting factor for the breeding success of several pairs with less breeding experience or inhabiting low quality territories limited by food availability (Margalida et al. 2003), then SSFS could be useful in increasing breeding performance. In addition, if the ingestion of poisoned baits is the most important potential mortality factor that principally affects the breeding population (Margalida et al. 2008b; Oro et al. 2008) and other vulture species (see Hernández and Margalida 2008, 2009), SSFS could contribute to reducing or eliminating the effects of this potential threat mitigating breeding failures as a consequence of adult or chick mortality.

Here, we present the first results of an experimental specific supplementary feeding programme for the Spanish breeding population of bearded vultures applied between 2002 and 2009. We discuss the effectiveness of this experimental supplementary feeding programme in order to improve future management conservation measures and optimise the resources invested in conservation programmes.

Materials and methods

The study species

The bearded vulture is a large, territorial bird of prey with a long lifespan, which nests in rocky cliffs (Brown 1988; Margalida and Bertran 2005). In monogamous pairs, both sexes invest equally in rearing the offspring, although males play a more active part in nest building and territorial defence, while tending the nest is more pronounced in females (Margalida and Bertran 2000). Although the species' diet is largely based on the bones of domestic and wild ungulates, they also feed on wild animals such as birds, small carnivores or micro-mammals during the breeding period to feed the nestlings (Margalida et al. 2009).

Study area and methods

The study was carried out in the Catalan Pyrenees in NE Spain between 2002 and 2009. The area contains 35 Bearded Vulture territories, and breeding regularly occurs in 29 of those territories. In this area, during the breeding season, there are seven FS at which supplementary food (principally bone remains and sheep limbs) is provided from November to April. These FS are situated at distances of 4–10 km from the nesting areas and are mainly used by the non-breeding population (see Oro et al. 2008). Taking into account the characteristics of food provided in the FS (bone remains) and the differences in the diet between the chick-rearing period and the rest of the year (Margalida et al. 2009), their use by breeding adults to feed their chicks is low (author's unpublished data). From 2002 to 2009, during the application of the SSFS, we supplemented 20 pairs (n=52 breeding attempts) with food in order to document whether food delivered increased breeding success. During the same period, non-supplemented nests (n=20 of which ten territories were also controlled as supplemented) in adjacent areas and in which hatching was also documented were considered as control nests (n=52 breeding attempts). The mean altitude of the nests studied was 1,450±230 m (range, 1,100–1,700). Prey remains were delivered from the hatching of the first chick until the first 2 months of chick-rearing and were placed at the top of the cliff in which the nest was situated or in a 500-m radius (area defended against conspecifics and heterospecifics; Margalida and Bertran 2005) around the nest. Prey items were delivered in the morning (9.00–11.00 a.m.) every 2 days and consisted of meat remains (generally rabbit remains). The quantity of food provided varied between 2 and 3 kg per delivery (Table 1) and consisted of small pieces of food scattered across a 5-m radius in order to make it easier for the bearded vultures to eat some of it in the presence of other species (e.g. the common raven *Corvus corax* and the griffon vulture *Gyps fulvus*). Observations carried out during the monitoring of the nests suggest that most of the pairs accepted the food supplied, although the way they used it was only quantified in a territory monitored by video cameras.

Table 1 Number of bearded vulture territories involved in the annual SSFP, time duration (in days) of the SSFP and the total number of young that fledged each year

Number of bearded vulture territories involved (n=20) in the annual specific supplementary feeding programme, time (in days) invested delivering food and the total number of young that fledged each year

	Territories supplemented (*n*)	Average number of days invested (range)	Chicks fledged (*n*)
2002	3	7 (6–8)	3
2003	5	18 (12–35)	5
2004	8	11.6 (4–16)	8
2005	12	10.1 (4–17)	10
2006	6	9 (6–15)	4
2007	6	8 (2–14)	3
2008	6	8.8 (2–19)	4
2009	6	8.3 (6–13)	4
Total	52		41

The age of the nestlings and causes of breeding failures during the chick-rearing period were determined by accessing the nest immediately after the confirmation of nest abandonment (generally 1–6 days after breeding failure) with the help of specialist climbers from the Government of Catalonia's Rural Agents Corps and video cameras (Margalida et al. 2006). First, we determined the age at which the chick died, taking into account the date of hatching or the date of egg laying and 53 days of incubation (Margalida et al. 2004). Subsequently, we determined the causes of breeding failure by analysing the remains found in the nest establishing two categories: natural mortality (e.g. adverse weather, predation) and non-natural mortality (e.g. poisoning). We considered adverse weather to be when the period of breeding failure coincided with persistent snow or rain, and it could be seen that the wool lining the nest was completely soaked. The breeding failure was then attributed to possible hypothermia. The remains found were examined and analysed by the Forensic Wildlife Laboratory (LFVS, Madrid). For a detailed description of the methods and techniques used to determine the cause of death, see Hernández and Margalida (2008, 2009) and Margalida et al. (2008b).

Statistical analyses

Using the Wilcoxon test for matched pairs, we began by comparing the average breeding success between supplemented territories in terms of controlling territories during the period in which the supplementary feeding programme (2002–2009) was applied. We then compared the breeding success of nine focal territories in which we obtained data of breeding success during the supplementary period for years in which no supplementation occurred (see Table 2). For these analyses, we only used territories supplemented for at least 3 years. In order to increase the sample size of control data (without supplementary food), we also used breeding attempts carried out during the period 2000–2001. The statistical significance was set at $P<0.05$. Values are presented as means ± SD.

Results

Remains provided were observed delivered to the nest or present in the nest of most of the pairs monitored intensively (with telescopes and/or video cameras) confirming their consumption by breeding bearded vultures. In the only nest monitored with video cameras during 14 days of observations, a total of 34 prey remains were delivered to the nest of which 26 (74.5%) pertained to the remains provided by the SSFP.

Other species as the griffon vulture, common raven, red kite (*Milvus milvus*), golden eagle (*Aquila chrysaetos*) and Egyptian vulture (*Neophron percnopterus*) were also observed eating the remains provided.

No relationship was found between the average number of days of food delivered (Table 1) and the breeding success (r_s=0.30, $P>0.05$, n=8).

Differences in breeding success

The average breeding success for the 20 territories supplemented with food was 0.793±0.193 chicks/pairs

Table 2 Differences in the breeding performance of nine focal bearded vulture territories with a without the application of the SSFP

Territory	With SSFP		Without SSFP	
	Success	Failure	Success	Failure
A	1	3	2	0
B	3	0	3	1
C	6	0	3	1
D	2	2	2	3
E	3	0	1	2
F	4	0	3	1
G	3	0	0	3
H	2	1	4	0
I	2	1	4	1
Total	26	7	22	12

with clutch hatched (n=52 breeding attempts) whereas in control territories (n=20) during the same period, breeding success was 0.771±0.185 chicks/pairs with clutch hatched (n=52 breeding attempts, Wilcoxon test, z=0.142, P=0.89; Fig. 1). When we compared the breeding success obtained in nine supplemented territories (n=33 breeding attempts) to results obtained in the same territories during the feeding period with no supplementation (n=34 breeding attempts), the differences were not significant (supplementary period, 0.712±0.307 chicks/pairs with clutch hatched; no supplementary period, 0.642±0.311 chicks/pairs with clutch hatched; Wilcoxon test, z=0.297, P=0.766; Table 2). As shown in Table 2, although the sample size was small, breeding success was improved in six (66.7%) territories.

Age and causes of breeding failure

The age at which the chick died was determined in 13 cases in supplemented nests and nine cases in non-supplemented nests. The age of the chick in failed nests that had received supplementary food was 20.96±20.78 days (range 5–85, n=13) whereas in non-supplemented nests, the average age was 28.61±18.23 days (range 3–60, n=9, Wilcoxon signed-rank test, z=1.96, P=0.050). Concerning the possible causes of breeding failure, only on three occasions was it possible to access supplemented nests to determine the cause, and in another three attempts, non-supplemented nests were accessed. Of these, the probable causes of the death of the chicks in the supplemented nests were poisoning (Endosulfan), adverse weather plus predation by ravens and colibacillosis (produced by *Escherichia coli*). With regards the non-supplemented nests, in three cases, the most probable cause of death was adverse weather, which probably caused hypothermia.

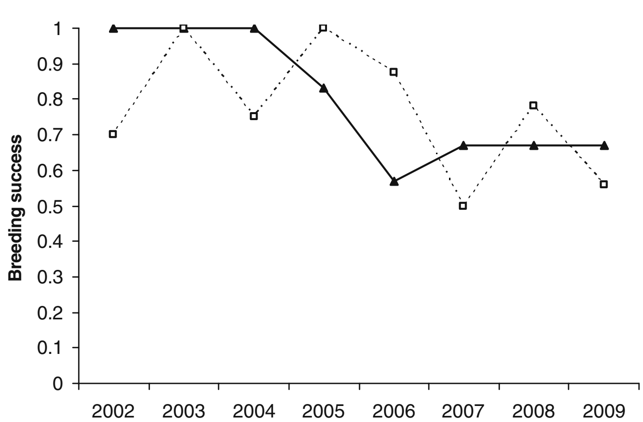

Fig. 1 Annual variation in breeding success in supplemented (*solid line*) and non-supplemented (*broken line*) bearded vulture territories from 2002 to 2009

Discussion

Although SSFS for breeding bearded vulture territories slightly increases the global breeding success and the individual breeding performance of the territories, the values obtained were very similar. This suggests that the SSFS programme applied after hatching is apparently not a useful measure for increasing breeding success, at least in the current study area. Thus, factors that provoke breeding failure after hatching continue to operate independently from the supplementary feeding programme. In fact, contrary to what was expected, breeding failures occurred earlier in supplemented nests than in non-supplemented nests. We have no concluding explanation for this trend, and more data are necessary to confirm this as a consequence of the low sample size.

A possible explanation for why the SSFS were unsuccessful could be related to the period of supplementation. The latter was carried out during the first 2 months of the chick's life, whereas—in non-supplemented nests—the chick-rearing period for this species is on average 4 months (see Margalida et al. 2003). Thus, covering the total chick-rearing period could reduce the number of breeding failures. However, our results suggest that the average time at which the chicks died was during the first 3 to 4 weeks, and the supplementary feeding programme ended during the seventh or eighth week, which implied that the most critical period was covered. Previous results about the age of breeding failures in the study area during the period 1992–1999 confirm that the most critical breeding stage is the hatching period (51.3%, n=39, with this period including the end of incubation and <7 days of chick's life; Margalida et al. 2003). During the chick-rearing period (considering the nests with chicks with >7 days), the age of the chick in failed nests was 37 days (range 10–74 days). Thus, the SSFP seems to adequately cover the critical period of chick rearing, when the diet of the chick is more dependent on high-quality food with meat remains (Margalida et al. 2009). On the other hand, the aim of the SSFS programme during the first 2 months after hatching is to avoid the dependency of breeding pairs on this management technique, as this action can have detrimental effects, such as changes in foraging behaviour (Anderson and Anthony 2005; Piper 2006). Finally, another goal is to avoid the attraction and habituation of other scavengers that could provoke inter and intra-specific conflicts during the breeding process, which may have a negative effect on breeding success or increase the risk of predation (see, for example, Bertran and Margalida 2004). Thus, it seems that factors that cause breeding failure are not avoided with SSFP.

Another possible factor than can affect the results is that not all the pairs make use of the food delivered in the same way. Observations of specialist and facultative scavengers eating the remains delivered suggest that, in several territories, the effectiveness of the SSFS can be limited by the presence of these species. If fact, inter- and intra-specific kleptoparasitic interactions in bearded vultures are common, and in 96.3% of all interactions observed in the study area (n=54), breeding bearded vultures acted as hosts and only in two did they act as kleptoparasites (Margalida and Bertran 2003). In addition, the low quantities of remains provided (2 to 3 kg) made it easy for the food to be consumed quickly by other species thus leaving none for the bearded vultures.

One example of the difficulty in ensuring breeding success when non-natural mortality factors occur is the case of the death of a 85-day-old chick in a nest supplemented with food, as a consequence of illegal poisoning. On the other hand, natural mortality factors such as the effects of adverse weather that provoked several failures were not avoided by the supplementation of food. Thus, although the SSFS may help to maintain or slightly increase breeding success during its application, if non-mortality factors (as illegal poisoning) or natural factors (adverse weather) continue to occur, the effectiveness of this conservation measure is limited. Indeed, in an experimental study using vulture restaurants against vulture mortality through diclofenac exposure in Pakistan (Gilbert et al. 2007), the results showed that this tool can reduce, but not eliminate, mortality related to the ingestion of this toxic substance.

Our results also show a decreasing trend in breeding success during the study period. One possible explanation for this could be related to the food regulations involved in sanitary policies implemented in 2003 and applied after 2006 as a consequence of bovine spongiform encephalopathy. In other vulture species, the decrease in breeding success has also been documented (see review in Donázar et al. 2009a), and in the study area, the breeding parameters of the Egyptian vulture and the griffon vulture have also decreased progressively over the last 10 years (García and Margalida 2009). Although the SSFS for breeding adults and the presence of FS may counterbalance the low food availability, it seems insufficient to avoid the effects of illegal poisoning (and other mortality factors that can lead to breeding failure) and to provide the food resources necessary for the scavenger population. In the bearded vulture, food quality (i.e. meat remains and nutritious bones) is important and selected during the first few weeks of chick's life (Margalida 2008; Margalida et al. 2009), and the temporal variation in food quality may influence breeding success (see Margalida et al. 2003). In addition, the low availability of food increases resource competition, favouring species such as the griffon vulture, which monopolises the resource (Cortés-Avizanda 2006; Donázar et al. 2009a). Thus, this period of low availability could contribute to the increase in breeding failure, as has been documented in other vulture species if the food availability situation is not reversed (see review in Donázar et al. 2009b). Nevertheless, several confounding factors such as density dependence of demographic parameters in this population as a consequence of the combined effects of the shrinkage of territories and the presence of floaters around supplementary feeding points (Carrete et al. 2006a; Margalida et al. 2008a), the increase of polyandrous trios that implies social interactions and a reduction in productivity (Carrete et al. 2006b; Bertran et al. 2009) are also influencing breeding parameters. Thus, additional research on this subject is necessary in order to determine the real effects of artificial feeding on breeding success.

Management measures

Our preliminary results suggest that the provision of supplementary food during the chick-rearing period aimed at increasing breeding success does not seem to be effective. The supplementary feeding programme apparently failed to mitigate the effects that influenced breeding failure, suggesting that in an obligate brood reducer, supplementary feeding to increase breeding success may be an ineffective conservation tool. The effects of the illegal poisoning on the breeding and population dynamics of this species (see Oro et al. 2008) are troubling, and until this activity has been reduced or eliminated, any management measure will probably be unsuccessful. Taking into account the fact that this factor led to the extinction of most populations of the species in Europe (Mingozzi and Estève 1997), this should be a focus of managers in optimising and to prioritising the investment of economic resources in conservation actions. Finally, from a conservation point of view, taking into account the possible detrimental effects of artificial feeding (see review in Donázar et al. 2009b), it may be more effective to invest in habitat management (i.e. increasing the carrion provided by extensive livestock or game species) and to provide natural food resources from extensive grazing or hunting practices to guarantee feeding resources and increase breeding success (see Donázar et al. 2009b; Olea and Mateo-Tomás 2009; Mateo-Tomás and Olea 2009). This has been put forward as the most inexpensive and efficient management method for the conservation of scavengers without modifying habitat quality artificially (Donázar et al. 2009c).

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