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THE DIET OF THE EGYPTIAN VULTURE (*NEOPHRON PERCNOPTERUS*) IN SICILY: TEMPORAL VARIATION AND CONSERVATION IMPLICATIONS

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FOOD HABITS
FORAGING STRATEGY
MANAGEMENT
MEDITERRANEAN
SUPPLEMENTARY FEEDING
SCAVENGERS
VULTURES

ABSTRACT. – Dietary habits of Egyptian vultures in Sicily have changed in the last 30 years mainly due to changes in livestock production. Here we describe and quantify Egyptian vulture's diet in Sicily; to compare it with previous studies; to discuss changes in diet composition in relation to changes in food availability; and to suggest conservation actions aimed at improving food availability for this endangered species in Italy. To this end, prey remains were collected in nests from 2005 to 2009 and were compared with previous studies conducted in 1981 and 2002 in the same study area. Monte Carlo simulations and different measures of dietary diversity indexes (*i.e.* richness, evenness and Shannon's index) were used for analyses. Prey individuals were classified into 33 different taxonomical categories, out of which 52.4 % (n = 77) were mammals (predominantly Wild Rabbits *Oryctolagus cuniculus*), 34.7 % (n = 51) were birds and only 11.6 % (n = 17) were domestic poultry. There were significant differences in diet composition among the three study periods. Considerable differences were also observed in terms of diet diversity indexes, with bootstrapping procedures revealing larger differences between 1981 and 2002 than between 2005 and 2009. In particular, indexes related to dietary evenness tended to decrease over time, whereas those related to diet dominance tended to increase. Dietary composition of Egyptian vultures differed significantly between the periods before and after changes of livestock ownership occurred in Sicily, with an observed reduction of livestock remains and the increase of wild medium size mammals and birds in the diet. Measures aimed at increasing food availability such as supplementary feeding stations would probably benefit population recovery through increase in survival and breeding success. From our point of view, taking these measures is urgently needed before the Egyptian vulture population will become eventually extinct in Italy.

INTRODUCTION

Studies on the dietary habits of birds are important in order to explore different issues in avian ecology such as understanding changes in demographic patterns over time, breeding performance, population density and habitat selection (Donázar & Ceballos 1988, Korpimaki & Norrdahl 1991, Simmons *et al*. 1991, Litvaitis 2000, Zuberogoitia *et al*. 2002, Sonerud *et al*. 2002, Sarà & Di Vittorio 2003, Lewis *et al*. 2004, López-López *et al*. 2009). Furthermore, in the case of raptors' diet, obtaining correct estimates is important to many aspects of ecological study such as predation, foraging energetics, prey selection and diet overlap (Redpath *et al*. 2001).

The Egyptian vulture (*Neophron percnopterus*) is a medium-sized long-lived vulture that feeds mainly on small vertebrate and domestic livestock, but which can also opportunistically prey upon small animals (Cramp & Simmons 1980). Most of the European population of this species is distributed on dry, mountainous and open Mediterranean landscapes (Cramp & Simmons 1980, del Hoyo *et al*. 1994, Sarà & Di Vittorio 2003). The species is qualified as endangered worldwide, owing to a recent and extremely rapid population decline in Asia combined with severe long-term declines in Europe and Africa (BirdLife International 2015). The endangered European population suffers considerable threats across its range, in particular poisoning, electrocution, reduced food availability, disturbance and changes in habitat composition (Kurtev *et al*. 2005, Dzhamirzoev & Bukreev 2009, Sarà *et al*. 2009, Zuberogoitia *et al*. 2014, BirdLife International 2015). The latest survey of the Italian population yielded only eight pairs, distributed across the southern part of the country.

The Sicilian population of Egyptian vulture includes five breeding pairs nowadays, and it was estimated in 30 pairs in the last 1980s (Iapichino & Massa 1989). After then, the population decreased gradually due to the intensification of agriculture and decrease in the traditional livestock management (Sarà *et al.* 2009). The Egyptian vulture's diet is extremely wide, feeding on a variety of animal corpses of a high variety of vertebrates, but also on cattle excrements, human garbage and also live preys hunted actively (Cramp & Simmons 1980, del Hoyo *et al.* 1994). One of the main sources of prey comes from carcasses of dead cattle of the animal husbandry industry (Cramp & Simmons 1980). However, the reduction of the available livestock due to changes in traditional husbandry practices as well as major habitat changes due to human alteration, are the main factors accounting for population decrease recorded in Europe (Tucker & Evans 1997, Baumgart 2001, Gallardo & Penteriani 2001, Íñigo *et al.* 2008, Donázar *et al.* 2009). Therefore, a detailed analysis of the dietary habits is important for planning solid measures to protect this endangered species, particularly in some Mediterranean countries where Egyptian vultures are still present but with a very small population size (*i.e.* Portugal, Italy, France, Macedonia, Serbia, Bulgaria and Greece) (BirdLife International 2015). In addition, detailed information about dietary habits could also help to improve current conservation actions under conservation projects aimed at recovering the species in Eastern European countries.

In this paper we: (1) provide updated and detailed quantitative information on the food habits of the Egyptian vulture in Sicily; and (2) compare diet composition with previous studies conducted in 1981, 2002 and 2005-2009 in the study area, with particular interest in the analysis of temporal changes in dietary composition in this Mediterranean island where the most important Italian population still remains (Sarà *et al.* 2009). We discuss the apparent changes in diet composition in relation to changes in food availability due to livestock reduction in recent years and we finally suggest conservation actions aimed at improving food availability for this endangered species in Italy.

MATERIALS AND METHODS

Study area: Sicily is the largest Mediterranean island with an extension of 25,414 km^2. The range of altitude varies from the sea level to 3,320 m of Mount Etna. At least 25 % of the territory of the island is mountainous, exhibiting a typical Mediterranean climate characterised by wet winters and hot and dry summers. In the past, traditional land use was characterized by extensive agriculture, which shaped a generalized mosaic landscape where extensive agricultural and natural areas were interspersed. However, Sicily has witnessed a dramatic change in forestry and agricultural practices in the last decades, as a result of the abandonment of traditional agro-pastoral practices. Consequently, this has caused important changes in landscape configuration, with an increase of reforestation of natural areas using exotic trees and a considerable reduction of pseudo-steppe landscapes, especially non-irrigated arable lands (Massa & La Mantia 2007).

Sampling design and field effort: The field study was conducted between 2005 and 2009. During this period, we conducted eight collections of diet samplings corresponding to five different pairs distributed as follows: four visits in 2005, one visit in 2006, and three visits in 2009. We sampled three nests visited in two different years (2 in 2005 and then in 2009, and one in 2005 and then in 2006) and other two nests visited only one time each. Importantly, to avoid biases in field effort and sampling design, we applied the same methodology to gather information throughout the study period. In order to collect food remains, we visited Egyptian vultures' nests to ring and measure the chicks during the first fortnight of July, when chicks were 40-50 days old in three nests, and after fledging for the other two cases. All the procedure was done putting the highest attention to the safety and proper handling of chicks.

Food remains consisted of bones, hides, feathers, scales and carcass parts of vertebrates and pellets in different states of preservation. In order to allow for meaningful inter-site comparisons, food items were identified to species level by comparison with feathers, hairs and bones collections at the Department of Animal Biology of the University of Palermo (Italy), applying the standard methodology used to study raptors' diet in similar studies (*e.g.* Donázar & Ceballos 1988, Ceballos & Donázar 1990, Litvaitis 2000, Zuberogoitia *et al.* 2002, Milchev *et al.* 2012) as well as using specialized guides (Von Den Driesch 1976, Desse *et al.* 1986, Cohen & Serjeantson 1986). We estimated the minimal number of individuals of each species per sample based on the number of skulls, feathers, feet or other recognizable body parts, reporting the number of skeletal fragment and bones (*e.g.* the distal parts of limbs, vertebrae, parts of skull, mandibles) as one individual (Milchev *et al.* 2012). Placentas and excrements, were collected in different nests; all their eventual fragments found in a single nest were considered as a single item.

Original data collected during the present study were compared to data reported in the literature from the same study area including a similar sample size of visited nests and collected prey items These studies were Massa (1981) and Di Vittorio & Campobello (2002). In particular, Massa (1981) collected 110 prey items from six nests, accounting for 25-30 % of the total monitored population. Di Vittorio & Campobello (2002) gathered 259 prey items from nine nests between 1997 and 2000, accounting for 80 % of the overall population surveyed in Sicily at this time. In order to allow comparisons, we followed the same field protocol used by Massa (1981) and Di Vittorio & Campobello (2002) in our study.

The data on livestock availability from 1990 to 2000 in the study area were obtained from ISTAT (Istituto Nazionale di Statistica) (2000), would highlight a change of livestock ownership occurred from 1990 to 2000, in which livestock and husbandry decreased gravely (–45 % sheep, –38 % goats, –40 % domestic fowl, –58 % pigs). This trend appears to be rather constant: indeed, in the period 2000-2010, the number of breeding facilities of sheep, goats, pigs and domestic fowl decreased by

–13 %, –17 %, –69 % and –91 %, respectively (ISTAT 2010). These reductions also affected the portion of Sicily where the Egyptian vulture is found, especially the provinces of Palermo –44.6 % of breeding facilities and –29.45 % of number of sheet and goat from 1990 to 2000) and Agrigento (–54.3 % of breeding facilities and –33.05 % of number of sheep and goat from 1990 to 2000) (ISTAT 2000). Accordingly, we compared data on diet (prey species) before changes in livestock availability (*i.e.* data in Massa (1981) and Di Vittorio & Campobello (2002) which were collected between 1997 and 2000) with data obtained after this period (this study).

Data analysis: We collected 41 items (28 % of total) in the nest of pair 1 in 2009, 15 items (10 %) in 2005 and 21 items (14 %) in 2006 in the nest of pair 2, 15 items (10 %) in the nest of pair 3 in 2005, 17 items (12 %) in 2005 and 4 items (3 %) in 2009 in the nest of pair 4, and 21 items (14 %) and 13 items (9 %) in 2009 in the nest of pair 5 in 2005.

Small sample sizes were dependent on that very few pairs of Egyptian vulture do occur in Sicily throughout the study period (6 pairs). None of the pairs of present analysis were supplemented by feeding stations during the survey years.

The collected items were included in seven prey type categories: (i) fish, (ii) amphibians and reptiles, (iii) birds, (iv) domestic mammals, (v) wild mammals, (vi) placentae, and (vii) excrements (see Table I).

To test for statistical differences in prey composition among the nests visited between 2005 and 2009, we applied a Montecarlo χ^2 test (1,000 iterations), after Bonferroni correction, setting the novel alpha significance at $p = 0.0005$. Frequency differences in the taxonomic prey composition and in the prey type categories (see Table I) across the three study periods: 1981 (data in Massa 1981), 2002 (data in Di Vittorio & Campobello 2002), and 2005-2009 (this study) were evaluated by a chi-square test. For this analysis, the above-mentioned seven prey type categories were considered.

Taxonomic diversity of diet was calculated for each sampling period as follows (Magurran 1988, 2004):

(a) group richness (group _S), *i.e.* the total number of operational taxonomical units recorded in the vulture diet within each sampling period.

(b) Evenness, calculated by Pielou's formula:

$$e = H / \log S$$

with H representing Shannon's index (see below), and S the total number of prey type categories recorded in each sampling period (Magurran 1988).

(c) Shannon's index (H):

$$H = -\sum [n / N \log(n / N)]$$

where n is the number of individuals of each species and N is the total number of individual prey items in each sampling period. This index measures the entropy of the prey community structure taking into account the number of individuals of a given species present in a given sampling period as well as the total number of taxa within each sampling period. This index varies from 0 for prey communities with only a single taxon to high values for prey communities with many taxa, each with few individuals.

We applied a Bootstrap analysis, with 1,000 random samples, in order to compare diet diversity indexes of the different sampling periods by computing approximate confidence intervals (Harper 1999). Each random sample was computed with the same total number of individuals as in each original sample. The random samples were taken from the total pooled data set. For each species in the random sample, the number of preyed individuals was chosen with probabilities according to the original pooled

Table I. – Prey items collected from eight sampling visits to five Egyptian vulture's nests in Sicily (southern Italy) during 2005-2009. In Bold letter the subtotals for each main category.

	N	%
Fish	**1**	**0.68**
Bufo bufo	5	3.40
Hierophis viridiflavus	1	0.68
Natrix natrix	1	0.68
Unidentified snake	3	2.04
Amphibians and Reptiles	**10**	**6.80**
Tyto alba	1	0.68
Columba palumbus	4	2.72
Corvus corone cornix	5	3.40
Pica pica	4	2.72
Falco tinnunculus	1	0.68
Turdus merula	1	0.68
Sturnus unicolor	1	0.68
Corvus monedula	3	2.04
Columba livia	8	5.44
Streptopelia sp.	1	0.68
Chickens	16	10.88
Goose	1	0.68
Unidentified birds	5	3.4
Birds	**51**	**34.69**
Canis familiaris	7	4.76
Felis catus	3	2.04
Goat	7	4.76
Sheep	3	2.04
Sheep or Goat indeterminates	5	3.40
Domestic rabbit	3	2.04
Horse	1	0.68
Pig	7	4.76
Domestic mammals	**36**	**24.48**
Vulpes vulpes	6	4.08
Oryctolagus cuniculus	26	17.69
Lepus corsicanus	1	0.68
Erinaceus europaeus	3	2.04
Wild Mammals	**36**	**24.49**
Excrements	**8**	**5.44**
Placentae	**5**	**3.40**

abundances. A 95 % confidence interval for the random sample was then calculated. Hence, according to this procedure, the diet diversity in the replicates is often less than, and never larger than, the pooled diet diversity in the total data set. Since all confidence intervals were computed with respect to the pooled data set, they did not represent confidence intervals for the observed samples (Harper 1999). This procedure was then used to identify samples where the diversity index falls outside the confidence interval, thus indicating that the calculated value does not come from a random sample (Harper 1999). All computations were performed using STATISTICA version 6.0 for Windows (StatSoft 2004), and bootstraps were computed using the PAST software (Hammer 2012). Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

We collected a total of 347 prey remains that were assigned to 147 different prey items (Table I). Prey items were classified into 7 prey type categories, and these latter in turn into 32 taxonomic groups, out of which 49.0 % (n = 72) were mammals, with birds accounting for 34.7 % (n = 51). Other food items included domestic cattle, with a frequency of occurrence (27.9 %, n = 41, including placentae) similar to data reported elsewhere (Donázar & Ceballos 1988, Hidalgo *et al*. 2005, Margalida *et al*. 2012, but see Milchev *et al*. 2012). Wild mammals accounted for 24.5 % of prey items (n = 36), free-ranging birds for 19.7 % of items (n = 29), and 11.6 % (n = 17) were domestic poultry (chicken and goose). Wild rabbits (*Oryctolagus cuniculus*) were the dominant prey, as reported also in Spain (Margalida *et al*. 2012). The Montecarlo χ^2 square test, after Bonferroni correction, showed that there were no differences in prey composition among nests sampled between 2005 and 2009 (p mean > 0.0005).

With regard to the origin of food consumed, overall, 55.2 % of prey items were wildlife. These prey items were probably originated from naturally died animals, road kills, and even from actively preyed ill or immature animals. The remaining prey items (44.8 %) were domestic animals, which were most likely taken from farms and rubbish dumps, or gathered along the streets and knocked down by cars. The presence of excrements in the diet could be explained by the coprophagic behavior of the species. In fact, excrements, particularly from cows and other ruminants, provide an essential source of carotenoids, which are used for ornamentation, providing the typical coloration of the head of this species (Negro *et al*. 2002).

Considerable differences in the vulture dietary habits among the three sampling periods were observed in terms of diet diversity indexes (Table II), with bootstrapping procedures revealing larger differences between 1981 and 2002 than between 2002 and 2005-2009 (Table III). More specifically, the indexes related to dietary evenness and to species diversity tended to decrease over time, whereas those related to diet dominance tended to increase, thus showing a change in food habits of the species. In general, our results seem to reflect a remarkable foraging eclecticism of this vulture species, similar to results reported in previous studies conducted across its distribution range (Bergier & Cheylan 1980, Cramp & Simmons 1980, Ceballos & Donázar 1990).

Table II. – Diversity indexes applied on diet taxonomic composition of the Egyptian vulture across three sampling periods. Calculated values are presented under the columns of years (1981, 2002, 2005-2009). Simulated values (with lower and upper confidence intervals of the estimates, LCI and UCI) obtained through 10,000 bootstraps of the original data matrix, are also shown. Symbols: group _S = prey type categories.

	1981	LCI	UCI	2002	LCI	UCI	2005-2009	LCI	UCI
group _S	6	5	6	7	5	6	6	5	6
Shannon_H	1.588	1.162	1.464	1.056	1.155	1.463	1.128	1.161	1.475
Evenness_e^H/S	0.8158	0.5811	0.8367	0.4105	0.5802	0.8377	0.515	0.5874	0.8427

Table III. – Summary of the statistical differences between pairs of sampling periods in terms of diet's diversity measures (see text for further methodological details). Abbreviations: Symbols: group S = prey type categories; Boot p(eq) = P value after bootstraps; Perm p(eq) = P value after Monte Carlo permutations.

	1981	2002	Boot p(eq)	Perm p(eq)
group S	6	7	0.486	1
Prey items	96	96	1	1
Shannon H	1.612	1.057	0.001	0.001
Evenness_e^H/S	0.8353	0.4111	0.001	0.001
	1981	2005-2009	Boot p(eq)	Perm p(eq)
group S	6	6	1	1
Individuals	96	97	0	0
Shannon H	1.612	1.132	0.001	0.001
Evenness_e^H/S	0.8353	0.5168	0.001	0.001
	2002	2005-2009	Boot p(eq)	Perm p(eq)
group S	7	6	0.543	0.964
Individuals	96	97	0	0
Shannon H	1.057	1.132	0.581	0.607
Evenness_e^H/S	0.4111	0.5168	0.23	0.28

The diet of the Egyptian vulture in Sicily differed significantly in the period before and after the change of livestock ownership ($\chi^2_{44} = 315.44$, $p < 0.000$, considering all prey species; $\chi^2_7 = 794.76$, $p < 0.001$, considering the main seven prey categories, see Table I), period in which a reduction of 38.5 % of livestock farms compared to 1990 occurred. The abandonment of husbandry practices by a large number of companies with a consequent reduction in the availability of livestock remains could account for this observed pattern. In fact, dietary changes came in parallel with a decrease in diet diversity and dietary breadth, with very low dietary overlap between the two analyzed periods (before and after livestock reduction, see Fig. 1). A similar shift from domestic animal prey consumption to wild animal necrophagy after a reduction of livestock availability has been also reported in other study areas (Zuberogoitia *et al.* 2008, Margalida *et al.* 2012, Milchew *et al.* 2012).

The increased frequency of birds and rabbits in the Egyptian vulture's diet can be interpreted as a consequence of the change in the traditional land use and farming practices in Sicily, forcing this raptor species to hunt for other food sources. In addition, about 85 % of garbage dumps which were active across the Egyptian vulture breeding area in Sicily have disappeared between the mid-80s and the beginning of 2000 (Sarà *et al.* 2009), thus perhaps causing a further reduction in trophic resource availability, as this species often collects remains in the garbages (Liberatori & Massa 1992). Interestingly, the density of livestock in Sicily seems to be highly correlated with the presence of Egyptian vulture breeding pairs (Sarà & Di Vittorio 2003, Sarà *et al.* 2009).

Many studies have highlighted that the main threats of Egyptian vulture included high adult mortality caused by both lead and intentional poisonings, collisions with infrastructures (wind turbines and power lines), electrocution, habitat alteration, human disturbance at breeding sites, change of weather conditions and shortage of food resources (Cortés-Avizanda *et al.* 2009, Donázar *et al.* 2009; Grande *et al.* 2009; Hernández & Margalida 2009; Sarà *et al.*2009, García-Ripollés & López-López 2011, Zuberogoitia *et al.* 2014, Tauler *et al.* 2015).

Hence, despite our results do not allow for any definitive conclusion on the relation between dietary shifts and population trends, the change in diet may have had a further effect on Egyptian vulture's demography, influencing the variability of breeding success and the nest site occupation or desertion (Sarà *et al.* 2009) and could have contributed, beside the other factors, to the regression of this critically endangered species observed in Sicily, especially in recent years.

Finally, our results have shown the capability of the species to utilize different resources. Several works have pointed out the importance of supplementary feeding in the so-called vulture restaurants on the persistence and productivity of the Egyptian Vulture (*e.g.* Ceballos & Donázar 1990, Meretsky & Mannan 1999, Del Moral & Martí 2002, Sarà & Di Vittorio 2003). Furthermore, recent studies using GPS satellite tracking technology have shown a clear relationship between food predictability and space use of scavenger species (García-Ripollés *et al.* 2011, Monsarrat *et al.* 2013) and, particularly, in the case of the Egyptian vulture (López-López *et al.* 2014). Although some authors discuss the role of artifi-

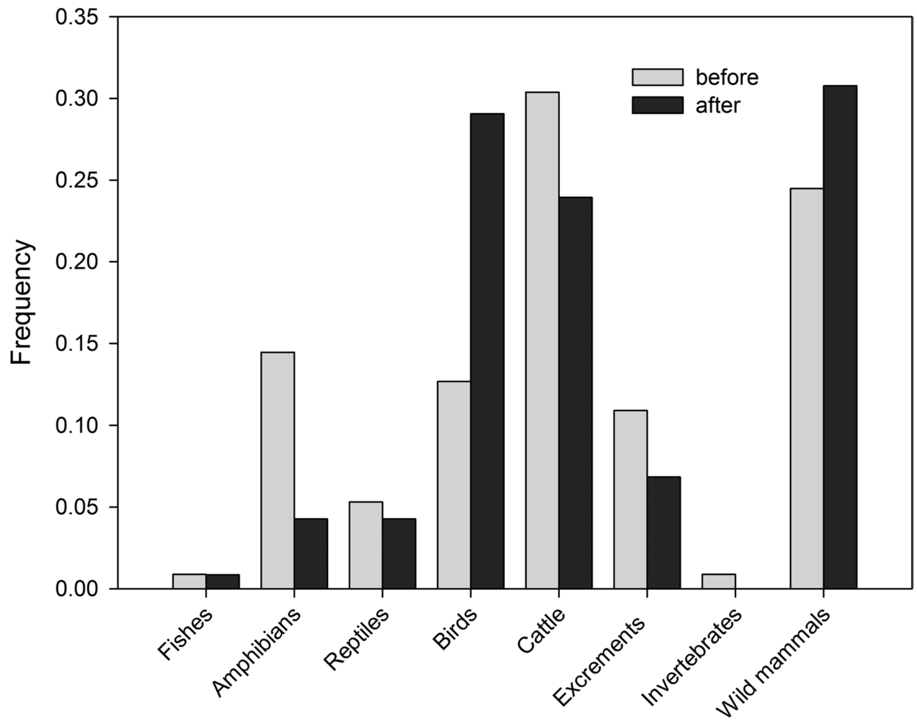

Fig 1. – Comparison of Egyptian vulture's diet composition in Sicily in two different study periods: before (pooled data from Massa (1981) and Di Vittorio & Campobello (2002), and after livestock reduction (this study: 2005-2009; see Methods). Results are shown as frequency of items grouped into eight main categories.

cial supplementary feeding stations and especially, how its uncontrolled management can impact on vultures' feeding ecology and interspecific relationships (see *e.g.* Donázar *et al.* 2009, Cortés-Avizanda *et al.* 2015), and that could have possible negative consequences resulting from ample aggregations of birds, altering intraguild processes and favoring density-dependent decreases in productivity and the assembly of predators, increasing predation risk on small- and medium-sized vertebrates near the feeding stations (Cortés-Avizanda *et al.* 2016) we consider that the installation of permanent artificial feeding stations across the area still occupied by the species, in which the low density of other scavengers could minimize the adverse effects described above, would be recommendable in order to reverse the negative population trend of the small and low density population of this endangered vulture in Sicily. Supplementary feeding has been largely applied as an effective conservation tool with successful results in terms of population recovery in other European countries (Terrasse 1985, Gallardo *et al.* 1987, Gómez *et al.* 2001), showing that when is managed simulating natural unpredictable conditions it may benefit endangered scavengers such as the Egyptian vulture (Arrondo *et al.* 2015). In addition, a very recent long-term study has demonstrated that the implementation of vulture restaurants improved the local survival rates and successfully stabilized the local demography of Egyptian vultures in south-eastern France (Lieury *et al.* 2015). In our opinion, the establishment of feeding stations in Sicily would contribute to increase breeding performance (Sarà *et al.* 2009) and would help to increase the survival and occupation rate of this critically endangered vulture before the species will eventually become extinct in Italy. It is known that poisoning and poaching have been dramatically affecting Sicilian Egyptian vultures, so perhaps this is more challenging than food in survival and consequently in the demographic trend of the local populations.

Essential for the conservation of this population, simultaneously with food supplementation, is setting management actions aimed at increasing the survival rate of adults (Tauler *et al.* 2015), as the maintenance of traditional healthful agro-grazing practices, the anti-poisoning campaigns, the changes of health regulations that allow to leave the carcasses (not treated with dangerous drugs) in the field (Cortés-Avizanda *et al.* 2016) and to avoid disturbance near the breeding sites, *e.g.* by the constitution of sensitive zones (*e.g.* the breeding sites), where the disturbing activities could be limited or prohibited during the breeding period (López-López, García-Ripollés & Urios 2014).

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