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Use of Logistic Regression Models to Predict Consumption of Carcasses by Griffon Vultures *Gyps fulvus*

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INTRODUCTION

Eurasian Griffon Vultures depend closely for their feeding on medium and big sized carcasses (Newton 1978; Houston 1979; Mundy *et al.* 1992). The presence of a carcass in the environment is unpredictable, both in space and time. In the Iberian Peninsula Griffons rely on carcasses from domestic livestock (Fernandez 1975; Marco & García 1981; Camiña 1993, 1994, in prep.). Most carcasses are not buried but are left by shepherds to be consumed by Griffons and other carrion-eaters.

The development of easily interpretable models that predict consumption of carcasses is necessary for decisions regarding the management of vulture populations . Our intention was to develop and test, through logistic regression analysis, carcass-habitat models that serve as descriptors of the ability of habitat variables to predict the consumption of carrion. Conclusions could be applied to management practices related to food provision for carrion-eaters.

STUDY AREA

The study area is located in the High Najerilla River Valley, La Rioja province (Northern Spain). It extends over 450km^2. Altitude varies from 900m to 2,262m a.s.l. on the top of Pico San Lorenzo, (Sierra de la Demanda). There the landscape consists of deep valleys with broad pastures, shrubland and wooded areas. Rain falls chiefly from November to May (hereafter winter season), 73% of the total annual rainfall (Instituto Nacional de Meteorologia 1985-1992). From June to October (hereafter summer season) there is a period with scarce rainfalls and mild temperatures. As a consequence of these climatic conditions there is seasonal livestock management. Livestock rearing is the basis of the economy here, comprised of sheep, cattle, goats and horses.

During winter cattle and sheep, which make up 93% of the total livestock, are held nearby or enclosed in villages. From this we could expect variations in the availability of food for vultures. Because dead animals are not buried carrion eaters have a good chance of obtaining food. The area also supports populations of three wild ungulate species: Wild Boar *Sus scrofa*, Red Deer *Cervus elaphus* and Roe Deer *Capreolus capreolus*. Among carnivorous predators we found the Wolf *Canis lupus* and the fox *Vulpes vulpes*. There vultures use trees and cliffs as roosting sites and a population of about 200 birds has been censused during summer seasons. The breeding colonies are located at an average distance of 40km.

METHODS

Consumption of carcasses by Griffons is a variable with only two values, consumption vs. non-consumption. Only the time required to demolish a carcass can differ between areas. Thus an advisable technique to analyse these types of variables is the logistic regression. The data were analysed by means of SPSS statistical package (see SPSS1983 and Norusis 1989 for more details of this procedure).

Between 1985-92 the following variables were measured for each of 100 carcasses (50 in each season, see study area). Variables 1 to 5 were related to landscape structure, while variables 6 and 7 were related with the size of carcasses and their consumption by Griffons. Separate models were developed for summer and winter seasons.

1. Physiographic Index (Pi): To measure this variable we quantified, on a 1:50,000 scale map, the average number of contour lines that a circular plot cut centred on the carrion. This circle had a radius of 250m. Pi varies from 12.5 in vertical land to zero on flat ground (see Beasom *et al.* 1982 for a similar approach).

2. Altitude (Al): Altitude in metres a.s.l. at which a carcass was found. This was taken from the map.

3. Distance to Vegetation Patches (DVe): Distance in metres between a carcass and the nearest shrub or forest patch more 0.5m tall, where predators could be hidden.

4. Vegetation Cover (Ve): Vegetation cover of the shrub or forest patch closest to the carrion. It was estimated visually in %.

5. Distance to Buildings (DBu): Distance in metres between the carrion and the nearest village or isolated house.

6. Size of Carcass (Sc): Five prey categories have been defined, based on weight:

I. Dog, fox and Roe Deer with average weights of 25kg.

II. Sheep and goats, 40kg.

III. Wild Boar and Red Deer, 80kg.

IV. Horses, 300kg.

V. Cattle, 400kg.

Livestock weights were taken from De Juana & De Juana (1984), weights of big game from Sáez-Royuela (1989) and Costa (1993); finally for dogs and foxes weights were calculated after weighing ten freshly dead individuals of both species.

7. Consumption of Carcasses: This is a categorical variable with two values, 0 for not consumed and 1 for consumed carcasses.

The stepwise procedure was used to identify a subset of variables that accounted for the majority of explainable variation in the consumption of carcasses data. We set the significance value necessary for an independent variable to enter (p-to-enter) in the stepwise procedure at ≤ 0.15. We evaluated prediction bias by determining the predictive power of the final models on a new set of data. These models were used to predict 1993-94 consumption of carcasses ("same place, different time" validation).

Altitude, type of carcass and distance variables were log-transformed, physiographic index and vegetation cover aercsin-transformed, prior to statistical analysis (Nie *et al.* 1975; Sokal & Rholf 1979).

RESULTS

As shown elsewhere (Camiña 1994, in prep.) livestock management in the area is the main reason for the observed differences in consumption of carcasses. Table 1 shows the results of the stepwise logistic regression models.

In winter, altitude , distance to buildings and size of carcasses explained the 84% of the variance (χ^2=37.96 df=3 and p<0.001). Altitude had the greater partial contribution (R column) followed by carcass size and distance to buildings.

In summer, altitude had also the greater partial contribution, followed by distance to vegetation patches. Both variables explained the 90% of the variance in consumption of individual carcasses (χ^2=31.96 df=2 and p<0.001).

Prediction bias was evaluated by determining the predictive power of the final models on a new set of data. Models correctly predicted the consumption of 86.6% and 80% of carcasses in winter and summer

Table 1. Logistic regression models (stepwise inclusion of variables) predicting consumption of carcasses.

Sig: signification level

R: partial contribution of each variable to the model.

Winter Season	Variables	Coefficient	Sig	R
	Altitude	28.1433	.0011	.3594
	Dist. buildings	1.3362	.0228	.2189
	Carcass size	-2034	.0156	.2409
	Constant	-212.449	.0011	

Summer Season	Variables	Coefficient	Sig.	R.
	Altitude	18.7318	.0034	.3381
	Dist. vegetation	.7040	.0444	.1877
	Constant	-137.517	.0032	

respectively. Failures only appeared on carcasses which were consumed although models predicted that vultures would not feed on them. Furthermore, results of tests between observed and predicted values showed no significant differences in both periods.

DISCUSSION

The models developed and tested for predictive power with the 1993-94 data - different time, same place validation - were able to predict a high % of the observed consumption of carcasses. We can conclude that the final models presented successfully predict the consumption of carrion by Griffons. However, models failed to predict consumption of a low number of carcasses. Failures were detected only on carrion for which consumption was predicted to be zero but which vultures fed on. The inverse trend (models predicted consumption but birds did not feed) was not observed. The consumption of that carrion could be related to temporary scarcity of food in the study area or caused by individual Griffons under famine conditions.

Models demonstrated that two factors were determined when feeding: the accessibility to food sources (altitude variable) and the protection against predators (distances to buildings and vegetation patches). The inclusion of a third variable in winter (size of carcass) could be related to the scarcity of food in this season. Then, Griffons would be forced to feed on almost any prey they encountered. The main application of this study is the use of logistic regression models to predict consumption of carrion by Griffons. Carcasses in the study area sometimes lie in places where vultures are not able to alight.

If they are left, carcasses may rot in the following days causing a bad smell and possibly infection by bacteria. Such carrion can be dropped where the probability of consumption is high. By means of these models the scavenging efficiency of Griffons was artificially increased after 1992. From 1985 to 1992 vultures consumed on average 65% of the overall amount of carcasses available. During 1993-94 the scavenging efficiency increased to 85% of carcasses available. The establishment of vulture restaurants was not necessary and shepherds themselves carried out carcasses to be dropped on suitable places for vultures to feed.

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