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EFFECTS OF MONITORING FREQUENCY ON ESTIMATES OF ABUNDANCE, AGE DISTRIBUTION, AND PRODUCTIVITY OF COLONIAL GRIFFON VULTURES

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Abstract.—Periodic monitoring of breeding Griffon Vultures (*Gyps fulvus*) at a large colony in central Spain was conducted to estimate survey accuracy. Detection of breeding Griffon Vultures varied in relation to the number of visits to the colony. Single visits resulted in low percentages of pairs being detected. At least four complete surveys conducted between January and March were necessary to detect most pairs. Estimated productivity of the colony decreased with an increasing number of surveys. An accurate estimate of productivity was only obtained with four surveys conducted prior to April. Other possible combinations of survey dates overestimated productivity. Estimates of the age structure of the colony improved with the frequency of visits because the number of known-aged vultures increased during the season. The proportion of breeding adults in the colony decreased until the end of March and then increased slightly because subadults vultures started breeding later than adults, and suffered a higher breeding failure than adults. Accurate surveys of breeding Griffon Vultures depend on multiple and time-standarized surveys as opposed to single and unstandardized counts. The best option is multiple survey dates centered around the late February peak in nesting activity.

EFECTO DE LA FRECUENCIA DE CENSO SOBRE LA ESTIMACION POBLACIONAL, LA DISTRIBUCION DE EDADES Y LA PRODUCTIVIDAD DE *GYPS FULVUS*

Sinopsis.—Se valora la precisión de los censos de Buitres Leonados (*Gyps fulvus*) reproductores mediante el control continuado de una colonia en España central. La proporción de parejas detectadas varió en función del número de visitas realizadas. Un sólo censo rindió resultados de detección muy bajos, siendo necesarias al menos cuatro visitas, realizadas en fechas seleccionadas, para detectar la mayoría de las parejas. La productividad de la colonia disminuyó al considerar los resultados de un mayor número de censos. Sólo la mejor combinación de cuatro censos se ajustó al valor real de productividad, mientras que el restro de combinaciones posibles de fechas de censo subestimó la productividad real en todos los casos debido a distintas causas dependiendo de las fechas de censo. La precisión para estimar las edades mejoró con la frecuencia de visitas al incrementarse el número de buitres muestreados. La proporción de adultos reproductores disminuyó hasta el final de marzo y entonces aumentó ligeramente debido a que los subadultos empezaron la reprodución más tarde y sufrieron un mayor fracaso reproductor que los adultos. Se destaca la importancia de censos múltiples en fechas seleccionadas frente a un sólo conteo en fechas no standarizadas. Se ofrece la mejor combinación de fechas de censo según el número posible de visitas como ayuda para programar los censos y el posterior control de la productividad.

Regular surveying of breeding vultures is necessary to assess trends in population numbers (Boshoff and Vernon 1980, Brown and Piper 1988, Dónazar and Fernández 1990, Martínez and Cobo 1993). However, a number of factors might influence the accuracy of these surveys (Fuller and Mosher 1981). If conducted in a standarized form, censuses may also be a valuable source of other information such as productivity and age composition of populations. These data may be indispensable in order to

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address questions concerning population dynamics and demography of vultures (Blanco and Martínez 1996, Piper et al. 1981, Robertson 1984), which are essential in management programs for colonies and populations (Donázar 1993, Mundy et al. 1992).

To assess trends in population numbers and distribution of Griffon Vultures (*Gyps fulvus*) in Spain, two national surveys (1979 and 1989) have been carried out (Arroyo et al. 1990, Sociedad Española de Ornitología 1981). The protocol for these projects directed volunteer observers to count vulture pairs at nest sites during the incubation and early nestling phases. Given the large population size (7529–8074 pairs in 1989) and widespread distribution of the Griffon Vulture in Spain, these surveys needed a large number of volunteers whose effort (the frequency of visits to the colonies) varied (Arroyo et al. 1990). Survey effort probably influences the accuracy of surveys because searching for nests of colonial vultures is a difficult and time-consuming task, and because of the long period potentially suitable to count incubating vultures (from late December to April). Surveys were encouraged when most pairs presumably could be detected (February–March). However, to date there has been no attempt to evaluate the proportion of pairs from the total population which is detected in any particular period. Furthermore, knowledge is scanty about the factors affecting the precision of counts and accuracy of population estimates of colonial Griffon Vultures.

In this paper, we present data on survey accuracy derived from periodic monitoring during the potential optimal survey period for breeding Griffon Vultures at a large colony in central Spain. We show that monitoring frequency and the timing of surveys influenced estimates of productivity and age distribution, and make suggestions for improving survey methodology.

STUDY AREA AND METHODS

During 1994 we censused the breeding population of Griffon Vultures inhabiting the gorges of the Riaza River (41°31′N, 3°36′W), north of Segovia Province, Spain. The area includes a complex of cliffs and canyons where a large (almost 340 pairs along 12 km of canyon in 1995, pers. obs.) and increasing population (Martínez and Cobo 1993, unpub. data) breeds. Most pairs nest in the Montejo de la Vega Birds of Prey Sanctuary (Martínez and Cobo 1993).

Five complete surveys were conducted on two consecutive days every 3–4 wk: 15–16 January, 5–6 February, 26–27 February, 26–27 March, and 16–17 April. Only two pairs were not regularly monitored because of their remote location. The colony had been censused every year since 1984 so we knew the location of most nest sites, many of which were occupied repeatedly from year to year. In addition, we made observations and partial surveys of the colony during the entire incubation period and received information from daily observations of the wardens of the raptor sanctuary and from numerous individual observers. We are confident that all or nearly all pairs breeding at the time of each complete survey were detected. Censuses spanned the period when most incubating pairs were detectable (January–April, mean laying date = 24 January). Only a few pairs incubating replacement clutches occurred outside the census period (pers. obs.). Adult Griffon Vultures are year-round residents in the study area; laying began in late December and the last clutches were laid by the mid-March (unpubl. data).

Nests were monitored by regular and intensive observations throughout the breeding season to determine the success of each pair in fledging young; young fledged from June–August. We are confident that we knew the fate of each pair because much observational effort was made to this aim by wardens, numerous individual observers, and ourselves (see Martínez and Cobo 1993).

Based on the total number of pairs censused in the colony throughout the whole period, we calculated the proportion of pairs detected on each single survey and each posible combination of two, three, and four surveys. Because we conducted five complete surveys, there were 5, 10, 10, and 5 possible combinations of survey dates for 1, 2, 3, and 4 visits, respectively. From this data, we calculated the mean proportion of vulture pairs detected in relation to the number of survey visits to the colony. We determined which single or combination of survey dates resulted in the highest proportion of pairs detected with respect to the total number of pairs in the colony. This was termed the best survey option. The overall productivity of the colony was calculated by dividing the total number of fledglings by the total number of pairs. We estimated the partial productivity of the colony considering the breeding success of the pairs detected in each survey or combination of surveys (as described above). We defined the best survey options as the combination of surveys that produced the highest proportion of pairs being detected (for estimating population size), or the one that produced the productivity value best fitted to the total productivity of the colony (for estimating breeding success).

The ages of the breeding Griffon Vultures detected in each survey were categorized as adults or subadults. Griffon Vultures were aged as subadults before acquiring fully adult appearance (at 5–6-yr old) on the basis of their general body color, bill color, and color, length, and shape of the ruff feathers (Blanco and Martínez 1996, Elosegi 1989). The aging criteria have been verified repeatedly by individually banding 145 nestlings, 96 of which were observed subsequently on 383 occasions from 1990–1995 (G. Doval and F. Martínez unpubl. data).

To estimate the age structure derived from the observation of breeding pairs in each single or combination of surveys, and to assess which of these surveys best fit the "real" age structure, we used the same methodology as indicated above for the analysis of population numbers and productivity. Although we did not record the age of all individuals in the colony, we assumed that the high proportion of aged vultures (64% of pairs and 82% of individuals, n = 302 pairs) represent an aproximation that fit well to the real age composition of the colony. During 1995, observations included most of the breeding population (84% and 92% of

TABLE 1. Mean proportion of breeding Griffon Vulture pairs detected at the gorges of the Riaza River according to the number of surveys. "Best survey date" is the date or combination of dates that produced the highest proportion of pairs detected in relation to the total number of pairs.

Number of visits	Mean % of pairs detected	SD	Range	*n* of possible combinations	Best survey date[a]
One	62.4	19.9	31.5–80.9	5	c
Two	80.8	8.3	63.3–89.5	10	b + c
Three	88.8	4.4	82.9–94.1	10	a + c + d
Four	95.5	2.8	92.8–100	5	a + b + c + d

[a] a = 15–16 January, b = 5–6 February, c = 26–27 February, d = 26–27 March, e = 16–17 April.

pairs and individuals respectively, n = 336 pairs) but no between-seasons difference in the age composition of individuals and pairs were found (Blanco et al. 1997). Although the age of breeding vultures was recorded throughout the breeding season it was impossible to age all the population because after breeding failure vultures usually do not remain in their nest sites. All observations were made by telescope at distances that avoided disturbance to the birds in the colony.

RESULTS

The proportion of breeding Griffon Vultures detected increased with the number of visits to the colony, especially from one to two visits (Table 1). Single visits detected aproximately 60% of pairs, with maximum detection at the end of February. By mid-January only a few pairs had occuppied their nesting sites while in April many pairs had lost their clutch or nestlings (Fig. 1). The number of pairs detected increased to the end of February (Fig. 1) when most pairs had settled, but breeding failure was still low. Four complete surveys combined during the optimal dates were necessary to detect all or most pairs (Table 1).

Estimates of productivity of the colony decreased with an increasing number of surveys (Table 2). The observed productivity (0.48 fledglings/pair; based on season-long observations) was only obtained by monitoring pairs detected with four visits in the best combination of possible dates. All other possible combinations of census dates overestimated the total productivity, with variable biasing according to the dates of visit. Counts of breeding pairs at the beginning of the breeding season overestimated productivity (0.69 fledglings/pair from a single count in January) because early breeding pairs, which mainly were adult pairs (Fig. 2), had relatively high breeding success (unpubl. data). Counts conducted from March overestimated productivity (0.67 and 0.89 fledglings/pair for 26–27 March, n = 220 pairs and 16–17 April, n = 165, respectively) because we failed to detect unsuccessful pairs.

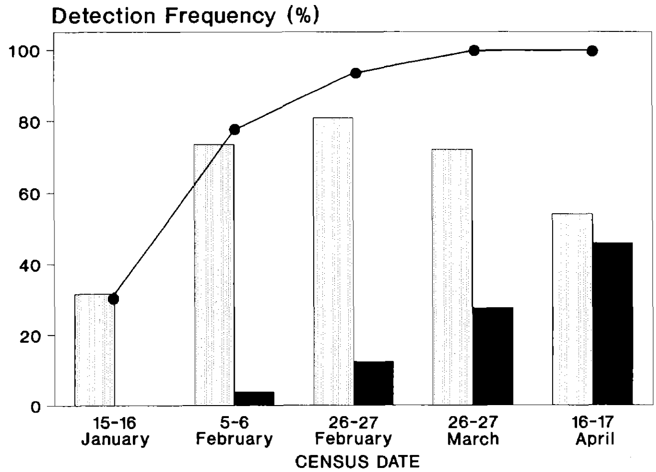

FIGURE 1. Proportion of breeding pairs detected (shaded bars) and proportion of pairs that had already failled, thus non-detected (black bars) on each census date in relation to the total population size. The line indicates the accumulated proportion of detected breeding pairs.

Single visits underestimated the proportion of adult-plumaged vultures in all cases; the survey at the end of February best fit the known age distribution (Fig. 2). The accuracy of estimates of the age estructure of the colony improved with the frequency of visits because the number of known-age vultures increased. The proportion of breeding adults decreased until the end of March and then increased slightly because subadult vultures started breeding later and suffered a higher breeding failure than adults (unpubl. data). We did not record the age of each individual vulture within a pair in each visit, so it was impossible to estimate

TABLE 2. Mean estimated productivity (number of fledglings/number of pairs) of Griffon Vultures in the gorges of the Riaza River calculated from estimates of breeding success made during each survey or combination of survey dates (see methods). Productivity calculated from all surveys and nest observations (0.48 fledglings/pair) is termed observed productivity.

Number of visits	Mean ± SD productivity	Range	Mean difference with observed productivity (Range)	Best survey date[a]
One	0.69 ± 0.12	0.59–0.89	0.21 (0.11–0.41)	c
Two	0.59 ± 0.07	0.53–0.76	0.11 (0.05–0.28)	b + c
Three	0.54 ± 0.03	0.50–0.60	0.06 (0.02–0.12)	b + c + d
Four	0.50 ± 0.01	0.48–0.52	0.02 (0.00–0.04)	a + b + c + d

[a] a = 15–16 January, b = 5–6 February, c = 26–27 February, d = 26–27 March, e = 16–17 April.

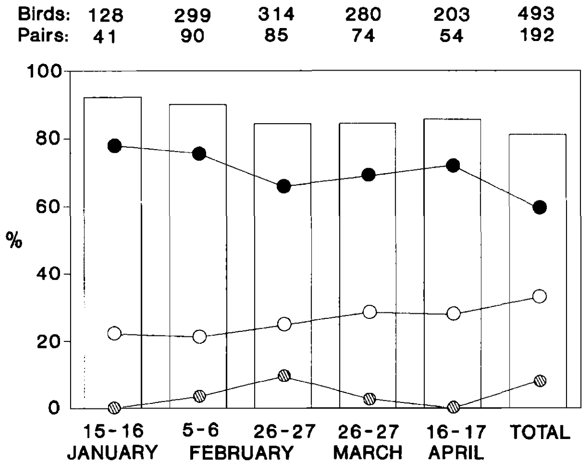

FIGURE 2. Proportion of adults (bars) and each within-pair age combination (black points = adult pairs, white = mixed pairs, hatched = subadult pairs) detected in each survey. Numbers above the bars indicate sample sizes. "Total" column indicates the overall estimated proportions (see methods).

the increased precision nor the best survey option in relation with the number of visits. However, a single visit between the end of February and the end of March may yield a result that correlates well with the total proportion of adults (Fig. 2). Pair bond distribution at each survey showed that the proportion of mixed pairs (adult-subadult) was always underestimated in favor of adult pairs (Fig. 2).

DISCUSSION

The results of the present study have shown that the accuracy of surveys increased with monitoring frequency because repeated counts during the breeding season compensate for breeding failures and late onset of breeding. The proportion of new breeding pairs detected increased until all pairs had layed, while the number of pairs that failed during incubation (hence not detected in a single one visit) increased with the season. After breeding failure the determination of the breeding status of individuals and pairs is usually difficult and subjective, because vultures then show variable nest-site attendance and pair-bonding behavior. Furthermore, the presence of a nest can not be considered a reliable sign of a breeding attempt because different pairs can use the same nest in succession during the same breeding season (pers. obs.). Further, some mated pairs do not built nests and most nests located inside caves can escape notice.

Single counts of nesting vultures detected 30–80% of pairs depending on the survey date. The best survey option for a single visist underestimated the breeding population by about 20%. About 10% of the pairs, which lost their eggs previous to our visit, and another 10% of pairs, which layed after the survey date, were not detected in a single visit. These results, applied to the last Spanish national survey of Griffon Vultures, with an average of 1.65 visits per colony (Arroyo et al. 1990), suggest that colony sizes and overall population size were underestimated by varying amounts depending on survey dates and other variables, including observer ability, experience in searching for nests, knowledge of the colony and breeding behavior, type of habitat and nest sites, etc. (Fuller and Mosher 1981). The effects of these additional variables were not quantified in this study.

The high nesting aggregation of Griffon Vultures in Spain (551 colonies and 100 isolated pairs in 1989; Arroyo et al. 1990) may facilitate surveys because several pairs can be monitored simultaneously. However, the insufficient monitoring frequency probably resulted in an underestimate of colony size, due to the large number of pairs per colony (34.9% of pairs were included in colonies holding 31–90 pairs in 1989). Our results were obtained in one of the largest colonies of Griffon Vulture in Spain, albeit well known due to intensive monitoring (Martínez 1985, Martínez and Cobo 1993, Sociedad Española de Ornitología 1981). Accuracy of population estimates could vary in colonies of different size, but ultimately it would depend on the time allocated for locating and monitoring breeding pairs. If surveys are conducted on a large number of colonies, it is usually not possible to visit them frequently given the constraints of time, manpower and money. The best combination of possible survey dates presented here can help in programming survey activity (in keeping with the time allocated for locating and monitoring breeding pairs), and to evaluate the error of the estimates when less than the best possible combinations are made.

Our data suggest that the accuracy of productivity and age composition estimates are also influenced by the dates and the frequency of monitoring (see also Fraser et al. 1983, Fuller et al. 1995). With regard to productivity estimates, accuracy improved by sampling the breeding population in a balanced manner with respect to the breeders' age distribution, because breeding performance is associated with the breeder's age and experience among other associated factors (unpubl. data, see also Saether 1990). Similarly, the population under study needs to be sampled throughout the breeding season because breeding success is closely related to the breeding dates (unpubl. data, see also Newton 1979).

In conclusion, we highlight the importance of multiple and time-selected surveys as opposed to single and unstandardized counts in estimating numbers of breeding Griffon Vultures. In this way, the accuracy of the estimates would improve notably and other valuable breeding biology data could be obtained at a large scale.

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