High density and distribution patterns of a Raven Corvus corax *population on an oceanic Island (El Hierro, Canary Islands)*

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Data are provided on the density and distribution of an oceanic island population of Ravens (El Hierro, Canary Islands). The density of both the breeding population (ca. 35 pairs/100 km²) and that censused from a vehicle (35 birds/100 km) is the highest recorded in island environments and the second highest in the species' entire distribution area. The high density is probably due to an abundant food supply and numerous suitable nesting sites. Relief and altitude influenced the distribution of breeding territories which showed a high level of constancy from one year to the next.

One characteristic of island communities is that they have a smaller number of species than similar continental ones. Because of this, many bird species tend to occupy more kinds of habitat on islands, have wider trophic niches and occur at higher population densities than they do in continental environments (McArthur et al. 1972).

Almost all studies of Raven *Corvus corax* populations have been carried out in continental ecosystems (Holyoak and Ratcliffe 1968, Hooper et al. 1975, Smith and Murphy 1982, Davis and Davis 1986) or islands close to continents, such as Shetland (Ewins et al. 1986), Orkney (Booth 1979), Isle of Man (Elliot and Nuttall 1983) and Sicily (Giudice and Mascara 1985). Despite the Raven's wide distribution throughout the Holarctic (Vaurie 1959), until now no populations inhabiting oceanic islands have been studied.

The Raven populations in the Canary Islands (including the subspecies *tingitanus*) are the only ones in the Macaronesian archipelagoes (Le Grand et al. 1985). They constitute the southernmost ones in the Palearctic, the biogeographic region to which the majority of bird species in the Canary Islands belong. Despite the fact that the Raven is widely distributed throughout the major island and islets of the Canaries, the decision to undertake this study on El Hierro was based on the fact that this island has a high population density of Ravens as already noticed in the last century (Bolle 1857, Meade-Waldo 1890). The study was carried out in 1986 and 1987 and aimed at documenting the density and distribution of Ravens on this oceanic island.

Study area and methods

The volcanic Canarian archipelago is situated in the Atlantic Ocean some 100 km (at the closest point) from the African continent. The island of El Hierro represents the south-western extreme of the Canary Islands, at 17°20'W and 27°45'N. As the smallest of the principal islands, its area is about 278 km², which represents 3.7% of the total for the Canarian archipelago. Its highest point is about 1500 m above see level. Mean temperatures vary with altitude from 21°C in coastal zones to 15°C at the highest altitudes. There has been a large number of studies of the island's vegetation (Ceballos and Ortuño 1976, Pérez de Paz et al. 1981).

The nesting population of Raven was censused during spring in 1986 and 1987. The island was divided into 61 squares of 6.25 km² (Fig. 1) which were systematically examined on foot. The position of each breeding territory was plotted on a 1:50,000 map. Breeding criteria were those used in ornithological atlas work (Sharrock 1976, Martín 1987). Estimates of the number of non-breeding adults were more difficult to arrive at because a number of flocks were continually moving over a large area.

Road censuses starting one hour after dawn were carried out monthly from November 1986 to October 1987. Two routes were selected (east and west) and driven on two consecutive days in each month in good weather. The eastern route began at Montaña de Iramas and ended in Las Montañetas (47 km), while the other crossed the western part of the island from Montaña de Las Casillas to Bailadero de las Brujas (68 km). Over the year a total of 1374 km (east: 558 km, west: 816 km) was covered, with in all 374 sightings of Ravens. The censuses were carried out by one person travelling on motorcycle at an average speed of 30–50 km h^{-1}. The gregarious nature of Ravens posed a problem as the number of birds sighted was dependent on locating flocks (cf. Santos and Tellería 1981).

Statistical analyses follow Sokal and Rohlf (1981). Non-parametric tests were used when the requirements of parametric tests were not met even after transformation of data (Siegel 1956).

Results

Ninety-five nesting pairs were found on El Hierro in the spring of 1986 (34.2 pairs/100 km²) and 99 in 1987 (35.6 pairs/100 km²). However, because of the rugged terrain, some parts of the island were difficult to census and I therefore estimate the total breeding population to have

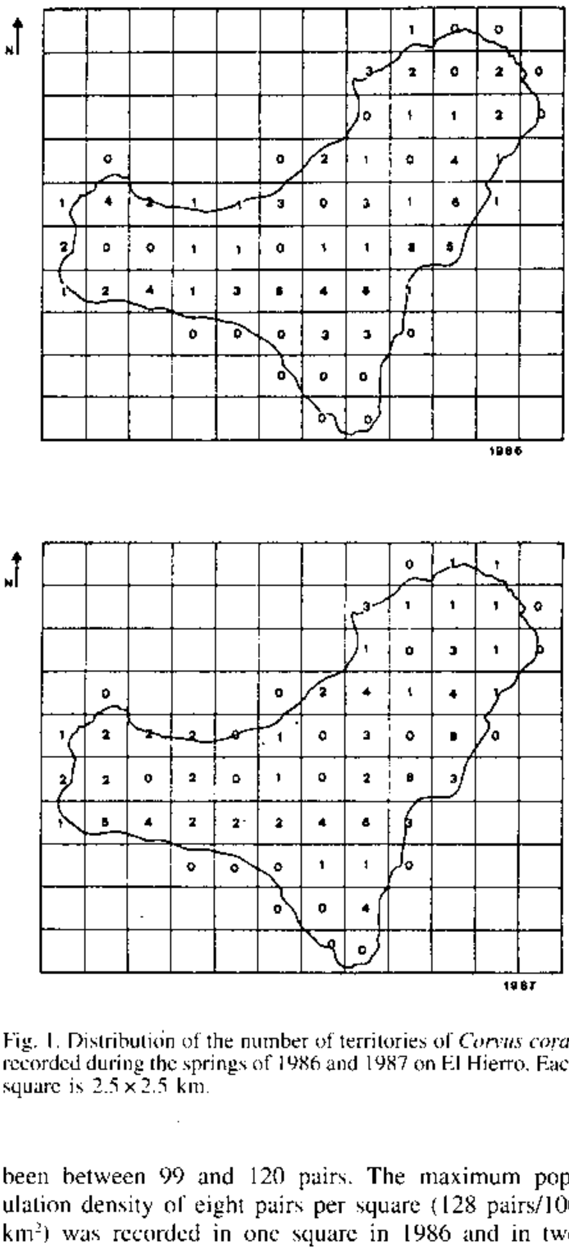

Fig. 1. Distribution of the number of territories of *Corvus corax* recorded during the springs of 1986 and 1987 on El Hierro. Each square is 2.5 × 2.5 km.

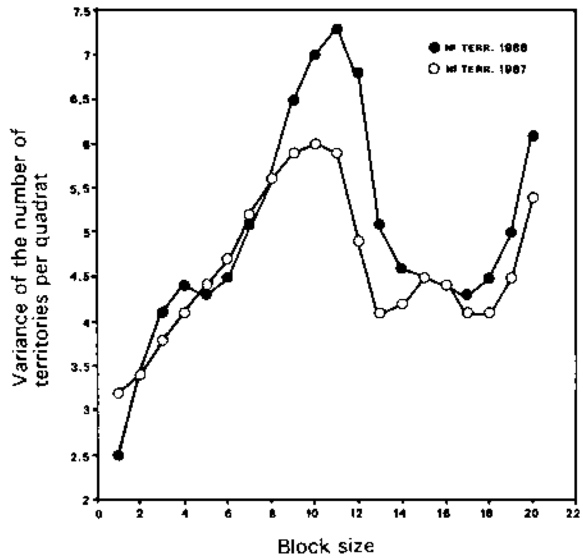

Fig. 2. Analysis of the spatial distribution pattern of *Corvus corax* territories on El Hierro, in 1986 and 1987. Variances in the number of territories for blocked squares are shown (see Fig. 1). Estimates were arrived at by means of the "Blocked quadrat variances" method (Ludwig and Reynolds 1988).

been between 99 and 120 pairs. The maximum population density of eight pairs per square (128 pairs/100 km^2) was recorded in one square in 1986 and in two squares in 1987.

Territories showed a clumped distribution (Fig. 2) with clusters in the in the eastern (Risco de las Playas) and south-western sectors (La Dehesa and Fuga de Gorreta) (Fig. 1). Squares with few territories were those on the coast, particulary in the south of the island. Ravens remain very faithful to their breeding territories so this pattern remained constant between the two years. Thus, the number of territories remained the same in 27 (44.3%) of the 61 squares. In the remaining 34 sligh changes took place, but the distribution of territory numbers among the squares did not differ between the two years (G = 2.27, P = 0.10).

In an attempt at interpreting the variability between squares in the number of territories, mean altitude and relief (the difference between the maximun and minimum heights in a square) were used as independent variables. Squares were also grouped according to the predominant direction in which they faced (N, S, E or W) and the degree of human influence as determined by their proximity to urban centres, rubbish tips, agricultural areas and pasture land. Highly significant correlations were found between number of territories and both mean altitude and relief (Table 1). In accordance with this, a large number of territories was found in areas of medium altitude with relatively prominent rocky escarpments. In neither 1986 nor 1987 did I detect any effect of human influence or the direction the squares faced (Table 1).

Results of the road censuses are presented in Table 2. For the eastern route, the mean number of Ravens observed per kilometre was 0.36 or one bird every 4.7 km.

Table 1. Relationship between the number of *Corvus corax* territories and the 4 differentiated parameters on the island of El Hierro, by means of the Spearman correlation coefficient and the Kruskal Wallis test.

	Statistic		Significance	
	1986	1987	1986	1987
Mean altitude	r_s = 0.34	r_s = 0.35	p<0.005	p<0.005
Slope index	r_s = 0.47	r_s = 0.47	p<0.001	p<0.001
Orientation	K = 3.59	K = 2.18	p>0.05	p>0.05
Human influence	K = 4.09	K = 5.92	p>0.05	p>0.05

Table 2. Results obtained from the road censuses of *Corvus corax* on the island of El Hierro (November 1986 – December 1987).

Months	Eastern route		Western route	
	Total no. of birds	Birds km^{-1}	Total no. of birds	Birds km^{-1}
January	10	0.2	42	0.6
February	22	0.5	20	0.3
March	8	0.2	1	0.0
April	6	0.1	22	0.3
May	4	0.1	6	0.1
June	6	0.1	6	0.1
July	9	0.2	6	0.1
August	67	1.4	3	0.04
September	14	0.3	12	0.2
October	12	0.3	32	0.5
November	20	0.4	14	0.2
December	28	0.6	5	0.1
Total	206		169	

For the western route, the corresponding figures were 0.21 birds or one bird every 13.2 km. Although these results seem to indicate that the number of birds along the eastern route was higher than that along the western route, the difference was not statistically significant (Wilcoxon's test, $z = 1.098$, $p = 0.27$).

Discussion

Of 27 European regions investigated so far, only three have been shown to hold Raven densities as high as 17–21 pair/100 km^2 (Table 3). However, in one North American study (at Snake River), M. N. Kochert (pers. comm.) found 72.6 pairs/100 km^2, the highest known density for the species.

In the only previous study of Raven in the Canary Islands (Martin 1987), the number of nesting pairs on Tenerife was estimated at some 70–80, i.e. a density of 3.4–3.9 pairs/100 km^2. The breeding density recorded on

Table 3. *Corvus corax* breeding pair densities in Europe, North America, Central America and the Canary Islands. *represents those studies cited by Elliot and Nuttall (1983). **represents articles cited by Davis and Davis (1986).

Study areas	Study area (km^2)	Number of territories	No. of pairs per 100 km^2	References
Shetland (Scotland)	1.450	196	13.5	Ewins et al. (1986)
Orkney (Scotland)	523	23	4.4	Booth (1979)
Orkney (Scotland)	523	27	5.2	Booth (1985)
Moffat Hills (Scotland)	502	11	2.2	Ratcliffe (1962)
Galloway Hills (Scotland)	440	23	5.2	Ratcliffe (1962)
Isle of Man (England)	587	33	5.6	Cowin (1941)
Isle of Man (England)	587	33	5.6	Cullen (1978)*
Isle of Man (England)	587	25	4.3	Elliot and Nittall (1983)
Lake District (England)	1.142	67	5.9	Ratcliffe (1962)
Snowdonia (Wales)	671	38	5.7	Ratcliffe (1962)
Snowdonia (Wales)	926	97	10.5	Dare (1986a,b)
Migneint-Hiriraethog (Wales)	477	20	4.2	Dare (1986a,b)
Cambrian Mountains (Wales)	160	14	8.8	Davis and Davis 1986
Cambrian Mountains (Wales)	315	65	20.6	Davis and Davis (1986)
Cambrian Mountains (Wales)	475	79	16.6	Davis and Davis (1986)
Dublin/Wicklow (Ireland) C.	1.600	>34	>2.0	Noonan (1971)**
Lausane-Prealp. Bernes (Switz.)	3.600	60	1.7	Blanc (1974)
Baselbieter Jura (Switz.)	600	9	1.5	Böhmer (1974)*
Valais (Switz.)	2.500	75	3.0	Oggier (1986)
SE Holstein (Germany)	1.220	23	1.9	Warckne (1960)**
NE Holstein (Germany)	170	8	4.7	Simson (1966)**
Schleswig (Germany)	2.280	49	2.15	Looft (1971)**
W. Mecklenburg (Germany)	750	24	3.2	Looft (1971)**
Wolgast (Germany)	107	20	18.7	Sellin (1987)
Botosani (Rumania)	490	47	9.6	Andriescu and Corduneau (1972)**
Tula Forest (URSS)	40	3	7.5	Likhachev (1951)**
Sicilia (Italy)	1.100	34	3.1	Giudice and Mascara (1985)
Granada (Spain)	104	6	5.8	Zũñiga et al. (1982)
Great Basin Desert (Utah) (USA)	207	4	1.9	Smith and Murphy (1982)
Ridge Valley (Virginia) (USA)	466	12	2.6	Hooper et al. (1975)
Goshen (Virginia) (USA)	44	5	11.4	Hooper et al. (1975)
R. Malheur (Oregon) (1976) (USA)	1.020	44	4.3	Stiehl (1978)
R. Malheur (Oregon) (1977) (USA)	1.020	41	4.0	Stiehl (1978)
Snake River (Idaho) (1986) (USA)	135	98	72.6	Kochert et al. (1976)
Los Escsmiles (El Salvador) C.	200	>12	>6.0	Dickey and Van Rosseau (1938)**
Tenerife Island (Canaries)	2.036	70–80	3.4–3.9	Martín (1987)
El Hierro Island (Canaries)	278	95	34.2	Present Study (1986)
El Hierro Island (Canaries)	278	99	35.6	Present Study (1987)

El Hierro (35 pairs/100 km^2) is the highest in any island ecosystem and the second highest rocorded to date anywhere in the species' range. The high density of Ravens on El Hierro may well be attributable to the wider trophic niche that the species occupies on this island in the absence of other Corvidae and carrion-eating species (M. Nogales unpubl.) as well as to the large number of apparently suitable breeding sites.

Relief and mean altitude of the square were factors that correlated with Raven abundance. A large number of territories was found in escarpment zones at 800 m a.s.l and in areas rich in food (M. Nogales unpubl.).

The Raven on El Hierro tends to choose open habitats rather than forest (M. Nogales unpubl.), as also found in Wales (Marquiss et al. 1978) and Wyoming (J. L. Dorn pers. comm.). Judging from the Ravens' diet on El Hierro (M. Nogales unpubl.), this may be related to the greater availability of food in the former. An example are the wet plains of Nisdafe (in the east) where insects, a relatively important animal food in the Raven's diet, abound during the first part of the year. This area is partially bordered by rocky escarpments suitable for nesting. These two factors, food and nest sites, may explain the species' clumped distribution on El Hierro (Fig. 2).

Although vehicles of various kinds have been widely used to census birds of prey (e.g. Mathisen and Mathisen 1968, Meyburg 1973, Fuller and Mosher 1981), they have rarely been used to census corvids (but see Sammalisto 1977, Thiollay 1977, Källander et al. 1977). One possible explanation are the methodological problems arising from the birds' tendency to flock. Because of this, few studies provide information on non-breeding densities of Ravens. In the Mohave Desert (California), Austin (1971) found a density of 2.1 birds/100 km (winter) and 0.9 birds/100 km (spring) while Santos and Tellería (1981) report corresponding densities of 3.4 birds/100 km (winter) and 2.5 birds/100 km (spring) from Spain. The densities recorded on El Hierro (32.9 birds/100 km in winter and 14.4 birds/100 km in spring) are considerably higher and are in fact the highest recorded to date in any part of the world.

The tendency towards fewer sightings along the western than the eastern route might be explained by the fact that this route ran along the edge of, and occasionally crossed forest, a habitat little used by the Raven. The eastern route, on the other hand, crossed the wet pasture land of Nisdafe where the largest numbers of Ravens were observed during the road censuses.

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References

Austin, G. T. 1971. Roadside distribution of the Common Raven in the Mohave Desert. – Calif. Birds 2: 98.

Blanc, T. 1974. Quelques données sur la vie et l'expansion du Grand Corbeau en Suisse romande. – Nos Oiseaux 32: 257.

Bolle, C. 1857. Mein zweiter Beitrag zur Vogelkunde der canarischen Inseln. – J. Orn. 5: 305–351.

Booth, C. J. 1979. A study of ravens in Orkney. – Scott. Birds 10: 261–267.

– 1985. The breeding success of ravens on Mainland, Orkney 1983–1985. – Orkney Bird Rep.: 59–62.

Ceballos, L. and Ortuño, F. 1976. Vegetación y flora forestal de las Canarias Occidentales. Excmo. Cabildo Insular de Tenerife. Santa Cruz de Tenerife.

Cowin, W. S. 1941. A census of breeding ravens. – Peregrine 1: 3–6.

Dare, P. J. 1986a. Raven *Corvus corax* populations in two upland regions of north Wales. – Bird Study 33: 179–189.

– 1986b. Aspects of the breeding biology of ravens in two upland regions of north Wales. – Naturalist 111: 129–137.

Davis, P. E. and Davis, J. E. 1986. The breeding biology of a Raven population in central Wales. – Nature in Wales 3: 44–54.

Elliot, G. and Nuttall, J. 1983. A survey of ravens in the Isle of Man. – Peregrine: 238–239.

Ewins, P. J., Dymond, J. N. and Marquiss, M. 1986. The distribution, breeding and diet of Ravens *Corvus corax* in Shetland. – Bird Study 33: 110–116.

Fuller, M. R. and Mosher, J. A. 1981. Methods of detecting and counting raptors: A review. – Studies in Avian Biology 6: 235–246.

Giudice, E. and Mascara, R. 1985. Corvo Imperiale *Corvus corax*. – Il Naturalista Siciliano 9 (Número speciale): 182–183.

Holyoak, D. and Ratcliffe, D. A. 1968. The distribution of the Raven in Britain and Ireland. – Bird Study 15: 191–197.

Hooper, R. G., Crawford, H. S., Chamberlain, D. R. and Harlow, R. F. 1975. Nesting density of common ravens in the Ridgevalley region of Virginia. – American Birds 29: 931–935.

Källander, H., Nilsson, S. G. and Svensson, S. 1977. The Swedish winter bird census programme. – Pol. Ecol. Stud. 3: 77–88.

Le Grand, G., Emmerson, K. W. and Martín, A. 1985. Situación de la Avifauna de la Macaronesia (Azores, Madeira, Canarias y Cabo Verde). – In: Situación de la Avifauna de la Península Ibérica, Baleares y Macaronesia. Ed. CODA-SEO.

Ludwig, J. A. and Reynolds, J. F. 1988. Statistical Ecology. – John Willey and Sons, New York.

MacArthur, R. H., Diamond, J. M. and Karr, J. R. 1972. Density compensation in islands faunas. – Ecology 53: 330–342.

Marquiss, M., Newton, I. and Ratcliffe, D. A. 1978. The decline of the Raven, *Corvus corax*, in relation to afforestation in southern Scotland and northern England. – J. Appl. Ecol. 15: 129–144.

Martín, A. 1987. Atlas de las aves nidificantes en la Isla de Tenerife. – Instituto de Estudios Canarios. Monografía XXXII.

Marzol Jaén, M. V. 1988. La lluvia: un recurso natural para Canarias. – Servicio de Publicaciones de la Caja General de Ahorros de Canarias.

Mathisen, J. E. and Mathisen, A. 1968. Species and abundance of diurnal raptors in the panhandle of Nebraska. – Wilson Bull. 80: 479–486.

Meade-Waldo, E. G. B. 1890. Further notes on the birds of the Canary Islands. – Ibis 6: 429–438.

Meyburg, B. V. 1973. Observations sur l'abundance relative des rapaces (Falconiformes) dans le Nord et L'Ouest de L'Espagne. – Ardeola 19: 129–150.

Oggier, P. A. 1986. Siedlungsdichte und Sozialverhalten des

Kolkraben *Corvus corax* im Wallis. – Orn. Beob. 83: 295–299.
Pérez de Paz, P. L., Del Arco, M. and Wildpret, W. 1981. Contribución al conocimiento de la flora y vegetación de El Hierro (Islas canarias). I. – Lagascalia 10: 25–57.
Ratcliffe, D. A. 1962. Breeding density in the Peregrine *Falco peregrinus* and Raven *Corvus corax*. – Ibis 104: 13–19.
Sammalisto, L. 1977. Twenty years of the Finnish winter bird census. – Pol. ecol. Stud. 3: 199–206.
Santos, T. and Tellería, J. L. 1981. El método de conteo de aves desde vehículo. Un ejemplo en el Sistema Central. – Cuad. Invest. Biol. (Bilbao) 2: 27–37.
Sellin, D. 1987. Zu Bestand, Ökologie und Ethologie des Kolkraben (*Corvus corax*) in Nordosten des Bezirkes Rostock. – Vogelwelt 108: 13–27.
Sharrock, J. T. R. 1976. The Atlas of Breeding Birds in Britain and Ireland. – British Trust for Ornithology and Irish Wildbird Conservancy.
Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. – McGraw-Hill, New York.
Smith, D. G. and Murphy, J. R. 1982. Nest site selection in raptor communities of the eastern Great Basin Desert. – Great Basin Natur. 42: 395–404.
Sokal, R. and Rohlf, F. J. 1981. Biometry. 2nd ed. – Freeman and Company, San Francisco.
Thiollay, J. M. 1977. Distribution saisonniere des rapaces diurnes en Afrique occidentale. – L'Oiseau et R. F. O. 47: 253–294.
Vaurie, C. 1959. The birds of the Palearctic Fauna. A systematic reference: Order Passeriformes. – Witherby, London.
Zúñiga, J. M., Soler, M. and Camacho, I. 1982. Status de la avifauna terrestre de la Hoya de Guadix. Aspectos ecológicos. – Trab. Monogr. Dep. Zool. Univ. Granada, (N.S.) 5: 17–51.