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SHORT REPORT

Habitat use by juvenile Golden Eagles *Aquila chrysaetos* in Spain

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Capsule Dispersing juvenile Golden Eagles are habitat generalists that do not regularly use temporary settlements.

We studied the patterns of Golden Eagle *Aquila chrysaetos* habitat use during the first year of their juvenile dispersal, the least known stage of life for this species (Watson 1997). The first stages of juvenile dispersal are critical for individual survival, because while birds are still improving their hunting techniques, they are facing the challenge of securing food in an unknown landscape. As a consequence, soon after independence juveniles of many species tend to restrict their movements to a few favourable areas. For instance, juvenile Bonelli's Eagles *Hieraaetus fasciatus* and Spanish Imperial Eagles *Aquila adalberti* (the other two large eagle species resident in our study area) restrict most of their movements to 'temporary settlements', a few sites within the boundaries of their dispersal areas (Ferrer 1993, 2001, Ferrer & Harte 1997, Real & Mañosa 2001, Balbontín 2005, Cadahía *et al.* 2005) that are used year after year by different juveniles of these and other raptor species (Ferrer 2001). Food availability seems to be the main reason for eagles to aggregate in these temporary settlements (Mañosa *et al.* 1998, Ferrer 2001, Real & Mañosa 2001). In contrast, juvenile Golden Eagles do not restrict their movements to a few, regularly used areas, but instead the size of their dispersal area increases throughout the first year of life (Soutullo *et al.* 2006a, 2006b). Here we explore whether, despite not restricting their movements to a few temporary settlements, Golden Eagles show preferences for some habitat types within their dispersal areas. This might provide insight into how dependent they are on some prey or habitat types during this early stage of their independent life.

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We used satellite telemetry to collect information on the locations of seven juvenile Golden Eagles (five females and two males) from a resident population in eastern Spain. Individuals were captured between June 2002 and October 2004, while still in the nest, at the age of about 50 days. Platform transmitter terminals (PTTs) were fixed to the birds' backs using a breakaway Teflon harness. The equipment never exceeded 2.5% of the juveniles' body mass, as suggested by Kenward (2001). For computational purposes all individuals were treated as if tagging had occurred when they were exactly 50 days old. Locations were collected using the Argos system (a satellite-based location and data collection system, Kenward 2001), and birds were tracked during their first year of life. Argos assigns a measure of estimate reliability (location class, LC) to each position estimate. Two of the PTTs had a geographical positioning system (GPS) incorporated, providing locations with an accuracy of <20 m; for the rest only locations assigned to LCs 3, 2 and 1 (with nominal accuracies between 150 and 1000 m) were used for the analyses (Soutullo *et al.* 2007). Given the ability of Golden Eagles to move several kilometres in a few minutes (Soutullo *et al.* 2006c), and the country-wide scale of the habitat data we used, we considered locations with an accuracy ranging from 20 m to 1 km as reliable descriptors of birds' use of different habitat types. Soutullo *et al.* (2006a, 2006b, 2006c) provide further details on the study area, the individuals studied, the tagging and tracking techniques, and PTT duty cycles.

Following Soutullo *et al.* (2006b) we used the first day that birds were located more than 10 km away from the natal nest as the date of the onset of juvenile dispersal (i.e. the date of independence). For each individual we estimated the size of the dispersal area used after independence as the minimum convex polygon including all locations obtained in that period (i.e. from independence to the end of their first year of life). We then calculated the proportion of different habitat types within each dispersal area using the Corine Land Cover map for Spain (CLC 2007) and performed a compositional analysis (Aebischer *et al.* 1993) to compare these proportions with the frequency of bird locations within the different habitat types. To calculate these proportions we generated 1000 random points within each dispersal area using Arcview's Random Point Generator (Jenness 2005), and assigned to each random point the corresponding habitat type. The same random points were later used to compare the altitude at which birds were located with that of the dispersal area. Computations for the compositional analysis were conducted in Matlab 7. In cases where habitat use or availability was 0% we replaced that value by 0.001% (Aebischer *et al.* 1993). For the pairwise comparisons between habitat types we used one-tailed *t*-tests (Aebischer *et al.* 1993).

Finally, we used Monte Carlo tests (Manly 1997) to compare the average altitude of the terrain at those places where birds were located, with the overall topography of the dispersal areas. For each individual we calculated the median of the altitudes at the locations, and compared them with the confidence interval including the central 95% of the values (a two-tailed test) obtained from choosing at random with replacement the same number of random points from the corresponding dispersal area. For both the random points and bird locations we obtained the altitude of the terrain from United States Geological Survey 30-arc-second Shuttle Radar Topography Mission (SRTM) digital elevation model (Global Land Cover Facility 2007). In each case a total of 1000 randomizations were performed using Excel's Poptools add-in (Hood 2006).

Significant differences were observed among individuals in both the availability of different habitat types within their dispersal areas, and the use they make of them (Table 1; $\chi^2_6 = 24.9$, $P < 0.001$). Differences were also observed in the altitude of the dispersal areas, with median altitude varying between 368 and 1057 m, and all but one individual showing no preferences for sectors located at particular altitudes (Table 2). Overall, the following ranking of habitat use was

Table 1. Habitat availability (A, %) versus habitat used (U, %) by seven Golden Eagles (identified by ID number) during the first year of juvenile dispersal in Spain.

	34465		34466		34472	
Habitat type	U	A	U	A	U	A
Non-irrigated arable land	30.0	50.2	0.0	40.0	18.6	39.5
Permanently irrigated land	20.0	0.2	8.7	6.9	1.7	4.6
Complex cultivation patterns	20.0	10.7	21.7	17.5	20.3	17.2
Coniferous forest	3.3	2.1	21.7	7.2	16.9	5.7
Sclerophyllous vegetation	10.0	6.9	21.7	7.9	20.3	14.4
Transitional woodland-shrub	6.7	6.0	0.0	9.4	10.2	5.2
Other habitat types	10.0	23.9	26.1	11.2	11.9	13.4

	34473		34474		49181		49182	
Habitat type	U	A	U	A	U	A	U	A
Non-irrigated arable land	7.0	4.1	10.3	42.9	16.9	21.3	4.8	28.8
Permanently irrigated land	2.3	5.9	0.0	6.2	1.8	4.3	0.0	4.1
Complex cultivation patterns	18.6	24.3	56.4	12.5	3.4	14.8	0.4	4.3
Coniferous forest	25.6	8.4	12.8	3.9	10.1	12.4	6.1	15.6
Sclerophyllous vegetation	7.0	19.4	5.1	9.4	25.2	18.1	63.0	16.5
Transitional woodland-shrub	16.3	5.8	15.4	6.6	30.7	8.5	12.1	9.7
Other habitat types	23.3	32.1	0.0	18.5	11.9	20.6	13.6	21.0

Table 2. Altitude of locations versus altitude of dispersal areas for seven juvenile Golden Eagles.

Eagle ID	Median altitude of locations (m)	Median altitude of dispersal area (m)			
		Mean	sd	Lower CL	Upper CL
34465	797.0	800.7	26.3	746.0	857.0
34466	830.5	837.5	21.0	794.5	874.5
34472	811.0	841.9	19.9	798.0	874.0
34473	509.0	367.6	82.2	232.0	530.0
34474	836.0	840.1	20.4	799.0	875.0
49181	868.0[a]	695.8	5.2	685.0	704.0
49182	1054.0	1056.5	18.1	1024.0	1096.0

For each individual the following information is provided: median altitude of the terrain at the points where birds were located; mean, sd, and lower and upper confidence limit of the median altitude of each dispersal area, calculated using random points and resampling techniques (see text). [a]The median altitude at which the bird was located is above the 95% confidence interval of the altitudes recorded within its dispersal area.

observed: Coniferous forest ~ Sclerophyllous vegetation ~ Complex cultivation patterns > Transitional woodland-shrub >> Other habitat types >> Non-irrigated arable land >> Permanently irrigated land (~ indicates not significant, $P > 0.1$; > indicates $P < 0.1$; >> indicates $P < 0.05$, differences in ranking order; $n = 7$).

These results suggest that despite showing some preferences for certain habitat types, juvenile Golden Eagles use a wide range of habitats during their first year of life, with dispersal areas of different individuals differing greatly in habitat composition. The individuals we studied centred most of their daily activities in areas with coniferous forest, sclerophyllous vegetation and complex cultivation patterns, while avoiding other habitat types, particularly arable and permanently irrigated lands. Areas with complex cultivation patterns, sclerophyllous vegetation, and ecotones between woodlands and shrubs (which constitute only a tiny fraction of the dispersal areas and hence their use might be underestimated due to the low frequency and limited accuracy of locations) are most likely used for hunting, since prey availability is higher in heterogeneous habitats, and most prey species (even carrion) are more easily detected in open landscapes (Ontiveros & Plaguezuelos 2000, López-López *et al.* 2004, 2006, Ontiveros *et al.* 2005). In contrast, coniferous forests are probably preferred for roosting, while their use of arable lands and other habitat types is probably mostly restricted to these habitats being crossed over during the eagles' daily movements to and from hunting areas and roosting sites.

Food availability seems to be the main reason for the aggregation of Bonelli's and Spanish Imperial Eagles in temporary settlements (Mañosa *et al.* 1998, Ferrer 2001, Real & Mañosa 2001). Hence, the fact that Golden Eagles do not aggregate in temporary settlements suggests that while sources of food available for juvenile Bonelli's and Spanish Imperial Eagles are aggregated and restricted to a few sites free of adult eagles, for juvenile Golden Eagles sources of food are more evenly distributed across their dispersal areas.

We suggest that Golden Eagles' ability to feed on carrion (Gil-Sánchez *et al.* 1994, Watson 1997) might play an important role in the unfolding of the first stages of their juvenile dispersal (Watson 1997, Halley & Gjershaug 1998, García-Ripollés *et al.* 2004), and explain the differences in ranging behaviour with Bonelli's and Spanish Imperial Eagles (although both may occasionally feed on carrion as well). For example, whereas in every year of their study García-Ripollés *et al.* (2004) observed one-year-old juvenile Golden Eagles feeding on carrion during the autumn and winter in the 'vulture restaurant' they studied, no juvenile Bonelli's Eagle was observed feeding there (despite both species breeding nearby).

This does not mean that juvenile Golden Eagles do not use some of the temporary settlements used by other juvenile large eagles. Instead, we suggest that since the diet of Golden Eagles is highly plastic and adjustable to prey availability (Fernández 1991, Watson 1997, 1998, Seguin *et al.* 2001, Takeuchi *et al.* 2006), birds do not need to concentrate on a few areas or habitat types for feeding. While Bonelli's and Spanish Imperial Eagles are largely dependent on rabbits, partridges and pigeons (Gil-Sánchez *et al.* 1994, 2000, Gil-Sánchez 1998, Mañosa *et al.* 1998, Ontiveros & Plaguezuelos 2000, Ferrer 2001, López-López *et al.* 2004, 2006, Ontiveros *et al.* 2005), Golden Eagles are not. Although in certain parts of their range these prey species may constitute 70% of the Golden Eagle diet

(Gil-Sánchez *et al.* 1994) and the proportion of grouse and hare in the diet can be as high as 90%, these items may constitute less than 30% of the diet, with areas where Golden Eagles feed mostly on snakes, or almost exclusively on tortoises or hedgehogs (Fernández 1991, Watson 1997, 1998, Seguin *et al.* 2001, Takeuchi *et al.* 2006). Finally, Golden Eagles might not need to aggregate in temporary settlements because their larger body size and lower metabolic rate allow them to store more reserves and feed on larger prey, and hence fast for longer (Fevold & Craighead 1958). In contrast, as the other species need to hunt more frequently, they are forced to restrict their movements to a network of sites that ensure that their chances of successful hunting are always high (Ferrer 1993).

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