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Short Communication

Survival and movements of satellite-tracked Bonelli's Eagles *Hieraaetus fasciatus* during their first winter

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Dispersal is one of the most important periods in a raptor's life, affecting both survival and subsequently evolution. It comprises three steps: (a) the decision to leave the natal area, (b) a transitional phase and (c) the selection of a new breeding location (Clobert *et al*. 2001). The entire period is called 'natal dispersal' (Greenwood & Harvey 1982) and has become an important study area for researchers and governmental agencies dealing with the conservation of endangered fauna.

Little is known about the transitional phase in most animal species, because not all methods available to study dispersal are effective at gathering good-quality information about this phase. Only methods that provide information continuously on the location of an individual (mainly radiotracking) are adequate to separate different behaviours shown by individuals in this phase of dispersal.

The development of light-weight satellite telemetry has made it possible to study both the migratory and the dispersal movements of medium to large birds (Fuller *et al*. 1995) by using devices generally termed platform transmitter terminals (PTTs) (Service Argos 2000).

The Bonelli's Eagle *Hieraaetus fasciatus* has a patchy distribution in the Western Palearctic, mainly around the Mediterranean Sea (Cramp & Simmons 1980). It is considered 'endangered' in Europe (Rocamora 1994) and 'vulnerable' in Spain (Blanco & González 1992), where 80% of the European population lives (Arroyo *et al*. 1992, Real & Mañosa 1997).

Here we report the results of tracking seven Spanish Bonelli's Eagles by satellite from fledging to 28 December 2002, including an estimate of survival and an analysis of their movement.

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STUDY AREA AND METHODS

Eight nestling Bonelli's Eagles were fitted with PTTs in five different provinces of eastern Spain (Fig. 1). Bonelli's Eagle nests are usually monitored twice in this region during the breeding season. Brood size was determined during the first visit, in order to determine whether a single nestling or a pair of siblings could be tagged. Nestling age was estimated using a telescope, on the basis of feather growth and pattern (Torres *et al*. 1981) and hatching date was calculated accordingly. Easily accessible nests were finally selected, which covered a range of latitudes (37°36′26″N, 41°18′05″N).

Nestlings were tagged at around 50 days of age. The exact age in days of each nestling was calculated afterwards using tail length (central rectrix) in the following formula: age = 0.200 × tail length (mm) + 16.262 (Mañosa *et al*. 1995).

Each nestling was removed from the nest, weighed, measured and fitted with a satellite PTT that had a small VHF radio-transmitter glued to it. These were fixed to the bird's back using a breakaway Teflon harness (Kenward 1987). The nestlings were then replaced in their nests.

Two different types of PTTs were used: battery powered (weight 30 g, 17.2 × 18.1 × 64.6 mm, antenna 17.8 cm) and solar powered (weight 35 g, 17.4 × 29.1 × 62.5 mm, antenna 17.8 cm, both from Microwave Telemetry Inc., USA). They were set to an 8-h on/120-h off duty cycle. VHF radio-transmitters (8 g) had an 8-month battery life expectancy. These were to be used in case of accident, making it possible to locate the injured animals. The full transmitter equipment never exceeded 3% of the juveniles' body mass (2.2 ± 0.45%, $n = 8$; range: 1.9–3.0%).

A blood sample was taken from each nestling for sex determination using the polymerase chain reaction (PCR)-based method described by Griffiths *et al*. (1998) and Fridolfsson and Ellegren (1999).

Reception of the locations was managed by Argos, which is a satellite-based location and data collection system (Service Argos 2000). Several factors may reduce the accuracy of satellite location determinations (Fancy *et al*. 1989, Keating *et al*. 1991, Service Argos 2000, Mech & Shannon 2002, Vincent *et al*. 2002).

The system provides seven location classes (LC) that reflect the nominal accuracy of a given location. The fact that one location is assigned to a given LC depends on how many times ('uplinks') the satellite receives a signal from the PTT and on the result of four plausibility tests that every datum must undergo. Three LC categories give a calculated accuracy (LC 3, 2 and 1) whereas the other three do not (LC 0, A and B) and there is one non-valid category (LC Z) (Table 1).

Location classes 3, 2 and 1 were used in this study. We also included locations belonging to lower quality LCs (0, A and B) when they were consistent with the juveniles' movements in terms of distance covered and time elapsed between locations. Thus, locations corresponding to movements in which the birds apparently covered unrealistically long distances in a very short period of time were

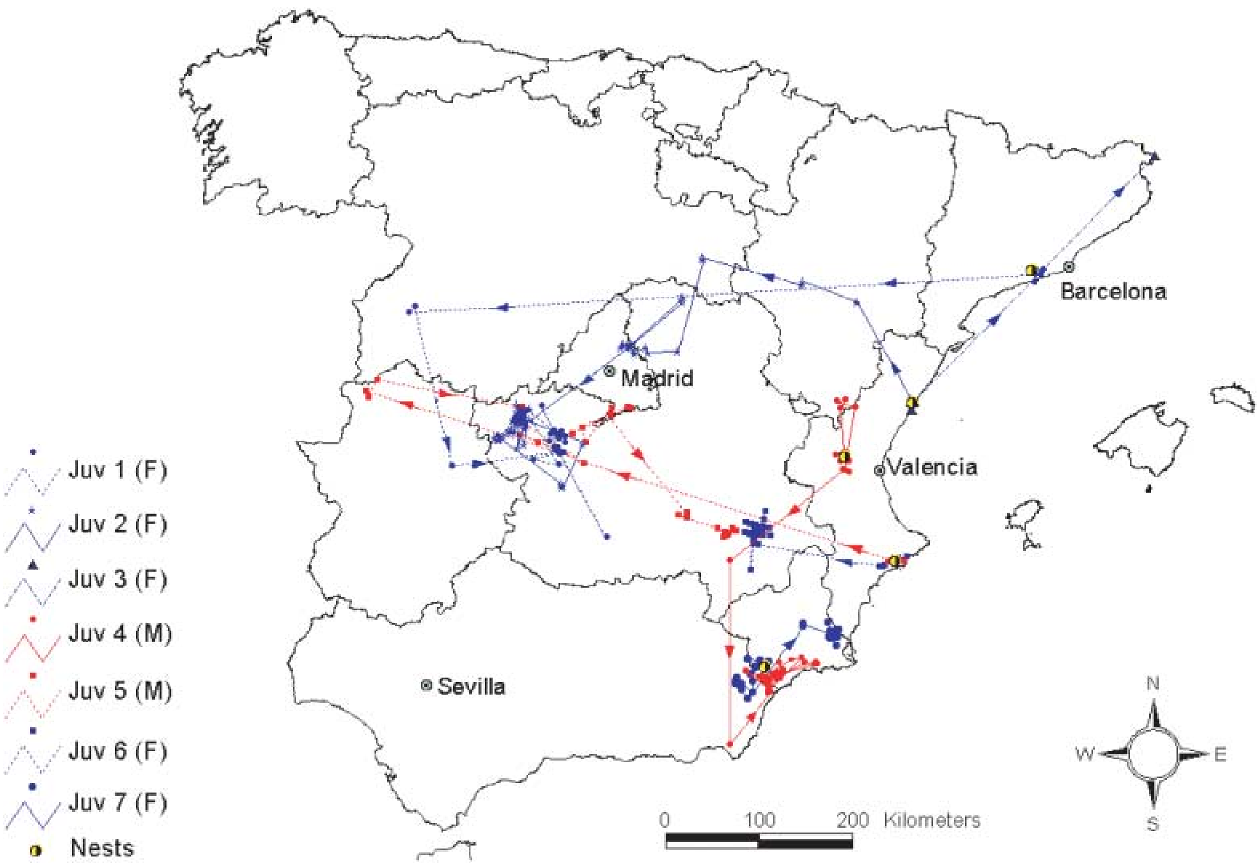

Figure 1. Movements of seven Bonelli's Eagles during their first winter in Spain in 2002. Full lines: females, dashed lines: males.

excluded (Hays *et al.* 2001), as were locations corresponding to movements at night or over the sea.

We considered the onset of dispersal to be the first movement that the juveniles took beyond 20 km from the natal nest (Arroyo *et al.* 1992, Ferrer 1993, Balbontín *et al.* 2000).

The maximum distance from the nest and the distance to the gravity centre of the furthest dispersal area were used as dispersal distance estimators. In the second case, we considered dispersal areas to be those more than 20 km from the nest, and where the distances between successive locations were less than 20 km (Balbontín *et al.* 2000, Ferrer 1993). The gravity centre of these areas was calculated as the arithmetic mean of the entire set of coordinates corresponding to a given dispersal area. Note that Juvenile 3 was not included in male–female comparisons because it died soon after dispersal and provided few reliable locations. Comparisons among siblings were also carried out, and the routes followed by juveniles were plotted using ArcView version 3.2. Statistical analyses were carried out using SPSS version 11.5.

Table 1. Summary of the satellite telemetry information used in this study (J1 to J7: valid locations for each bird; n.c.: not calculated).

LC	Total locations	J1	J2	J3	J4	J5	J6	J7	Valid locations	% used	Location acccuracy	No. of uplinks
3	10	1	2	0	1	3	2	1	10	100.0	< 150 m	4
2	20	2	5	1	3	0	5	4	20	100.0	150–350 m	4
1	86	8	18	4	15	8	17	16	86	100.0	350–1000 m	4
0	148	9	17	2	12	6	13	11	70	47.3	> 1000 m	4
A	107	2	13	1	7	8	7	12	50	46.7	n.c.	3
B	176	7	7	1	1	2	1	4	23	13.1	n.c.	2
Total	547	29	62	9	39	27	45	48	259	_	_	_

Table 2. Dispersal parameters for averaging the first winter movements in seven Bonelli's Eagle juveniles.

	Age at dispersal (days)	Dispersal date	Date of death or signal lost	Departing direction from parental territory	Maximum distance from nest (km)	Distance dispersal area from nest (km)
Female 1	151	30/08/02	–	266° (SW)	663	536
Female 2	103	25/06/02	–	331° (NW)	444	416
Female 3	122	10/07/02	31/07/02	49° (NE)	367	367
Male 4	175	05/09/02	–	227° (SW)	332	244
Male 5	146	06/08/02		298° (NW)	589	376
Female 6	149	10/08/02	–	278° (NW)	165	151
Female 7	149	02/08/02	01/12/02	231° (SW)	87	80

RESULTS

One of the eight tagged nestlings died before leaving the parental area and dispersing. Here we present results for the remaining juveniles tracked from fledging until 28 December 2002 or until the individual died. In total, five females and two males were tracked, and 547 locations were received from dispersal to the end of the study period: 259 (47.3%) were useable (Table 1).

Two birds were confirmed dead. Juvenile 8 died before leaving its natal area in Murcia, and the cause of death could not be determined. We therefore consider survival from fledging to dispersal to be 87%. Juvenile 3 died from strychnine poisoning 367 km from its nest at the age of 152 days (August 2002) (Toxicology Service, University of Murcia). The tag fitted to Juvenile 7 ceased working in early December 2002, when the bird was 268 days old. As the individual was not found, its death cannot be confirmed, so survival from dispersal to the end of the study period ranged from 71% (if Juvenile 7 had died) to 85% (if it had not).

Dispersal movement occurred at an average age of 142 ± 23 sd days. The maximum distance from the nest varied from 87 km (Juvenile 7) to 663 km (Juvenile 1). Distances from dispersal areas to the nest ranged from 80 km (Juvenile 7) to 536 km (Juvenile 1) ($n = 7$) (Table 2).

We found no differences between sexes either in maximum distance from the nest or in distances from dispersal areas to the natal nests (maximum distance Mann–Whitney $U = 3.000$, ns; dispersal areas distance Mann–Whitney $U = 4.000$, ns; $n = 6$).

Only one pair of siblings could be compared, because one or both siblings died in the remainder of the cases. Juvenile male 5 was found further from the nest than his sister Juvenile 6; this was the case both when comparing maximum distances and when comparing the distance from the dispersal areas to their natal nest.

DISCUSSION

The beginning of the dispersal period in the Bonelli's Eagles in our study can be described as wandering behaviour (Cugnasse & Cramm 1990) followed by settlement in dispersal areas. The mean age at dispersal (142 days) was similar to those reported for Bonelli's Eagles in central Spain (141.5 days) (Arroyo *et al.* 1992), Andalucia (146.7 days) (Balbontín *et al.* 2000) and Catalonia (163 days) (Real *et al.* 1998).

Our results concerning distances travelled and locations of dispersal areas agree with previous studies using visual sightings of wing-tagged birds and band recoveries (Real & Mañosa 2001), radiotracking (Arroyo *et al.* 1992, Balbontín *et al.* 2000) and previous satellite tracking (Alcántara *et al.* 2001). However, the majority of our juveniles moved further during these first months than did those studied by other authors. Cheylan *et al.* (1996) found movements to locations 32 km from the nests during the first winter in southern France, and Balbontín *et al.* (2000) reported a maximum distance of 100 km from the nest in young eagles tagged in Andalucia (southern Spain) in 1998 and 1999. Real and Mañosa (2001), studying birds from Catalonia (northeast Spain), found a large proportion of short-distance dispersers and few birds moving to more distant areas. In addition, Bonelli's Eagles from an isolated population in southern Portugal are known to travel short distances during dispersal (Palma, L., Mira, S. & Cancela, L. pers. comm.).

These differences may be the result of different factors, including the method used to monitor dispersal. In conventional radiotracking and sighting/recovery studies the fact that birds are reported more commonly in areas near the nests may simply reflect the difficulty for researchers to move to distant areas in order to locate the birds. Thus, long-distance dispersers might not be detected. On the other hand, the proximity of potentially suitable dispersal areas might influence the different distances travelled by juveniles (Walls *et al.* 1999). Genetic aspects could also influence dispersal tendencies (Greenwood *et al.* 1979, Newton & Marquiss 1983).

The lack of a sex difference in the distances travelled disagrees with the general dispersal pattern observed in raptors (Greenwood & Harvey 1982). Although sex differences have been reported in previous work on the Bonelli's Eagle (Mañosa *et al.* 1998, Real & Mañosa

2001), our data might not fit this pattern because of the reduced sample size or the relatively short period of time considered.

The dispersal areas found in this study are common to several individuals. This means that juvenile Bonelli's Eagles do not hold territories, but share the general foraging areas to which they move. Overlapping of dispersal areas has already been described for a number of raptor species, including the Spanish Imperial Eagle *Aquila adalberti* (Ferrer 1993), the Northern Goshawk *Accipiter gentilis* (Walls & Kenward 1994) and the Common Buzzard *Buteo buteo* (Walls & Kenward 1995, 2001). Previous studies of Bonelli's Eagle have also shown the probable presence of these common dispersal areas in Spain (Arroyo *et al*. 1992, Cheylan *et al*. 1996, Real & Mañosa 1997, 2001). The present study confirms the existence of these areas and the location of some of them, mainly in regions where small game is abundant in the centre of the Iberian Peninsula.

Many deaths of Bonelli's Eagle are caused by electrocutions and collisions with power lines (Arroyo *et al*. 1990, Cheylan *et al*. 1996, Real *et al*. 2001). However, the death of Juvenile 3 by strychnine poisoning highlights another factor affecting juvenile survival, and which has been increasing in Spain in recent years (Mateo *et al*. 2004). Poisoning is responsible for 3% of mortality cases in this species in Spain (Real *et al*. 2001). The death of Juvenile 8 could be related to its hunting inexperience or to a predator attack, both of which are likely causes of death in juveniles, because they are typically naïve and vulnerable (Newton 1979). Predation on juvenile Bonelli's Eagles has been reported in Spain (Real & Mañosa 1990).

Juveniles cover large areas after natal dispersal. The areas in which they settle in their first winter are known to hold high densities of prey. The birds we tracked basically moved to central Spain. Because of this, conservation efforts of Bonelli's Eagles, even when aimed at a regional breeding population, should consider factors at a larger scale.

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