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The first case of successful breeding of a Golden Eagle *Aquila chrysaetos* tracked from birth by satellite telemetry

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Abstract. The natal dispersal of a Golden Eagle from its natal eyrie to the site where it reproduced for the first time was monitored. After covering > 16 000 km^2 in its three years of juvenile dispersal, and despite flying > 130 km from its natal site, the eagle finally settled in a vacant territory just 26 km away from the place where it had hatched. Almost 95% of the total dispersal area was visited for the first time during the first year of tracking; less than 40% of the dispersal area was used during the remainder of the dispersal period. During dispersal the eagle regularly visited territories occupied by adult Golden Eagles. Previous records of the occupancy of the territory the eagle currently occupies show an alternation between periods when it remained vacant with periods when subadults occupied it. Although the other member of the breeding pair is also a subadult eagle, the birds managed to raise two fledglings.

Key words: breeding, juvenile dispersal, natal dispersal, raptors, satellite tracking

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"The life of the Golden eagle from its first winter to its forth or fifth summer is still largely a mystery" (Watson 1997), or at least it was only a decade ago. However, in the last few years, and mostly due to the application of satellite technology to the study of birds movements, there has been a remarkable progress in our understanding of the behaviour of Golden Eagles during their first years of life (Grant & McGrady 1999, O'Toole et al. 1999, McIntyre & Collopy 2006, McIntyre et al. 2006, Soutullo et al. 2006a, 2006b, 2006c, in press).

However, detailed knowledge on the process of natal dispersal, which includes the movements undertaken by individuals from their birth site to the place where they first reproduce (Greenwood & Harvey 1982), is still lacking. Dispersal of individuals has, however, crucial implications for populations. It affects their dynamics and persistence, and thus the distribution and abundance of species, as well as community structure (see Clobert et al. 2001 and references therein). Yet, dispersal is still one of the least known phenomena in population ecology and evolutionary biology. Here we provide the first detailed account of the natal dispersal of a Golden Eagle, tracked by satellite telemetry since its 50th day of life to its first breeding attempt.

On 9 June 2004 we captured a young male Golden Eagle in Sierra de Salinas, Alicante, Spain (38.52°N, 0.95°W). The chick was captured while still in the nest at the age of ca. 50 days. It was weighed, measured, tagged with a 70 g Argos/GPS Solar PTT-100 satellite transmitter, and returned to the nest. Since then, the bird has been tracked using the Argos system, obtaining 3800 highly-accurate (< 20 m error) locations (see Soutullo et al. 2006a, 2006b, 2006c, 2007 for further details on the study area, the individual monitored and the tracking techniques).

To describe the eagle movements from tagging to its first breeding attempt we pooled daily locations into monthly values, starting in July 2004. For each Gregorian month we calculated the minimum (D_{Min}), average (D_{Mean}) and maximum (D_{Max}) Euclidean distances to the nest, the size of the minimum convex polygon including all the locations of the month (MCP_M), and its centroid. The size of the whole dispersal area was calculated as the size of the minimum convex polygon including all the locations. The size of the areas used between July 2004 and June 2005 (the first year of tracking), and between July 2005 and March 2007 were calculated in the same manner. All spatial analyses were conducted using ArcView 3.2 and the Convex Hulls (Jenness 2007) and Animal Movement (Hooge & Eichenlaub 1997) extensions.

To describe temporal trends in the size of the dispersal area and the distance to the nest, monthly values for D_{Mean} and MCP_M were plotted against time. Only data from September 2004 to June 2006 were used, as the bird did not become independent until September 2004 (Soutullo et al. 2006c), and since June 2006 it has remained in the territory it currently occupies. To test whether there was serial correlation in either measure we constructed correlograms (e.g., Chatfield 2004). For the distance data, which presented autocorrelation, we removed the serial correlation using a first-order moving average process (an ARIMA (0, 0, 1) model; Chatfield 2004). A logarithmic decay and a quadratic model were then fitted to the MCP and the (filtered) distance data, respectively. The time series analyses were conducted in Statistica 6 (StatSoft 2001); all other calculations were conducted using SPSS 13.0 (SPSS 2003).

In February 2007, after suspecting the bird might be attempting to breed, we visited the area where it has been dwelling for the last months to locate active nests. On 20 March 2007 we confirmed that the studied individual was sharing with another subadult an active nest in a cliff located 26 km away from its natal nest (Sierra del Maigmó, Alicante: 38.5N, 0.65W). The cliff is 40–50 m height, north-west-orientated, and surrounded by a forest of Alepo Pine *Pinus halepensis*, mixed with traditional non-irrigated cultures and abandoned country houses. The area is near a small game reserve, with abundant Rabbits *Oryctolagus cuniculus* and partridges *Alectoris rufa*. Two alternative breeding places are located 4 and 6 km away from the active nest (A. Izquierdo, pers. com.). During a third visit, in April, we confirmed that the pair was still there, and that they were either incubating eggs or brooding very young nestlings. On 18 May two eaglets of 40–45 days-old were observed in the nest, indicating that the eggs had been laid around the 20–25 of February. Nestlings' age was estimated on the basis of their plumage' development pattern (Mathieu 1985). In our last visit, in June, eaglets were full-fledged and ready to fly.

The total area used by the Golden Eagle during its three years of juvenile dispersal encompassed 16 500 km^2, with 15 483 km^2 corresponding to the total area used during the first year of tracking, and 6 260 km^2 used during the rest of the dispersal period (Fig. 1). Yet, the size of the area used in a month decreased logarithmically (MCP_M = 6630.5 – 1410.7 × ln (time); $F_{1,19}$ = 5.153, p = 0.035, R^2 = 0.213) after the first winter, and since June 2006 the bird has remained within an area of 230 km^2 that includes the territory it currently occupies (Fig. 2). In contrast, for the whole first year of tracking the eagle tended to move away from the natal area, to start moving closer during the second autumn (adjusted D_{Mean} = - 18.54 + 5.30 × time - 0.24 × time^2; $F_{2,18}$ = 5.153, p = 0.005, R^2 = 0.450; Fig. 2). After independence the maximum distance to the natal nest (131 km) was recorded in March 2005 and the minimum (3 km) in February 2006.

Although Golden Eagles do not usually breed until their 4th or 5th year of life (Watson 1997), the individual we studied was recruited to the breeding population in its 3rd year. As far as we know, this is the first detailed report of the successful recruitment of a Golden Eagle tracked from its natal nest (at least for the subspecies *A. c. homeyeri*).

Throughout the nearly three years of juvenile dispersal remarkable changes were observed in its ranging behaviour. Almost 95% of the total dispersal area was visited for the first time during the first year of tracking, with less than 40% of the dispersal area used for the rest of the dispersal period. The size of the area used in a month decreased after the first year of life. This is in line with previous suggestions of the existence of two distinct phases during juvenile dispersal, with an early

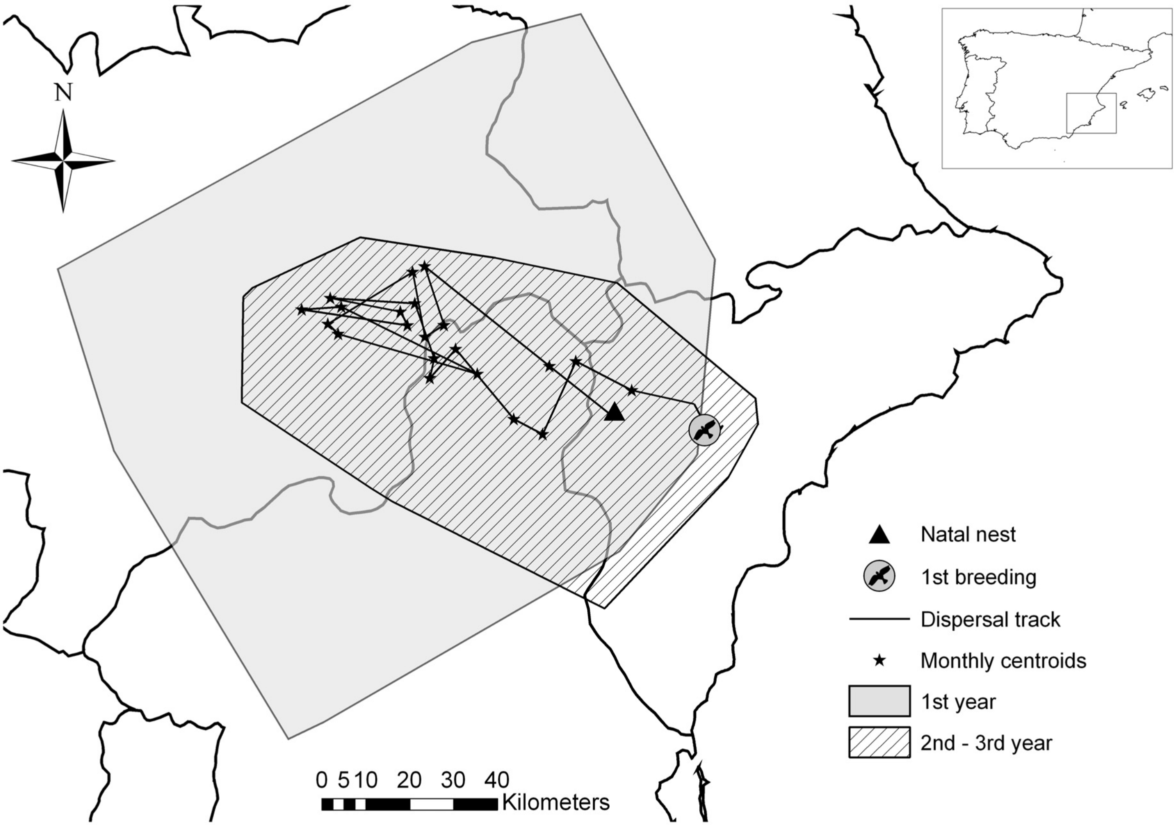

Fig. 1. Dispersal area of a juvenile Golden Eagle tracked by satellite telemetry during its natal dispersal in Spain. The polygons indicate the minimum convex polygon including all the locations obtained during the first and second-third year of tracking; asterisks indicate the centroid of all the locations obtained in a each month.

"dispersive" phase characterized by frequent long-range exploratory movements, and a second phase in which, having become proficient hunters and gained a knowledge of the location of reliable sources of food, birds restrict their movements to an area closer to their place of birth (Watson 1997).

This seems to be reinforced by the fact that whereas the nest of its first breeding attempt is located only 26 km away from its natal nest, during most of the juvenile dispersal the bird was located more than 50 km away from the place of birth. Moreover, the territory it currently occupies is located in a marginal sector of the dispersal area that was not visited during the first two years of life, supporting the idea that as Golden Eagles mature they tend to move to places closer to their natal area (Watson 1997). Yet, this return to the natal area is not restricted to this stage, but rather seems to occur throughout the whole period of juvenile dispersal. After the first winter, and until it finally settled in the territory it currently occupies, almost every month the eagle was recorded in the vicinity of the parental territory (i.e., < 10 km from its natal nest). This suggests that, like Spanish Imperial Eagles *Aquila adalberti*, Golden Eagles make frequent visits to the natal territory, probably using these well-known sites as alternative sources of food, or monitoring the availability of breeding opportunities (Ferrer 2001). The fact that returns are not concentrated in the prebreeding season seems to stronger support the former hypothesis (Ferrer 2001). A similar pattern of visits was observed with regard to the other adult territories in the area, suggesting that dispersing juvenile Golden Eagles regularly use adult territories during their dispersal. This is in line with previous observations that suggest that there might be two different zones within a

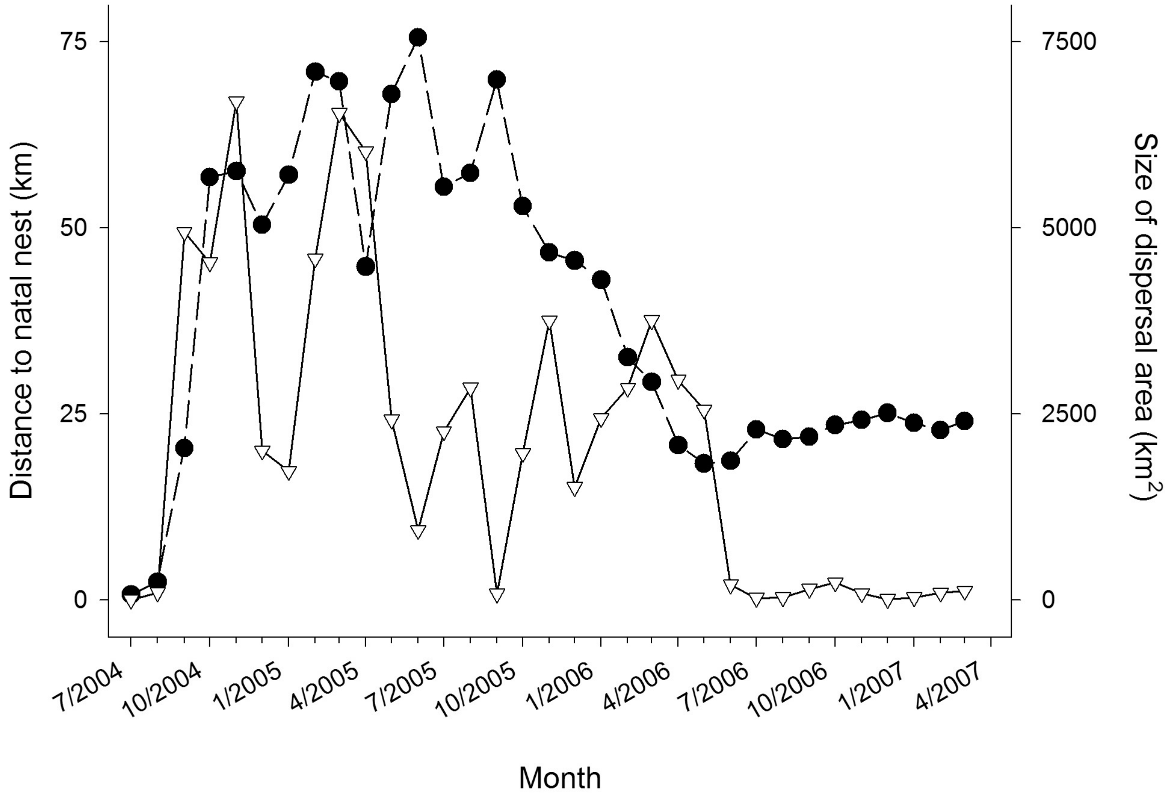

Fig. 2. Changes in the average monthly distances of a dispersing juvenile Golden Eagle to its natal nest (black dots), and the size of the areas used in its monthly movements (white triangles).

territory, with the territorial pair actively defending the area surrounding the nest, but being more tolerant to the presence of conspecifics in other sectors. It is also in line with reports of "trios" sharing the same territory and collaborating in chicks' care (see Watson 1997 and reference therein). Actually, in our study area it is not unusual to observe a juvenile eagle sharing the same territory with a pair of adults during the breeding season. In any case, our interpretations are hardly conclusive, as they are the result of tracking of only one individual.

Interestingly, the other member of the pair was also a subadult. This is important because age at first breeding and the proportion of immature breeders in a population have been suggested as reliable early warning signals of changes in adults' mortality or breeding performance, and hence, the viability of raptor populations (Balbontín et al. 2003, Ferrer et al. 2003, Whitfield et al. 2004). Alternative, an increase in the proportion of immature breeders may result from an increase in the availability of resources (Netwon 1979, Watson 1997, Balbontín et al. 2003), with non-adults attempting to breed in territories with poor environmental conditions or where mortality or emigration rates are high (Ferrer & Bison 2003, Ferrer & Penteriani 2003). The latter seems to be the case in our study area. Despite of the abundance of rabbits in the vicinity of the territory occupied by the Golden Eagles we studied, mortality associated with a power line has been observed to be high in the past (two subadults were found dead in 2003), with years of territory occupancy alternating with years in which the territory remains vacant (A. Izquierdo, pers. com.). Since 2000 only another three breeding events have been observed in the territory (2001, 2003 and 2006). In all cases one of the members of pair was a subadult. In 2006 the adult member of the pair was found dead in a nearby pond during the breeding season, but the other member still managed to raise one fledgling. The new pair has so far managed to raise two fledglings.

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STRESZCZENIE

[Udane pierwsze lęgi młodego orła przedniego monitorowanego telemetrycznie]

W okresie od 2004 (rok wyklucia) do 2007 monitorowano przemieszczenia młodego osobnika orła przedniego. W tym czasie penetrowany przez niego obszar miał wielkość w sumie około 16 500 km^2, ponad 130 km od miejsca pochodzenia (Fig. 1). Niemal 95% obszaru było penetrowane w pierwszym roku badań, zaś poniżej 40% — w pozostałym okresie. W czwartym kalendarzowym roku życia orzeł zajął wolne terytorium znajdujące się 26 km od gniazda skąd pochodził. W parze z innym subadulturalnym osobnikiem wyprowadził lęg składający się z dwóch młodych.