Autumn migration of juvenile Short-toed Eagles *Circaetus gallicus* from southeastern Spain

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Pavón D., Limiñana R., Urios V., Izquierdo A., Yáñez B., Ferrer M. & de la Vega A. 2010. Autumn migration of juvenile Short-toed Eagles *Circaetus gallicus* from southeastern Spain. Ardea 98: 113–117.

This study provides the first description of autumn migration routes of juvenile Short-toed Eagles *Circaetus gallicus* tagged in southeastern Spain. Three nestlings were tagged with Argos/GPS satellite transmitters, of which two reached their wintering grounds in Mali, close to the Inner Niger Delta. Onset, duration and routes of migration differed between the two individuals, but both eventually settled in approximately the same area (c. 170 km apart). The wintering grounds were located more than 2500 km away from the breeding sites, although the birds covered some 3800–4700 km to reach the wintering area. The observed differences in migration strategies may be related to juvenile eagles migrating, or not, in mixed flocks with adults; the latter depart earlier from the breeding grounds and follow a more direct route to the wintering grounds.

Key words: *Circaetus gallicus*, migration speed, migratory routes, raptors, satellite tracking, wintering grounds, GPS

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The Short-toed Eagle *Circaetus gallicus* has a wide breeding distribution in the Palearctic region and in NW Africa, and spends the winter in the Sahel (Cramp & Simmons 1980). The Iberian Peninsula, with 2000–2772 pairs, holds half of the European breeding population (Mañosa 2003). Several migratory raptor species in the Palearctic-Afrotropical migratory flyway, including the Short-toed Eagle, are in steep decline in their Sahelian wintering areas (Thiollay 2006). The lack of information on migratory pathways, stopover sites (if any), pre- and post-migratory behaviour and habitat use during migration and wintering prevent the identification of bottlenecks in the life cycle of Short-toed Eagles.

In recent decades, the use of satellite transmitters in monitoring birds has enabled the collection of accurate information about long-distance journeys of migrating raptors, including timing, speed, daily activity and wintering sites. GPS satellite tracking allows high precision in delineating migration routes and stopover sites (Meyburg & Fuller 2007).

Here, we report the autumn migration of two juvenile Short-toed Eagles tracked by GPS satellite telemetry from their natal area in the Iberian Peninsula to their wintering grounds in West Africa. We also provide information on timing and speed of migration. The only previous tracking studies on Short-toed Eagles involved an adult (Meyburg *et al.* 1998) and an immature rehabilitated bird (Meyburg *et al.* 1996), using conventional Argos satellite telemetry.

Methods

In 2008, three juvenile Short-toed Eagles were taken from three nests at the end of the breeding season (late June – early July) in the province of Alicante (southeastern Spain). Nestlings were handled at the age of 55–60 days old, when nearly fully grown but not yet prone to premature fledging. Birds were measured and ringed, and a Microwave Telemetry 45-gram solar/GPS PTT-100 transmitter was affixed to the back using a tubular Teflon ribbon harness. A blood sample was obtained from the brachial vein and conserved in ethanol for sex determination. The entire procedure took less than an hour. During the following weeks we visited the nests to check whether juveniles fledged and exhibited normal behaviour. One of the transmitters suddenly stopped sending information on 4 October, when the bird had not yet left the natal area, probably because the bird had managed to cut the harness and lost its transmitter (which was found near the nest).

Satellite transmitters were programmed differently for autumn and spring migration (one GPS position recorded every 2 hours from 0:00 to 24:00 local time, and transmission of data to the satellites once every 3 days) as compared to the stays in the breeding and wintering areas (recording one GPS position every 2 hours from 6:00 to 22:00 local time, to transmit every 5 days). All data were retrieved and managed with the Satellite Tracking and Analysis Tool (STAT, Coyne & Godley 2005).

Migration routes were delineated using ArcView 3.2. Data on timing and other parameters were calculated from raw position data, after converting locations from geographic to UTM coordinates (Gudmundsson & Alerstam 1998). The Short-toed Eagles tracked in this study did not show pre-migratory movements, and this, together with the use of GPS data, made it possible to accurately estimate the onset of migration. The end of migration was estimated as the day that birds ultimately settled in an area in the Sahel region, i.e. were moving less than 20 km for more than 15 days. We calculated the distance from the natal site to the wintering area (straight line), the total distance covered during the journey (sum of all movements recorded between onset and end of migration), the mean daily distance covered during migration (calculated for every day as the mean of the sum of distances covered during every hourly segment of every day, excluding those days when no positions were recorded during the active migration time; see Results) and the hourly distances covered during the journey. The latter were also plotted against local time (as provided by the satellite transmitters), to show the hour of day during which most migratory movements occurred. Home ranges used by the juvenile eagles during the northern winter were estimated using the 95% fixed kernel of the positions for the wintering period (Silverman 1986, Worton 1989, Kenward 2001); for bird #80422 we used data obtained from the end of migration up to the end of signal transmission, and for bird #80423 up to its northwards movement in early May. Means are reported ±SD.

Results

During the migration journeys, a total of 369 and 288 GPS locations were obtained for bird #80422 and bird #80423, respectively. The eagles left their natal areas in early-mid September and moved southwest to the Strait of Gibraltar, where birds crossed the Mediterranean Sea to Africa without delay (see below). Both birds arrived in the same area in Mali in the northern Inner Niger Delta (where wintering grounds for both birds were c. 170 km apart), although timing and routes were different (Fig. 1). The birds arrived on the wintering grounds in early October, more than 2500 km away from the natal sites, after having covered a distance of 4674 and 3787 km respectively (Table 1). To cover this distance, birds spent between 25 and 34 days migrating, moving on average between 146 and 151 km/day (Table 1). During migration, the birds only travelled during daytime, remaining stationary between 20:00 and 08:00. Maximum travel speeds were recorded between 12:00 and 16:00.

Bird #80422

This male started its migration before 10:00 on 4 September, flying southwest until it reached the Strait of Gibraltar on 7 September at 14:00; two hours later it was already located on Africa's mainland. From there, it traversed through Morocco, Algeria and Mauritania, to arrive in Mali on 19 September. In the next five days, it covered another 850 km, and on 27 September settled in an area located 110 km north of the site where its Sahelian peregrination had started. The ten days spent here can be considered as the only stopover. Next, it back-tracked to the vicinity of Lake Débo in the Mopti Region on 8 October (considered to be the end of autumn migration). It stayed there until 23 November, then performed an eastward loop of c. 660 km via the Niger River to Gao and back again to arrive south of Lake Débo on 28 November. The eagle stayed in this region till at least 22 February, when the PTT stopped sending information.

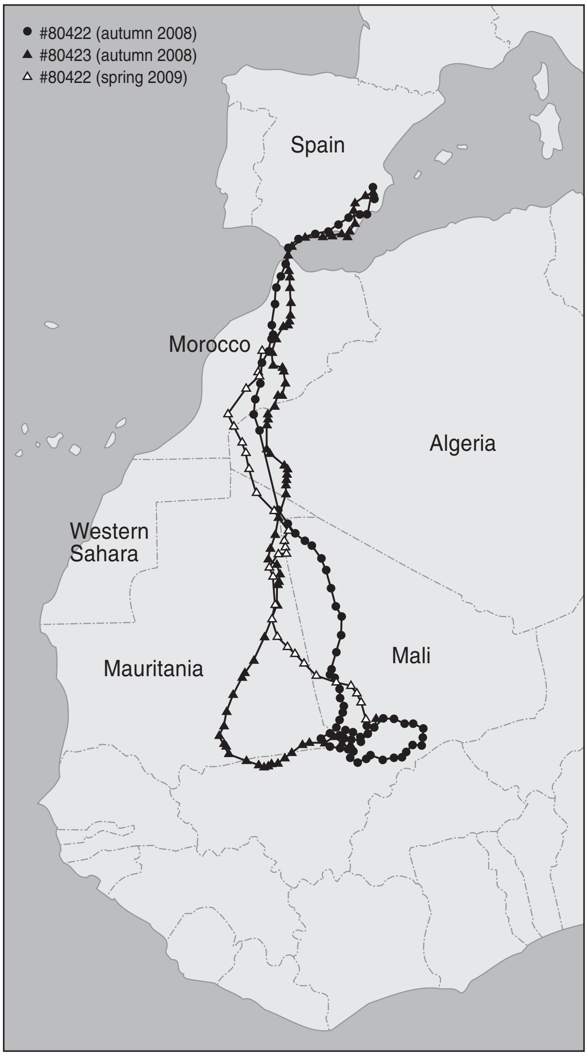

Figure 1. Migration routes of two juvenile Short-toed Eagles followed by satellite telemetry during autumn 2008.

BIRD #80423

This female left the natal area on 17 September and was located at the Strait of Gibraltar at 12:00 h four days later. It had arrived on mainland Africa by 14:00 h, from where it continued through Morocco, Algeria and Mauritania. Via a large detour it finally reached Mali, where it settled in the vicinity of lakes Horo and Télé in the southern Tombouctou Region (35 km apart) on 12 October. It primarily stayed near Lake Horo, but moved northwards to Lake Télé on 9 November. The bird also made several forays to Lake Faguibine, some 40 km north of Lake Télé. This eagle remained in the northern Inner Niger Delta until 5 May 2009, when it embarked upon a northwards journey of 16 days to Morocco, where the bird spent the summer in cereal cropland with isolated trees (Fig. 1). This area was c. 1760 km distant from the wintering area. On 10 September, the bird started its second autumnal journey, flying southwards until it reached last year's wintering area between lakes Horo and Télé, covering the journey in only 11 days.

Discussion

This study provides the first description of the autumn migration routes and timing of juvenile Short-toed Eagles (see Meyburg *et al.* 1996, for an immature). Both birds crossed to Africa by way of the Strait of Gibraltar and wintered in the Sahel, mostly in the northern Inner Niger Delta in Mali. Despite following different flight paths in Africa, both juveniles settled in the same wintering area. Short-toed Eagles are known to migrate in flocks of a single age (adult or juvenile) or mixed (Agostini *et al.* 2009). In mixed flocks, juvenile birds may learn a shorter or safer migration route from adults (Agostini *et al.* 2004). For instance, the adult Short-toed Eagle tracked by Meyburg *et al.* (1998)

Table 1. Timing, distance covered and speed of two juvenile satellite-tracked Short-toed Eagles during their autumn migration from southeastern Spain to Mali.

PTT-ID	Sex	Body mass at tagging (g)	Migration onset	Migration duration (days)	Migration end	Distance covered (km)	Distance between breeding and wintering site (km)	Distance (km) per day (max in brackets)	Mean speed (km/h) (max in brackets)	Size of wintering area (95% fixed kernel; km^2)
80422	Male	1686	4 Sept 2008	34	8 Oct 2008	4674	2630	146.06 ±119.05 (543.43)	5.76 ±10.64 (48.25)	1734
80423	Female	1945	17 Sept 2008	25	12 Oct 2008	3787	2494	151.48 ±109.59 (451.09)	6.29 ±12.03 (68.43)	254

covered the distance between France and Niger in just 20 days, whereas the 30 days needed by an immature, which was released after ten months of captivity (Meyburg *et al.* 1996), is more in line with our juveniles. Migration in company of adults, or not, may account for the different migration path followed by our juveniles. In this respect, it is interesting to note that #80422 reached the Strait of Gibraltar via a more direct route than #80423 and started migration almost two weeks ahead of #80423, both strategies complying with adult migration (Agostini *et al.* 2004). On the other hand, detours, stopovers (just once, for 10 days by #80422) and variations in migratory paths may have also been influenced by adverse weather, dominant winds or even ecological barriers (Strandberg *et al.* 2009).

The juveniles migrated only during daytime. The birds reduced their activity around 17:00, and commenced flying next morning between 06:00 and 08:00. These hours roughly coincide with sunset and sunrise at the latitudes where migration occurred. It is known that Short-toed Eagle takes advantage of thermals during migration, which develop during day-time. However, during migration our birds started to move before thermals developed, even though maximum flight speed recorded before 10:00 was only 7 km/h.

The eagles covered on average between 146 and 151 km/day (including the stopover for bird #80422, Table 1), less than the 234 km/day recorded in an adult (Meyburg *et al.* 1998). This difference may be due to experience gradually acquired in long-lived birds like raptors (Kjellén *et al.* 2001, Strandberg *et al.* 2008). However, maximum daily distance did not vary much between our juveniles (543 km by #80422; Table 1) and an adult (550 km, Meyburg *et al.* 1998). The average speed of juvenile Short-toed Eagles falls within the range for other migratory raptors crossing the Sahara in autumn (148–173 km/day; Trierweiler & Koks 2009). Maximum hourly speed for #80422 registered 48 km/h, and 68 km/h for #80423. These data compare quite well with an adult (51 km/h) and an immature (43 km/h), tracked by Meyburg *et al.* (1996, 1998), and with spring data obtained via radar-tracking in Israel (49 km/h, Bruderer & Spaar in Meyburg *et al.* 1998).

Both eagles settled near lakes in the northern Inner Niger Delta in Mali, where Short-toed Eagles are known to occur along the edges of the floodplains and near permanent lakes (Lamarche 1980, see also Meyburg *et al.* 1998). This Sahelian landscape is under great stress from various sources, including periodic drought, overgrazing and wood cutting (Zwarts *et al.* 2009). Most Palearctic raptors, notably the bigger species, wintering in the Sahel have been in steep decline for decades (Thiollay 2006). Information on habitat use and survival in relation to local conditions in the Sahel and along the migratory pathways is important to understand population dynamics in migratory birds like Short-toed Eagles (Newton 2008, Zwarts *et al.* 2009). Satellite tracking is particularly useful to monitor individual variations in peregrinations, stopovers and habitat use. Enlarging sample sizes and increasing the duration of individual tracks should be given priority.

We are indebted to Excelentisima Diputación Provincial de Alicante for support and funding, particularly to Ángel Lozano who supervised the project. We are also grateful to Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge (Generalitat Valenciana) for providing permits for tagging the eagles and useful data, especially to Juan Jimenez and Pedro Mateo. Special thanks are due to Sergio Morán, Pepe García and José Aragoneses (Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge), who helped in finding nests and handling chicks. Miguel Gallardo, Juan Manuel Pérez and Pascual López also collaborated in the fieldwork. Ugo Mellone made comments on a draft of the manuscript. Finally, we are grateful to Rob G. Bijlsma, Dr. B.-U. Meyburg and an anonymous referee whose comments greatly improved the manuscript. Tagging of individuals complied with current laws in Spain. This paper is part of Diego Pavon's PhD thesis at the University of Alicante.

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Samenvatting

Dit onderzoek beschrijft de herfsttrek van jonge Slangenarenden *Circaetus gallicus* die op hun nest in het zuidoosten van Spanje van een satellietzender waren voorzien. Twee van de drie gemerkte vogels (de derde verloor al snel zijn zender) konden worden gevolgd tot in het overwinteringsgebied in Mali, vlakbij het stroomgebied van de Niger. Beide vogels lieten een verschillend trekpatroon zien, waarbij het begin, de duur en de route van de trek sterk uiteenliepen. Ze overwinterden echter uiteindelijk op een afstand van slechts 170 km van elkaar. De twee vogels legden respectievelijk 3.800 en 4.700 km af tussen het broed- en overwinteringsgebied (in een rechte lijn is de afstand 'slechts' 2.500 km). De grote verschillen in trekpatroon tussen de twee jonge vogels kan veroorzaakt zijn doordat een van de twee met volwassen vogels optrok en de ander niet. Volwassen vogels beginnen namelijk in het algemeen eerder in het seizoen te trekken en volgen een meer directe route naar het zuiden dan jonge vogels. (RGB)

Corresponding editor: Rob G. Bijlsma
Received 23 October 2009; accepted 17 December 2009