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Post-fledging movements of Cinereous Vultures *Aegypius monachus* in Turkey revealed by GPS telemetry

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We studied the movements, home ranges and roost site preferences of three first-year Cinereous Vultures *Aegypius monachus* after they fledged at the Türkmenbaba Mountains, Eskişehir, western Turkey. We captured chicks at the nest in 2009 and 2010 and fitted them with GPS-GSM transmitters. After fledging, we received a total of 993 locations from all birds during 105–148 days of tracking. Tracked birds initially used small foraging areas, covering a mean 90% kernel home range of 356 ±134 SE km^2, and on average moved <10 km per day. As they started to migrate, daily movements increased to 59.3–120.3 km on average and took place largely during midday. Birds preferred to roost at sites with higher altitude, steeper slope and more wooded land. Our data suggest that first-year birds from Turkey disperse south in October and November to desert habitats in middle latitude Arabia, and may cover up to 2765 km during migration.

Key words: *Aegypius monachus*, Cinereous vulture, GPS-GSM telemetry, habitat use, juvenile dispersal, satellite tracking

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It is widely accepted that age-related dispersal plays an important role in animal population dynamics, affecting reproduction and survival (Greenwood & Harvey 1982, Clobert *et al.* 2001). Many raptor species, for example, leave their natal area during their first year, only to return in the following breeding seasons (e.g. Cadahía *et al.* 2005, Soutullo *et al.* 2008). Understanding the movements and whereabouts of individual birds is important for the conservation of most species. Threats such as poisoning, shooting, and electrocution during dispersal or wintering may lead to serious declines in birds (Cadahía *et al.* 2005, Panuccio 2005, Lehman *et al.* 2007, Meyburg & Meyburg 2009a). Therefore, conservation efforts should encompass information on dispersal areas and the threats that they may face there.

The Eurasian Black or Cinereous Vulture *Aegypius monachus* qualifies as "Near Threatened" worldwide (IUCN 2011). While the species has increased in Spain, other populations have suffered drastic declines in Europe and Asia (Birdlife International 2011). With 50–200 pairs, Turkey has the second largest Cinereous Vulture population in Europe (after Spain), with all known colonies located in northwestern central Turkey (Heredia *et al.* 1997, Yamaç *et al.* unpubl. data). Unlike the situation in Spain, the size of the Turkish population appears to have remained stable, despite high breeding success (Yamaç 2004).

In the western half of their range, adult Cinereous Vultures are resident and do not migrate (Meyburg & Meyburg 1983, Ferguson-Lees & Christie 2001, Corbacho *et al.* 2012). In Spain and in Greece most juveniles were found to disperse to only limited distances (Vasilakis *et al.* 2008). In contrast, not only juveniles but also adults are reported to migrate between breeding and wintering areas in eastern populations from Central Asian Republics, Mongolia and China (Shibnev 1989, Batbayar *et al.* 2008, Kenny *et al.* 2008, Reading *et al.* 2010).

Although raptor populations are most sensitive to changes in adult mortality rates (Newton 1979), high juvenile mortality has an important impact on the population (Anders & Marshall 2005, Newton 2006, Hobson *et al.* 2009, López-López *et al.* 2009). Therefore, understanding the fate of young vultures after they leave the nest remains a high priority in Turkey as movements of juvenile Cinereous Vultures are practically unknown.

In this study, we aimed to gain knowledge of the movements and habitat use during dispersal of juvenile Cinereous Vultures from a breeding site in Turkey.

MATERIALS AND METHODS

In order to investigate the movements of newly fledged birds, we used Global Positioning System (GPS)-Global Systems Mobile (GSM) telemetry. This technology is increasingly being utilized in ornithological research, because in regions with considerable GSM coverage it can provide detailed information about movements, migration routes, daily and seasonal activities, habitat preferences and home ranges of birds under study at a fraction of the cost of satellite telemetry alternatives (Meyburg & Meyburg 2009a, Hebblewhite & Haydon 2010).

The breeding colony where studied birds were captured and tagged is located at the Türkmenbaba Mountains, between Eskişehir and Kütahya provinces (39°24'N, 30°18'E). With 26 breeding pairs, this site holds the largest known Cinereous Vulture colony in Turkey (Yamaç 2004). The study area was visited several times in mid-summer to select accessible nests and determine the age of nestlings, when nests were monitored with a telescope at a safe distance to avoid disturbing breeders. The age of chicks was estimated according to Puente and Gamonal (2006). Nestlings were captured in the nest when they were 95–100 days old, as by this age they have almost reached adult size but need at least 10 days before their first flight (pers. obs.). Nestlings were briefly removed, measured, weighed, had a transmitter attached, and then placed back into the nest. To determine the sex of individuals, blood samples were taken and/or a single contour feather was removed from each individual. Sex was genetically determined through DNA isolated from those samples (Lee *et al.* 2010).

One nestling in 2009 and three nestlings in 2010 were tagged with GPS-GSM transmitters from Vectronic Aerospace GmbH (Germany). Transmitters were fixed as a backpack using a Teflon ribbon harness. The weight of the transmitter (200 g) was less than 3% of the bird's body mass (Kenward 2001). They were programmed to take three GPS positions a day to ensure at least 1 year of battery life. The first position was taken at 7:00 or 7:30 GMT, the second at 12:00 or 13:00 GMT, and the third at 17:00 or 19:00 GMT. These roughly correspond to late morning (3–4 hours after sunrise), late afternoon (a few hours before or around sunset) and evening (a few hours after sunset). We assumed the evening positions represented roost sites since vultures do not move after dark. Only locations with a dilution of precision (DOP) value of less than 8.0 were used in the analyses. We divided the period of tracking into three stages: pre-migratory, migration, post-migratory. We defined migration as fast and long (typically 50–150 km/day) movements in a particular direction. Unlike the other two stages, the migration stage did not involve any stays at a particular roost more than two consecutive nights. On the other hand, both pre- and post-migratory behaviour is characterized by short, local movements without an obvious directionality.

The total travel distance covered by each bird was calculated as the sum of the geodesic distances between successive night roosts used by each vulture. Travel distance in the early morning was calculated as the sum of the geodesic distance between consecutive coordinates for the roost site (from the previous night) and the first position received that morning. The distance travelled during midday was calculated as the sum of geodesic distance between the first and second (late afternoon) positions of the day. Similarly, travel distance in the late afternoon was calculated as the geodesic distance between second position of the day and the last position received in the evening of the same day (i.e. roost site). Since the bird might have actually not travelled in a direct path between fixes, these parameters represent minimum distances for the defined period.

Home ranges were calculated using ArcGIS 9.3 software (ESRI, Redlands, CA) in conjunction with the Hawth's Analysis Tools for ArcGIS extension (Beyer 2006). We used adaptive kernels to calculate 90% (home range) and 50% (core area) contours.

In order to test whether roost sites with certain characteristics were selected, 100 random circular plots with a radius of 300 m and at least 30 km apart were generated using ArcGIS, within a geographical range about 25% larger than the actual area used by the tracked vultures. Data pertaining to those plots were used as a random set to compare with same sized plots around actual roosting points of all three birds. If two roost sites actually used by a bird were adjacent, then only one was used in analyses to reduce autocorrelation. Altitude, slope, wooded area coverage class, cultivated area coverage class, distance to nearest village and distance to nearest paved road were measured for each point/plot during migration, using either Google Earth maps or ArcGIS. Wooded or cultivated area coverage were classified into low (<10%), medium (10–50%) and high (>50%) and coded as 1–3, respectively. Since measured parameters did not meet the assumption of normality, the non-parametric Mann-Whitney U-test was used to compare actual and random points in terms of altitude, slope, and distance to nearest village or paved road. Similarly, the Chi-squared test was used for landscape features such as wooded and cultivated cover classes. Statistical significance was considered for $P < 0.05$. All statistical tests were carried out with Statistica 7.0 for Windows (StatSoft Inc. 2006).

RESULTS

All four birds fledged successfully within two to six weeks after being fitted with transmitters. After receiving a mortality signal, one of those birds was found dead, apparently from starvation, about 180 km southeast of its nest. The following findings are based on the remaining three birds which were all male.

We received a total of 993 GPS locations (of which 98.7% with DOP<8.0) after fledging (Table 1). Each bird was tracked for a minimum of 105 days but no signals were received from any of them after the end of five months. The reasons for this premature end of transmission are unknown. All tracked birds first spent varying amounts of time near the nest, followed by daily forays of 10–60 km, and finally a sustained movement to the east and/or south that took them up to 2000 km away (Figure 1).

Bird 1 fledged on 29 August 2009 and spent the next 70 days near the nest site. After an apparent false start on 3–4 November, it began steadily moving south-southeast on 7 November. After a 3-day long stop at the barren plains near Lake Tuz (38.47°N, 33.49°E), it reached the Central Taurus in a week's time. The bird then passed over the 2200 m high mountains and made a brief detour towards the west, only to turn back the next day and proceed eastward along the foothills. On 23 November, Bird 1 reached the Euphrates Valley, two days later contact was lost with it near the Syrian border.

Bird 2 spent 54 days near the nest site after fledging on 24 August 2010. In contrast with other tracked birds, it first moved north towards forested hills, where other Cinereous Vulture colonies and communal roosting sites are known to exist. It then continued east, ending up farther north in eastern Turkey than any other tracked birds. Bird 2 changed direction only then, continuing southeast to the Mesopotamian plains during the last week of October, and eventually crossing the Zagros Mountains in Iraq and Iran. It continued

Table 1. Data for three Cinereous Vultures tracked by GPS-GSM telemetry.

Parameter		Bird 1	Bird 2	Bird 3	Bird 4
GPS-GSM code		6185	6186	6187	6184
Weight at handling (g)		7600	7700	7800	7400
Date when first location received		12–08–2009	24–07–2010	28–07–2010	12–08–2010
Date when last location received		25–11–2009	19–12–2010	24–11–2010	14–11–2010
Number of days tracked		105	148	119	95
Pre-migratory period	Date fledged from nest	29–08–2009	24–08–2010	02–09–2010	06–10–2010
	Days until migration	70	54	56	25
	Total distance covered km	530	175	577.8	15.2
	Mean daily distance km/day	7.6	3.3	10.3	0.6
Migratory period	Start of migratory behaviour	07–11–2009	17–10–2010	29–10–2010	31–10–2010
	Total days on migration	18*	28	14	14**
	Total distance covered km	1127*	2765.6	1507.7	226.3
	Mean daily distance km/day	59.3	98.5	120.3	16.17
	Min/max daily distance km	0 / 188	0 / 227	89.8 / 146.9	0/50.8
	Arrival at wintering grounds	-	14–11–2010	11–11–2010	-

* Signals stopped before the migration movement ended.
** Mortality signal received before the migration movement ended.

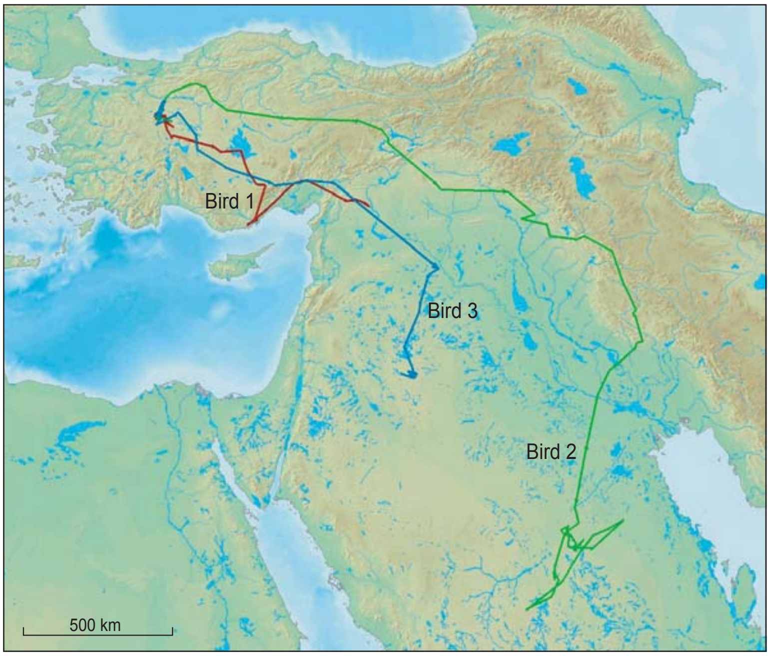

Figure 1. Autumn migration routes of 3 Cinereous Vultures, hatched in Turkey.

south through west central Iran and reached the lowlands of Khuzestan (Iran) and Basra (Iraq) provinces by 10 November, and the sandy deserts of north-central Saudi Arabia by 13 November. The vulture spent the next 28 days wandering in the latter region when its signal was lost on 19 December 2010.

Bird 3 fledged on 2 September 2010 and was within at most 80 km of the nest site until 29 October, when it started moving southeast, almost along the same path as Bird 1. It crossed the Taurus Range on 1 November and continued east and south along the Euphrates Valley into Syria. After a temporary loss of signal, it was again recorded further south along the same valley in central Syria (8 November); then it flew south to the Jordan-Saudi Arabia border where it appeared to settle down. The signal was lost 13 days later on 24 November 2010.

Although the birds fledged within at most ten days of each other, they spent varying amounts of time (54 to 70 days) near the nest site and therefore commenced migration at dates separated as much as twenty days. Average daily movements ranged between 3.3 and 10.3 km per day during the pre-migratory period, but increased to 59.3–120.3 km per day when on migration (Table 1). Tracked birds travelled less than 100 km/day on 58% of the occasions; however, mean daily distance for one bird (#3) was 120.3 km. This latter individual covered daily distances that were always within the range of 75–150 km (Figure 2).

On a few days of migration, the tracked vultures remained stationary; maximum daily distance travelled was 227 km on 31 October 2010. During migration, birds travelled significantly longer distances in the middle of the day (as defined here) than earlier or later

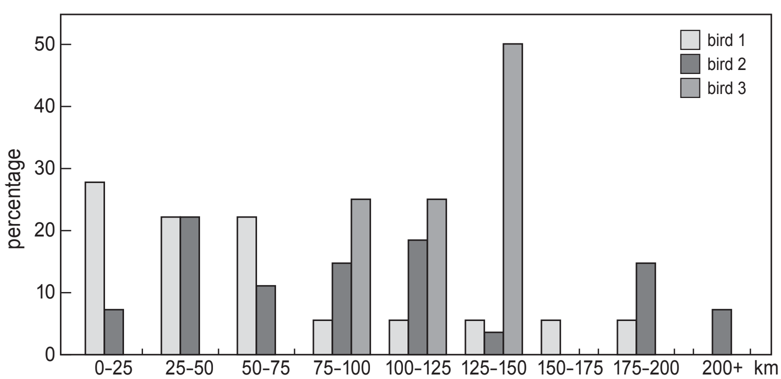

Figure 2. Frequencies of daily distances travelled by each tracked bird during migration.

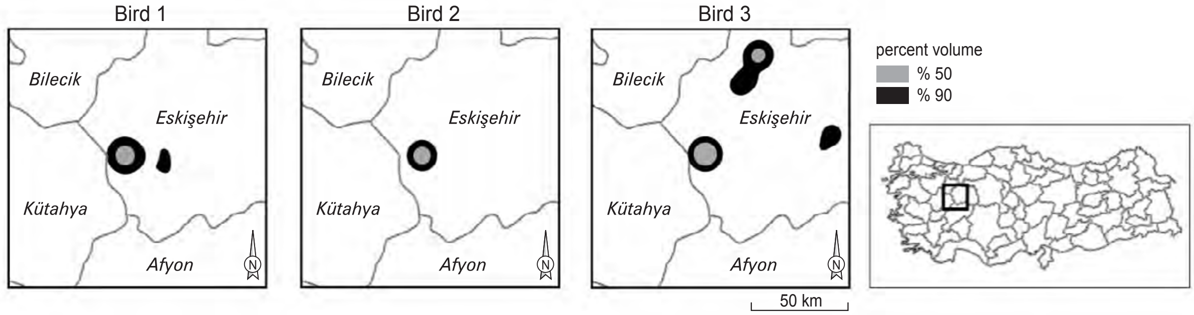

Figure 3. Home ranges of the three birds during the pre-migration stage. Kernel analysis results for 50% and 90% density are shown as shades of grey. Nests were located in the centre of the leftmost patch. Locality names represent provinces.

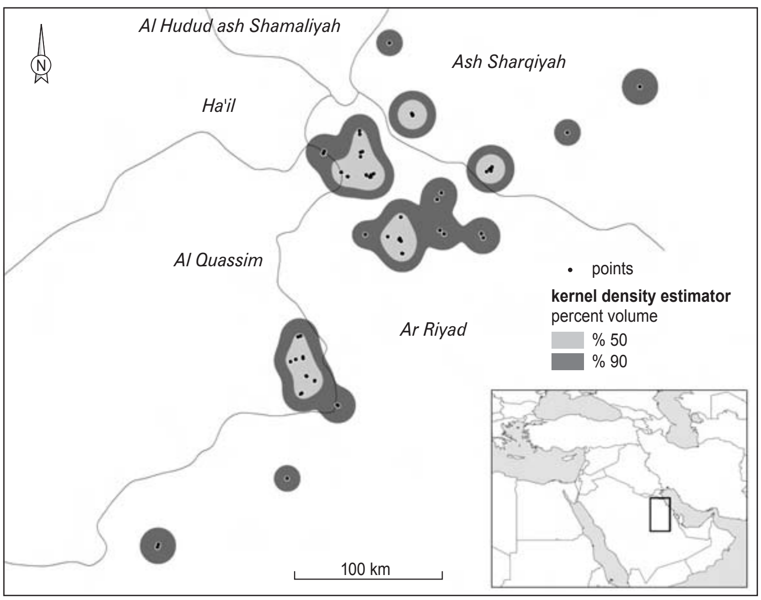

Figure 4. Home range of Bird 2 (6186) during the post-migratory stage in Saudi Arabia. Kernel analysis results for 50% and 90% density are shown as white and grey, respectively. Locality names represent provinces.

in the day (averages of 78.2 km versus 4.8 km and 6.9 km per day for all three birds pooled, $P < 0.001$).

Before migration started, all three birds remained close to their respective nests initially, and two of them remained so even until they started their migration (Figure 3). However, one bird (Bird 3) made longer exploratory flights to the east and northeast of its natal site in the second half of its pre-migratory stage. The 90% kernel area used during this period was 315.5, 147.7 and 606.4 km^2 for Bird 1, 2 and 3, respectively.

Only Bird 2 sent signals long enough to assess wintering range and behaviour. This individual finished migrating on 14 November 2010 and was tracked for a further four weeks. During this time, it covered an oblong area roughly 300 km by 100 km in north-central Saudi Arabia. Three large and several smaller activity clusters were identified where the bird spent one to six consecutive days in each (Figure 4). The larger activity clusters were repeatedly visited by the bird, up to three times, separated by absences of a maximum of one week.

Tracked vultures preferred to roost at sites with higher altitude, steeper slope and more wooded land. However, there were no significant differences between actual roosts and random sites for either distance to nearest village, distance to nearest paved road, or proportion of cultivated land (Table 2). For almost all parameters measured for roost sites, there was considerable variation. For example, elevation ranged between 5 and 2415 m, distance to villages ranged from 0.5 to 153 km, and distance to roads ranged from 30 m to 80 km. As can be expected from that part of southwest Asia, proportions of cultivated or wooded land around roost sites were in generally low.

Table 2. Roost site preferences during the migratory and the post-migratory stages.

Parameter	Actual roost		Random site		Test statistics	
	Mean	SD	Mean	SD	Z or χ^2	*P*
Altitude (m)	874.50	448.30	749.70	547.90	-2.16	0.03
Distance to village (km)	28.10	36.80	42.10	62.00	0.49	0.62
Distance to paved road (km)	16.80	17.60	25.10	30.50	1.13	0.25
Slope (degrees)	7.35	10.19	4.50	7.24	-2.06	0.04
Cultivated land cover class	1.21	0.59	1.34	0.71	2.90	0.23
Wooded land cover class	1.29	0.64	1.14	0.49	23.40	<0.0001

DISCUSSION

GPS-GSM telemetry enabled us to track three juvenile Cinereous Vultures for up to five months after fledging and through most of the first migration. These three birds exhibited a consistent migration pattern by travelling from Turkey southeast to Arabian deserts to spend their first winter.

Movements

After their first flights, the tracked birds spent about two months near their nest sites. Following limited movements around the nest, the daily distances travelled gradually increased and birds progressively went further away, although there were individual differences. One particular individual spent three weeks 50 km north, near another breeding colony, before embarking on migration. The size of home ranges at this stage ranged from approximately 150 to 600 km^2. Movements restricted to the natal nest area immediately after fledging have been recorded for several raptor species (Cadahía *et al.* 2005, Soutullo *et al.* 2006, Balbontín & Ferrer 2009). It is likely that in this way juveniles improve flight capabilities in a familiar environment.

Our results show that the migratory routes did not vary much between individuals. Migratory movements started in mid October-early November. All three birds followed roughly the same route, one that takes them first east/southeast, and then south.

Two individuals reached the deserts north of Saudi Arabia from different entry points, one (Bird 3) following the Euphrates Valley, and the other (Bird 2) following a three-times longer route that passed over northern and southern Iraq, and western Iran; this latter bird eventually settled further south than the former individual. These results resemble Gavashelishvili and McGrady's (2006) findings on the dispersal of juvenile Cinereous Vultures from Georgia. Indeed, the winter range of Bird 2 coincides largely with the winter range of the single individual reported by those authors.

The longest total distance travelled by the birds studied is about 4000 km from the nesting area (by Bird 2); this corresponds to some 2000 km as the crow flies, and is comparable to the maximum 2742.5 km reported for the same species in eastern Asia (Batbayar *et al.* 2008). Average daily distances covered (59.3–120.3 km per day) during the migratory stage are less than the averages for long-distance raptor migrants such as Peregrine Falcon *Falco peregrinus* (172 km/day; Fuller *et al.* 1998), Lesser Spotted Eagle *Aquila pomarina* (144–213.5 km/day; Meyburg & Meyburg 2009b) or Osprey *Pandion halietus* (183 km/day; Alerstam *et al.* 2006). As a species that almost never uses powered flight, and instead exclusively relies on soaring over thermals, a relatively slow progression as such is expected. Nevertheless, one of our tracked vultures was able to cover as much as 227 km in one day. This figure is on par with the maximum daily distance (240 km) recorded for adult Cinereous Vultures in Mongolia during the breeding season (Batbayar *et al.* 2008).

Roosting site preferences

Selection of roosting sites by the birds might have important implications where predation or persecution is a problem. Since juveniles may have not been exposed to people, they may be more prone to human-mediated mortality. According to our findings, there are no differences between actual roosting sites and random points in terms of distance to the nearest village or paved road. The closest a roost site was to a village was 550 m, while the average value (28 km) shows that any possible effects due to settlement proximity can be safely ignored.

Three topographical and land use parameters appeared to influence roost site selection by the tracked vultures. First, higher elevations were preferred. Second, the birds roosted at sites with higher slopes. These two parameters may reflect the need for large birds with heavy wing loading to use elevated positions to get airborne. Alternatively, these sites may be more likely to contain trees, which in turn might be preferred as roosts. Indeed, at a landscape scale, sites with higher proportions of woods were also positively selected. In addition, roosting in trees would reduce the risk of predation.

Implications for management and conservation

The first-year migration of Cinereous Vultures covers a critical period in the life cycle of the species and may have important implications for the viability of the Turkish population. Pre-adult mortality in large raptors is typically higher than that of adults (Gill 2006), as naïve birds migrating long distances through unfamiliar terrain are expected to encounter increased sources of mortality, particularly human-caused mortality such as poisoning or shooting. Migrating to the middle latitudes of Arabia might enable young birds to escape competition and harsh winter climate in the breeding territories. The inferred wintering regions within Saudi Arabia or Jordan are either protected (e.g. Northern Wildlife Management Zone; IUCN/UNEP-WCMC, 2010) or have exceptionally low levels of rural human densities (<2 per km^2), and hence may lead to improved survival of vultures in their first year. Long-term monitoring of particular cohorts through mark–resight analysis, telemetry tracking of larger numbers of juveniles in the winter quarters, or a combination of both approaches would be necessary to identify the levels and proximate causes of mortality of first year birds during migration and wintering.

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SAMENVATTING

Om meer te weten te komen over de trek van de Monniksgier *Aegypius monachus* werden in 2009 en 2010 drie jonge gieren in het noordwesten van Turkije voorzien van een GPS-GSM zender. De techniek van deze zenders berust op het doorgeven van GPS-posities door gebruik te maken van het reguliere GSM netwerk. Tot de zenders stopten met werken werden de vogels 105–148 dagen gevolgd. Na het uitvliegen bleven de vogels in de buurt van het nest en bestreken een gebied van gemiddeld 356 km2. In deze tijd werd per dag minder dan 10 km afgelegd. Tijdens de trek vanaf half oktober legden de vogels 59,3–120,3 km per dag af. Verplaatsingen vonden vooral rond het middaguur plaats. Als rustplaats hadden de gieren een voorkeur voor relatief hooggelegen plekken, steile hellingen en beboste plekken. Na een trekweg van 2765 km bereikten de vogels woestijngebieden in de noordelijke helft van Saoedi-Arabië. (JP)

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