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Migrations and sojourn in Africa of Egyptian vultures (*Neophron percnopterus*) tracked by satellite

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Abstract By means of satellite telemetry, the migrations of three young Egyptian vultures (*Neophron percnopterus*) from France and Bulgaria were studied and data obtained (over 4,300 Argos locations) to describe movement patterns, timing of migration, routes followed, speed of flight and ranging behaviour in Africa. Two French vultures migrated at almost the same time and, after travelling ca. 3,570 km, remained in the Sahelian zone, in southern Mauritania. The Bulgarian bird, after travelling 5,340 km, ended in south-east Chad, in the Sudano-Sahelian zone. It was possible to determine two remarkably long daily flight distances of this bird of over 500 km on two successive days (1,017 km in total) when crossing the Sahara. In January and February, the Bulgarian bird wandered extensively over 2,600 km, even as far as north-east Nigeria. Both French vultures remained in their home ranges in Mauritania once they had adopted them, which extended to 69,000 km² and 50,000 km², respectively. One continuously-tracked vulture from France first left its African home range when 3 years old (probably in its fourth plumage type).

Keywords Egyptian vulture · Home range size · Migration · Satellite telemetry · Sojourn in Africa

Introduction

The European Egyptian Vulture is a typical long-distance migrant, spending the winter in Africa. Apart from observations at concentration points (Gibraltar, the Bosphorus, Suez etc.; review in Bijlsma 1987; Zalles and Bildstein 2000; Shirihai et al. 2000), almost nothing is known about their migration and sojourn in Africa (Mundy et al. 1992; Donázar 1993). It is also unclear at what age the young birds first return to their breeding area.

Since the species is seriously declining in many parts of its breeding range, especially in Europe, it is important to learn as much as possible about its life history, including its wanderings and behaviour in its winter quarters. According to Ferguson-Lees and Christie (2001), in general, migratory populations have decreased far more than the sedentary ones.

Satellite telemetry (ST) has in recent years established itself as a highly effective method of investigating the migration of raptors (e.g. Grubb et al. 1994; Meyburg et al. 1995a, 1995b, 1998, 2001, 2003, 2004; Brodeur et al. 1996; Ueta et al. 1998, 2000) and other animal species. We therefore used this technique to study the Egyptian vulture.

Methods

We marked two nestlings (vultures 1 and 2) from two nests 30 km apart in the Luberon mountain range (Vaucluse) in the south of France east of Avignon, and equipped them with 35-g solar-powered satellite transmitters (PTTs) manufactured by Microwave Telemetry (USA). Similarly, one nestling (vulture 3) west of Varna in Bulgaria and a rehabilitated adult in north-west

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Greece were fitted with 40-g solar-powered PTTs manufactured by North Star (USA) (Table 1).

All location data were analysed individually and entered into databases by B.U.M. and C.M. With the aid of digital maps, spurious data were eliminated. Next, any remaining unreplicated, distant, outlying fixes were culled. We used the computer programme Mapit (Allison 1997) to plot Argos locations, measure distances between locations and trace the migration routes.

Software programme Home Range (Ackerman et al. 1989) was used to calculate areas of minimum convex polygons (100%, 95% and 75%) and mean distances from locations to the arithmetic centre, and to plot chronological (date/time ordered locations) movements. We excluded any low-quality fixes from the home range calculations.

Habitat use in Africa was analysed using satellite photographs of two different maps of the Global Land Cover Characteristics programs. Afugs (USGS Land Use/Land Cover System) distinguishes between 24 habitat types and Afslcr (African Seasonal Land Cover regions) between 197 different habitat types.

Results

The three transmitters of the young birds provided over 4,300 Argos locations for widely varying lengths of time (Table 1). At least one transmitter clearly ceased to function a good while before the death of the bird. For unknown reasons the transmitter of the adult never sent any messages.

All three young birds migrated to south of the Sahara in Africa. The transmitter of vulture 1 delivered a very high number of locations over a space of nearly 3 years (Table 1). After its autumn migration to Mauritania this bird stayed in Africa until it was 3 years old (and probably in its fourth plumage type).

Vulture 2, aged 3 years (in subadult plumage or fourth plumage type according to Forsman 1999) was observed with its transmitter by G. Frechet on 3 July 2000 in the Gorges de la Vis (l'Herault), 140 km from its nesting location. On 7 and 8 July 2000, it was observed without a transmitter by P. Maigre in the Gorges du Verdon (Commune of Rougon), less than 100 km from its nesting location and around 250 km from where it was observed on 3 July. Two years later, on 2 May 2002, the bird was found dying (poisoned) by a shepherd in the department of Aude, near Carcassonne in southern France. It was in adult plumage and the autopsy showed it to be a female.

Owing to numerous high-quality Argos locations (LC 2 and LC 3) the extent of the home ranges in Africa and their exploitation of them could be analysed precisely.

Autumn migration

The complete autumn migration of both French birds could be traced in considerable detail (see Fig. 1); that of the Bulgarian bird only from Iskenderun in southern Turkey.

Vulture 1 fledged on 19 August 1997, left the breeding area on 24 August (Table 2) and flew 36 km on this first day of its migration. On 31 August, it crossed the Pyrenees between Perpignan and Andorra. In Africa, it flew south in an almost straight line between 5° and 9°W as far as southern Mauritania. The total distance covered to its wintering grounds, which it reached on the evening of 21 September, amounted to 3,573 km. It thus flew an average of 123 km each day. On 4 days, however, it did not migrate, and if these are omitted the average was 143 km per day. On 15 days, the distance flown could be calculated as the distance between two consecutive overnight roosting-places, varying between 44 and 394 km (mean 184 ± 120 km). On 4 days, the bird flew over 300 km, of which three in succession (18–20 September) were spent crossing the Sahara in Algeria and Mauritania.

Vulture 2 fledged on 20 August 1997, left its breeding site on 25 August and crossed the Pyrenees at mid-day on 28 August about 30 km from the Mediterranean coast. From 1–14 September, it rested in north-east Spain (at 40°47'42"N, 1°16'48" W) ca. 100 km south of Zaragoza and some 50 km NNW of Teruel. It flew relatively straight across Morocco and Algeria between 5° and 9°W to its wintering grounds in southern Mauritania, where it arrived on 27 September. The bird had in all travelled 3,571 km.

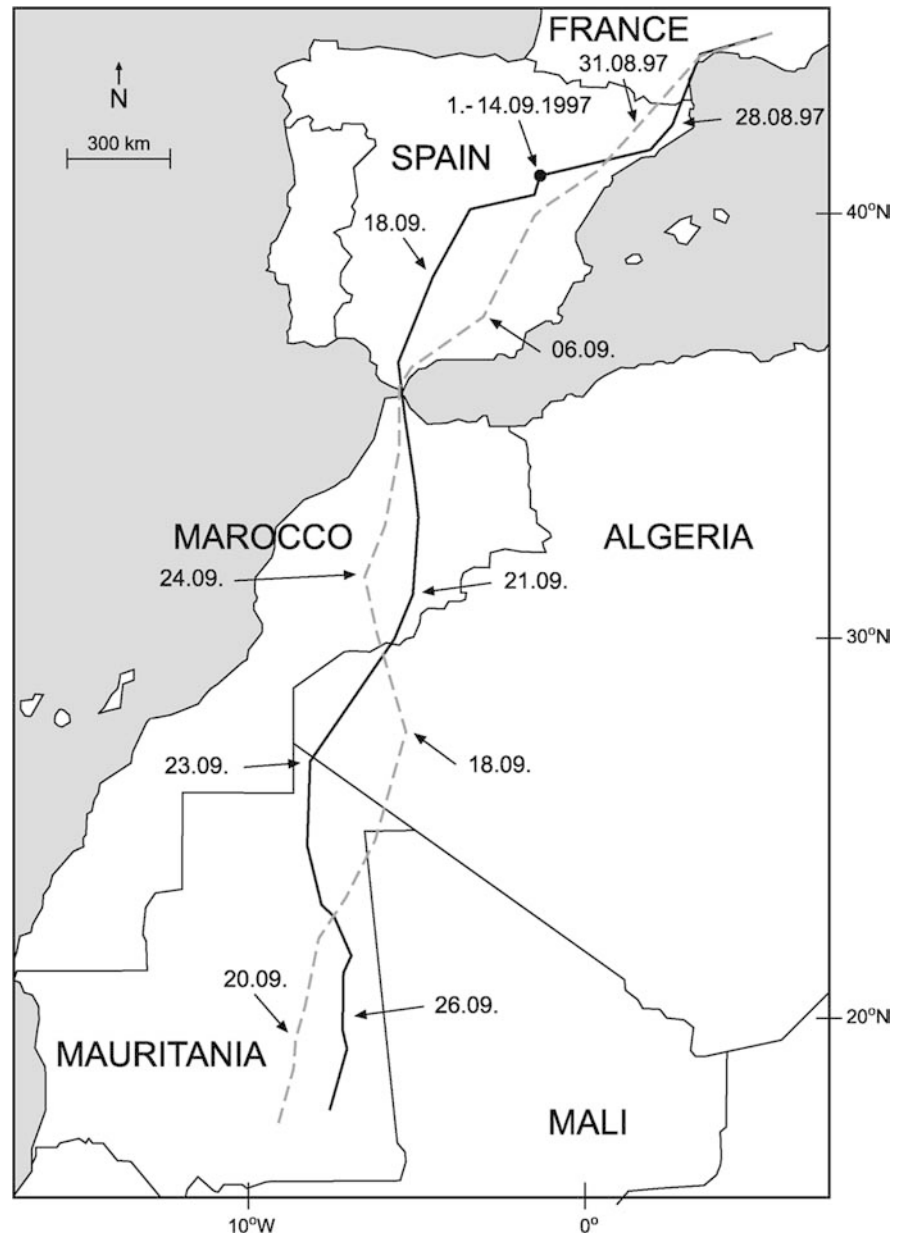
Discounting the break in north-east Spain, no further rest was taken and a total of 20 days were spent in travel. On 14 of these the distances flown could be reckoned, varying between 55 and 433 km, giving a mean of 214 ± 93 km daily. Altogether, excluding the 14 resting days, the bird on its migration covered 178 km each day.

At the nest site of Vulture 3, where two nestlings fledged, one young was observed in the nest on 23 August 2001 and on 28 August a young was flying nearby. In both cases it was not clear if it was the bird with the transmitter. On 7 September, neither adult nor young birds were observed any longer at the nest site.

Table 1 Equipment of three young Egyptian vultures (*Neophron percnopterus*) with transmitters

Vulture number	Argos ID-Number	Natal country	Number of locations received	Date radio-marked	Date last location received
1	08135	France	3,216	4.8.1997	12.5.2000
2	08136	France	714	4.8.1997	1.1.1998
3	24019	Bulgaria	378	8.8.2001	17.3.2002

Fig. 1 Migration routes of the two Egyptian Vultures from France to Mauritania (vulture 1 *broken line*, vulture 2 *unbroken line*) showing dates of arrival at selected points en route



Because of lack of reliable locations, no conclusions could be drawn regarding the date of departure and the first 1,400 km of the outward journey. The bird passed near Iskenderun (i.e. the Belen Passes) in southern Turkey on 16 September 2001. On 20 September, it was located at Eilat and on 24 September at Suez. From there it flew almost directly to Chad. On 7 November, it reached a resting-place (C) (see Fig. 4) in eastern Chad (100 km NE of Fort Monou) and, since it proceeded no further south but moved westward and back, we regard this as its arrival in winter quarters.

During its journey the bird had rested in Chad once for 25 days and once again for 6 days (resting places A and B) (see Fig. 4). In all, it had flown ca. 5,337 km to reach its wintering grounds.

From Iskenderun, its route could be closely followed. Omitting the 31 resting days the bird covered 3,925 km in 20 days. On 7 days, the distances flown could be computed, varying between 64 and 309 km (mean 185 ± 79 km per day).

On two days (28 and 29 September 2001) (Fig. 2), the bird flew a total of 1,017 km (in SW Egypt, NW Sudan and NE Chad), travelling an average of over 508 km per day, extremely long stretches for a bird of prey. Unfortunately, its roosting place during the night 28/29 September could not be located in order to calculate the exact distances covered each day. During 28 and 29 September up to 1228 hours (GMT) on 29 September, it flew altogether 825 km (e.g. 627 km in 25 h 32 min, from 1056 hours on 28 September to 1228 hours on 29 September).

Table 2 Comparison of the autumn migration of three Egyptian Vultures with that of two Short-toed Eagles

	Vulture 1	Vulture 2	Vulture 3 (From Iskenderun)	Short-toed Eagle 1 ^c	Short-toed Eagle 2 ^d
Date of departure	24 August	25 August	(29 August – 6 September) ^a	3 September	25 September
Crossing of Pyrenees and Straits of Gibraltar (Iskenderun and Suez for vulture 3)	31 August 9 September	28 August 19 September	16 September 24 September	5 or 6 September 10 September	29 September 3 October
Arrival at wintering grounds	21 September	27 September	7 November	6 October	14 October
Total days spent on migration	29	34	51	34	20
Total distance in km	3,573	3,571	(ca. 5,337) ^b 3925	4,045	4,685
Actual days spent migrating	25	20	20	30	20
No. of days spent resting	4	14	31	4	0
Mean km flown daily on total days of migration	123	105	77	119	234
Mean km flown daily on actual days travelling	143	178	196	135	234
Minimum and maximum daily flight distances (km)	44–394	55–433	64–309 ^e	Ca. 100 to ca. 234	17–467
Average daily flight distance for days with known daily flight distance (km)	184	214	185	?	234

^a Probable departure time from the nesting area

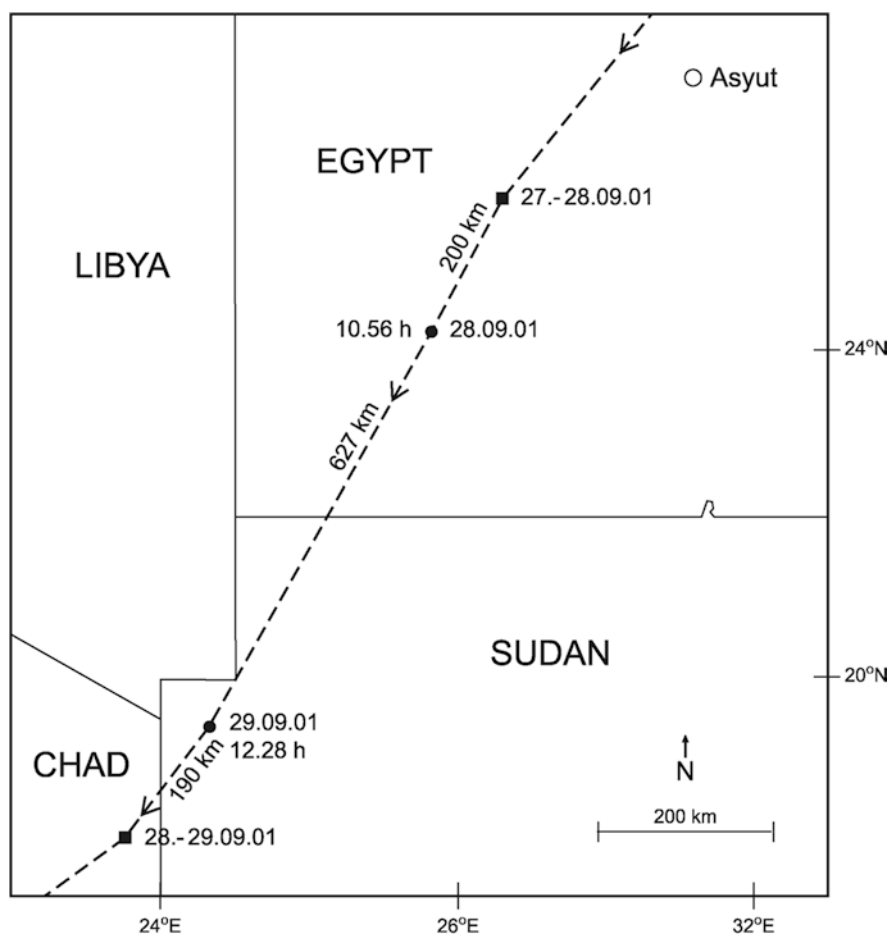
^b Approximate total distance from the breeding place

^c Rehabilitated bird (Meyburg et al. 1996)

^d Trapped breeding adult (Meyburg et al. 1998)

^e Not taking into account two remarkably long daily flight distances of over 500 km on two successive days (1,017 km in total)

Fig. 2 Distances covered by vulture 3 on 28 and 29 September 2001, the 2 days with the greatest distance covered, showing the overnight roosting-places (*squares*) and further locations (*dots*) during the day with the time of location and distances covered between two locations



Sojourn in Africa

Interesting data were obtained from all three birds on their wintering grounds. All three vultures spent their time after arrival in Africa in very sparsely populated areas (under ten inhabitants per km²) with little to very little rainfall. Both vultures from France were most often located in grassland and less frequently in savanna, shrubland and barren or sparsely vegetated habitat according to Afusgs. According to Afsler, vulture 1 used mostly grassland/shrubland, but also semi-desert grassland with shrubland, whereas vulture 2 used, almost equally, semi-desert grassland with shrubland, Sudanian woodland/savanna and barren or sparsely vegetated habitat. Vulture 3 used almost exclusively savanna, according to Afusgs, and predominantly Sudanian woodland with crops, according to Afsler, but also transitional forest/Sudanian Woodland and woodland/Acacia/grassland mosaic.

Vulture 1 spent over 2.5 unbroken years in its chosen grounds, from its arrival in the evening of 21 September 1997 to its departure on 13 April 2000. Fig. 3 shows the use it made of this area. Pinpointed on the map are only the best Argos locations per day with accuracies of 350 m or better (LC2), and 150 m or better (LC3), respectively.

Most of the time the bird remained in an area which extended 80 km north/south by 50 km east/west and the

centre of which lay at 16°2'N/9°52' W (Fig. 3, Table 3). Within this area the bird moved only relatively short distances daily; however, on 12 April 1998, for example, 63 km and on 5 November 1998 74 km between one overnight roosting place and another. At the end of March 1998, however, it flew 500 km to the east and for 2.5 months (28 March – 12 June 1998) adopted another home range, subsequently returning to the first area.

From this first area the bird frequently strayed, but always for a few days only and virtually in all directions, except to the north. For example, on 16–22 October 1998 it went 161 km to the northwest, flying back 65 km on 22 October. Outside the area used most, the region which it exploited widely, but only sporadically and at random, extended for 660 km north/south and 510 km east/west (Fig. 3). The furthest point it ever reached from its home range centre was in mid-May 1999, over 400 km to the northeast. On seven occasions it flew rather far south to Mali.

Vulture 2's home range partly overlapped with that of bird 1 and extended 400 km east/west and 150 km north/south (Fig. 3, Table 3). The bird made use of the whole expanse of south-west Mauritania more or less uniformly. No core area could be identified from the locations. Outside Mauritania only one point just south of the border in Mali was visited.

Vulture 3 confined itself predominantly to five areas (C-G) in south-east Chad (Fig. 4), but nevertheless fre-

Fig. 3 Home ranges of vultures 1 (*circles*) (from 21 September 1997 until 13 April 2000) and 2 (*stars*) (from 27 September 1997 until 1 January 1998) as revealed by Argos LC2 and LC3 locations. Only one location per day has been plotted

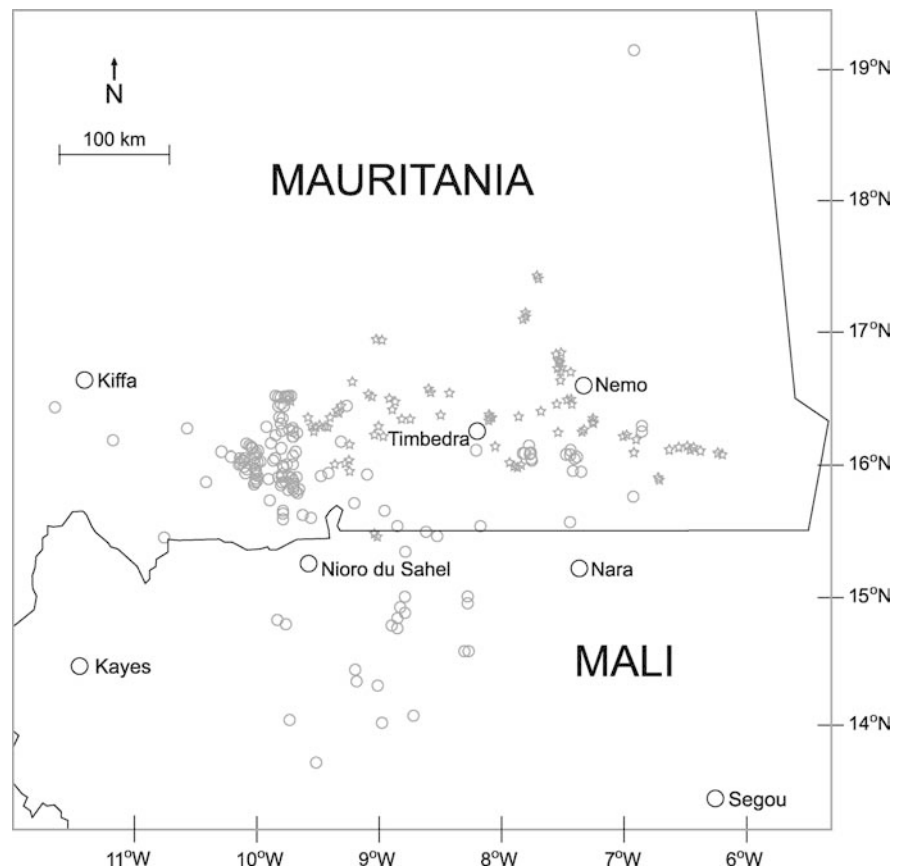
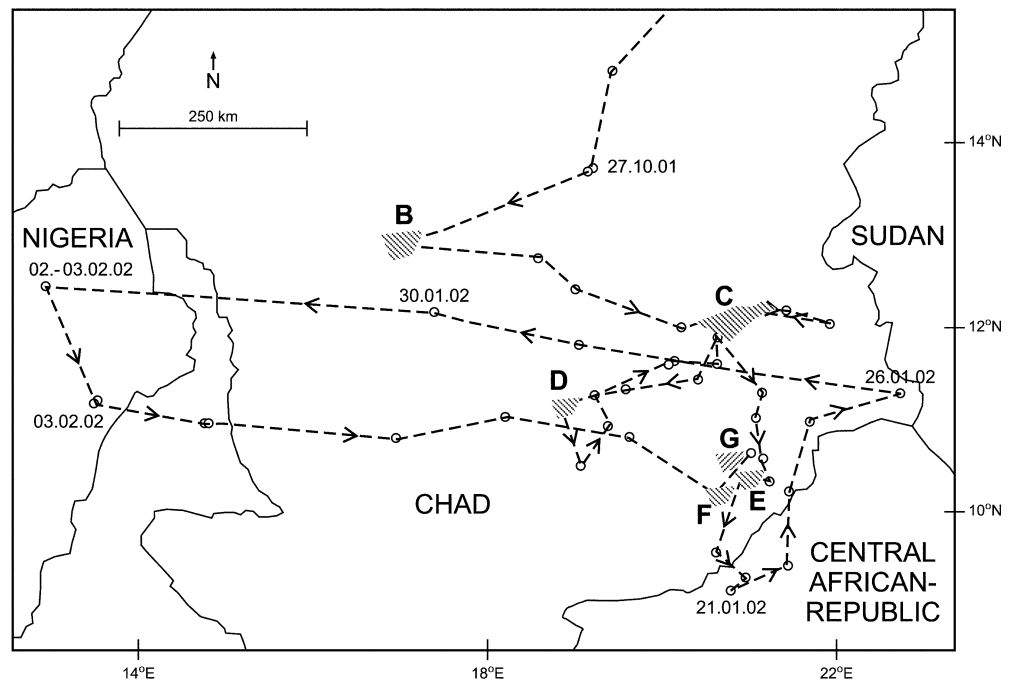


Table 3 Home ranges of both French Egyptian vultures in Africa

	Total wintering area of vulture 1	Core area of vulture 1	2nd home range of vulture 1	Home range of vulture 2
Centre	16°40', 9°53'W	16.2 N, 9.52 W	16°03'N, 5°39'W	16°31'N, 7°53'W
Northernmost point	19°6'N, 6.55 W	16°31'N, 9°49' W	19°6'N, 6°55' W	17°30'N, 7°39'W
Southernmost point	13°43'N, 9°31'W	15°47'N, 9°49'W	13°43'N, 9°31'W	15°27'N, 9°01'W
Easternmost point	16°16'N, 6°51'W	16°00'N, 9°41'W	16°16'N, 6°51'W	16°05'N, 6°04'W
Westernmost point	13°43'N, 9°31'W	16°01'N, 10°10'W	16°25'N, 11°38'W	16°31'N, 9°47'W
Extent (km ²) ^a	33,420	5,600	4,690	56,500

^a Calculated by the minimum convex polygon method

Fig. 4 Main sojourn areas (B 29 October to 4 November 2001, C 11–15 November 2001 and 8 December 2001 to 10 January 2002, D 17 November to 1 December 2001, E 14–20 January 2002, F 11–17 February 2002, G 1–8 March 2002) of vulture 3 in Africa until 17 March 2002, also showing dates of arrival at selected points en route. Resting area A (15°43'N, 21°23'E) in north eastern Chad visited during migration (1–25 October 2001) is not within the area of this map



quently changed places, covering 3,926 km in all, up to the breaking off of locations on 17 March 2002. From 21 January to 10 February 2002 it undertook its most extensive excursion over a total distance of 2,598 km, during which, on 21 January 2002, it reached the southernmost point in the Central African Republic (9°07'N, 20°47'E) and then, on 26 January, the easternmost point in Chad near the Sudanese border (11°18'N, 22°45'E). From there it followed a virtually straight course 1,078 km to the west, as far as north-east Nigeria, where on 2/3 February 2002 its most westerly overnight stop was at 12°26'N, 12°56'E, after which the bird returned to the south-east of Chad. Overall, it flew a daily average of 130 km during these 20 days, with a maximum of 486 km on 2 days together.

Homeward journey

On 13 April 2000, vulture 1 left its area in southern Mauritania and began to move slowly north. In 10 days it covered only 863 km as far as the former Spanish

Sahara (now respectively Western Sahara or part of Morocco). During the following 10 days it flew a further 1,234 km to Morocco. Over the next 10 days it covered only 247 km in Morocco. It was located for the last time in the evening of 12 May 2000, about 28 km south of the Straits of Gibraltar. Overall the bird flew a daily average of 78 km over the 2,344 km journey.

Discussion

Autumn migration and daily flight distances

The autumn migrations of the two French vultures differed little as regards timing, duration and speed (Table 2). They overwintered in the same region (southern Mauritania), as did young vultures from Spain (Benítez et al. 2003). The Bulgarian vulture's place of birth lay in fact only slightly further north than that of the two French birds, but nevertheless it clearly flew further south (by five latitudes), involving it in a journey at least 1,800 km longer. It arrived at its wintering

grounds over a month later. If, however, one reckons the Bulgarian bird's first resting place in north-east Chad, where it arrived on 30 September, to be already part of its wintering grounds, then it would have reached these at the same time.

This bird's stretch of over 1,000 km spread over two successive days while crossing the driest part of the Sahara was among the highest achievement by raptors we have tracked. The highest overall migration performance recorded in a male adult lesser spotted eagle (*Aquila pomarina*) from Slovakia was from 30 March to 2 April 2001 from northern Uganda through Ethiopia and Eritrea to the Red Sea. On four successive days the bird flew over 400 km per day, in all 1,650 km (Meyburg et al. 2004). The highest daily performance of a pair of lesser spotted eagles from Germany on several autumn and spring migrations was that of the female on 16 November 1998 in Sudan, when it travelled 521 km (Meyburg et al., unpublished data).

Since in the literature to date no telemetry data exist on the Egyptian vulture it is useful to draw a comparison (Table 2) with two similarly tracked short-toed eagles (*Circaetus gallicus*) from a region north of Bordeaux in France (Meyburg et al. 1996, 1998). The performances of the two birds appear, roughly speaking, to be the same.

Wintering areas, wintering behaviour and home range sizes

According to Mundy et al. (1992), these vultures may reach 5°N on the east side of Africa, whereas most stay north of 13°N in West and Central Africa. The three tracked vultures did not penetrate as far as this southern limit.

The differing characteristics between the two French vultures and the Bulgarian bird are remarkable. Tracking of more birds may well bring other surprises. The home range sizes of immature raptors in Africa are to date apparently known only from that of a Short-toed Eagle in Burkino Faso. With its moderate size of ca. 410 km² (Meyburg et al. 1996), it is much smaller than the home ranges of both French vultures, which are similar to those of two immature Bald Eagles (*Haliaeetus leucocephalus*) (Grubb et al. 1994) in North America.

Do immature Palearctic Egyptian Vultures remain in Africa during the northern summer ?

Reiser (1894) already found it strange that, in Bulgaria as in other Balkan countries, no Egyptian vulture in dark plumage had ever been sighted, and this was earlier mentioned by Lord Lilford (1860, in Stresemann 1944) referring to Greece (Corfu and Epirus). Various other early authors offered the opinion that many immature Egyptian Vultures in fact remain in Africa during the northern summer (e.g. Verner 1909, p. 376). Stresemann

(1944) developed this theme more thoroughly and believed that the young aged 2 or 3 years "dally" for several years in Africa.

In older Bulgarian publications young birds in dark plumage are never mentioned. Only in more recent time have isolated observations been made known. During the second half of the 20th century evidence of such birds has been increasingly reported (Baumgart 1991). Mundy et al. (1992) conclude that "it would seem to us that most juveniles remain in Africa during the northern summer whereas Yosef and Alon (1997) conclude that few non-adult vultures die or remain for the summer in Africa". According to Finlayson (1992), the records of the Gibraltar Ornithological Group for the autumns of 1971–1974 reveal that, of the 476 Egyptian Vultures classified by age, 64.3% were adult, 2.7% were fourth-year, 1.3% were third-year, 4/4% were second-year and 27.3% juvenile. His own observations from Gibraltar in spring show that up to 39% are immatures.

According to T. Conzemius (personal communication), during his raptor migration counts held at Tarifa from late August to early September, Egyptian Vultures of all age classes pass through on their way to Africa, so that at least individuals aged 2, 3, 4 and 5 years old return to Europe. From their own field work in Spain (B.U.M. and C.M.) and Bulgaria (B. Miltshew, personal communication), non-adult birds were observed only very rarely.

In south-east France, within the scope of his work on ringing and marking young birds in the nest, M.G. noted a rate of 30% return of these birds to their place of birth (i.e. 18 out of 60) belonging to the following age classes: birds in their 2nd year (immatures): 11%; birds in their 3rd year (immatures): 33%; birds in their 4th year (subadults): 40%; birds in their 5th year (adults): 16%.

Both birds tracked from France perhaps returned to their places of birth when 3 years old. One bird certainly first left its winter quarters at the age of three.

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