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MIGRATION STRATEGIES OF AN ADULT SHORT-TOED EAGLE *Circaetus gallicus* TRACKED BY SATELLITE

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La migration post-nuptiale d'un Circaète Jean-le-Blanc adulte a été suivie pour la première fois par satellite grâce à une balise Argos à cellules solaires émettant en permanence. La balise a fourni 506 localisations de l'oiseau au total, depuis son site de nidification au nord du Saintes (Charente-Maritime) jusqu'à sa zone d'hivernage dans le sud-ouest du Niger. La qualité des localisations obtenues a permis de suivre l'oiseau de manière très détaillée pendant les 20 jours qu'a duré sa migration de 4685 km (FIG. 1).

La migration a commencé, vraisemblablement en fin de matinée, le 25 septembre 1996 et l'oiseau est arrivé dans sa région d'hivernage dans la soirée du 14 octobre. Il a passé le Détroit de Gibraltar le 3 octobre et il a été possible de le localiser chaque nuit avec précision pendant toute la durée de sa migration (TAB. I). Les étapes journalières parcourues ont varié entre 17 et 467 km (234 km par jour en moyenne) et furent à trois reprises inférieures à 100 km. C'est dans le nord du Mali, à la fin de sa traversée du Sahara, que le circaète a effectué les étapes les plus longues, les 8 et 9 octobre, avec respectivement 467 et 401 kilomètres (FIG. 2).

On a pu constater que la longueur des étapes journalières dépendait fortement des conditions météorologiques. Le circaète a en effet parcouru lors des journées ensoleillées 311 km en moyenne, une distance plus de trois fois supérieure à celle qui a été parcourue les jours où le temps était couvert et pluvieux (92 km en moyenne). Grâce à la précision des localisations obtenues, la vitesse de migration a pu être calculée à trois reprises: 37, 44 et 51 km/h. L'oiseau quittait son dortoir de 45 minutes à deux heures après le lever du soleil et s'arrêtait le soir entre 30 minutes et deux heures avant son coucher, restant en activité jusqu'à 10 heures et 30 minutes pendant des journées longues de 11 heures et 45 minutes.

INTRODUCTION

Although first used in ornithological research only a few years ago, satellite telemetry has already provided surprising new information regarding raptor migration (MEYBURG *et al.,* 1995 a, b, 1996 b; MEYBURG & MEYBURG, 1998 a, b). It has made it possible for the first time to keep constant track of individuals on their migrations throughout the world and thus obtain a concise picture of migration dynamics, which was never possible with the methods hitherto available.

Whereas we had already tracked by satellite telemetry more than five individuals of several raptor species, and even ten and more individuals of both Lesser Spotted and Steppe Eagles *(Aquila pomarina* and *A. nipalensis)* (MEYBURG *et al.,* 1995 a, 1996 b) we had so far equipped only one Short-toed Eagle with a satellite transmitter (PTT) (MEYBURG *et al.,* 1996 a). This, however, was a rehabilitated immature bird which bad spent 10 months in captivity and which satellite telemetry showed to have successfully reintegrated itself in the wild following release.

We began our satellite telemetry programme with the aim of investigating the behaviour on migration of the larger eagle species, above all to record as fully as possible the complete annual cycle of adult birds, i.e. the routes taken from their breeding territory to their wintering grounds and back to their breeding territory. This has already been achieved for several species (Lesser Spotted Eagle, Imperial Eagle A. heliaca, Osprey *Pandion haliaetus,* Wahlberg's Eagle *Aquila wahlbergi,* etc.). We concentrate less on tracking juvenile and immature birds, the migration strategy of which is different in many ways, on account of their substantially higher mortality rate and hence lower degree of success in relation to the costs involved.

One of our objectives was to discover the yearly routes taken by adult Short-toed Eagles from the population which crosses the western and eastern ends of the Mediterranean. In July 1995 we accordingly attempted to trap an adult in Slovakia which ended in failure. We were equally unsuccessful with another pair in 1996. However, our first attempt in France met with success.

METHOD

Adult Short-toed Eagles bad already been occasionally trapped by other ornithologists using bal-chatris (eg. W. S. CLARK, pers. comm.), a method which in our experience is not often successful with larger birds of prey during the breeding season. We therefore settled on the dho-ghaza method, with which we had already caught a series of Lesser and Greater Spotted Eagles *(Aquila clanga)* and Ospreys (MEYBURG *et al.,* 1995a).

On 29 July 1996 we erected two mist nets set at right angles round a live Eagle Owl *(Bubo bubo)* tethered to a stump in a small clearing some 80 m. from an occupied Short-toed Eagle‘s nest, situated north of Saintes (Département Charente Maritime, west-central France) and containing one nearly-fledged young. Developments were observed from a hide 40 m. away from the Eagle Owl and also from a distance of 800 m.

An adult appeared after ca. 30 minutes with prey, fed the young in die nest, then flew over the Eagle Owl with an audible cry of alarm and promptly attacked it. In doing so it narrowly missed one of the nets, brushing it with one wing as it flew past. lt then perched for a few minutes on a nearby tree, giving constant alarm calls, before making a second attack during which it was caught in the net.

This bird weighed 1,700 g, with a wingspan of 176 cm, a wing-length of 52 cm and a body-length of 57 cm. Its bill was 34.6 mm long and 25 mm in depth. lt was fitted with a solar-powered satellite PTT of the same design and size an the one fitted to our first Short-toed Eagle (MEYBURG *et al.*, 1996a). The transmitter in this instance was so programmed that, given sufficient light, it gave out constant signals, so that as many locations as possible could be obtained during the migration. For further details on the technique of satellite telemetry, see MEYBURG *et al.* (1993, 1995 a, b, c; 1996 a, b).

The eagle was released directly it had been equipped and showed perfectly normal behaviour thereafter. Despite close observation during the following weeks, it proved impossible to determine whether the fitted bird was the male or the female. Although both birds were often seen close together there was no visible difference in their sizes. The young fledged about three weeks later and was last observed together with the adult fitted with the PTT on 6 September and with the other adult on 19 September.

For the tracing of the migration route and computer calculation of distances covered between Argos locations we used an integrated global mapping system displaying a true Mercator projection. The migration route was also tracked by a variety of CD-ROM-Atlases, in order to ascertain dependence on altitude, habitat types, etc. During the migration the length of day and times of sunset and sunrise at each overnight roosting-place were calculated using the “internet” by means of a special computer programme (Fly-By-Day Consulting, Inc., CompuSolve, Inc., and Leslie O’Shaughnessy Studios). Various programmes on the “internet” were consulted for weather data, particularly satellite photographs.

RESULTS

The behaviour on migration of an adult Short-toed Eagle was recorded for the first time by means of satellite telemetry. Its autumn migration from West Central France to south-west of Niger over a stretch of 4,865 km took 20 days.

The transmitter yielded a total of 506 locations in the space of 78 days. There was only one day (22 September), during a period of rain, when the eagle was never located. On 13 days it was located five, six and eight times per day respectively, on 14 days seven times, on 7 days nine times and on 2 days ten times. On only 20.4 % of the days were less than five locations received. Thus we were able to trace the course of the autumn migration more thoroughly than for any other migrant raptor previously. Only during a brief but pronounced spell of bad weather around the date of departure from the breeding area, with almost continuous rain and heavily overcast sky, was there insufficient light to power the transmitter's solar cells.

Up to its departure from the breeding territory on 25 September the eagle was located 384 times, and 116 times during its subsequent migration.

Shortly after arriving on its wintering grounds on the evening of 14 October the bird died for reasons unknown. lt was located for the last time on 16 October at 06.45 hrs (all times are UTC) near the river Dallol Bosso at 13° 34' N / 3° 6' E, 107 km east of Niamey. Two days later a telephone call from an official at the Presidential Palace advised us of its death.

Departure

The bird left the breeding territory on 25 September. At 09.15 hrs it was located for the last time near the nest; by 14.07 hrs it had already left and was located at its first overnight roosting place on its journey 38 km south-east of the nest site. The migration continued during a spell of bad weather; it had already been raining virtually without stopping for two days at the time of its departure.

The departure date corresponds very well with the dates given by Boudoint (1984). According to this author adult Short-toed Eagles leave before their offspring.

Migration route

The migration continued in SSW direction, leading over the low end of the Pyrenees near the Atlantic coast. Here the bird spent the night of 27/28 September 11 km inland and 11 km south-east of Saint Jean-de-Luz, where a very precise Class 3 location (better than 150 m) was obtained. This agreed closely in timing with the passage of Short-toed Eagles through the Pyrenees in late September (Urcun, 1996).

The onward journey continued in an almost steady direction straight through Spain to the upper reaches of the Guadalquivir river. Here, on 2 October, there was a shift to the south-west as the bird flew along the Guadalquivir valley for 220 km. At a point 50 km south-east of Seville (37° 13' N / 5° 27' W), at 14.30 hrs, on that same day there was a further change of direction southwards. On 3 October, at 12.36 hrs, the eagle was located over the Straits of Gibraltar at 36° 2' N / 5° 25' W, about 11 km from Gibraltar. In 1977 the greatest number of Short-toed Eagles were recorded here passing through on 1 October (Bernis, 1980).

The southerly direction was maintained, roughly along the 5th longitude west, to the south of Mali. The Atlas Mountains were crossed at one of the highest parts of the range. In Mali at 16° 4' N / 5° 33' W, 21 km from the Mauretanian border, the bird swung almost 90° to the east. After crossing the basin of the Niger there was yet another shift south-eastwards, after spending the night of 11/12 October at 15° 33' N / 1° 2' W. The north-east tip of Burkina Faso was then crossed, leading finally to Niger.

Daily flight distances

Few researchers have attempted to quantify the distance migrants fly in one day (Kerlinger, 1989). The paucity of measurements is related to technical difficulties and the expense of following birds for long distances. Researchers have been thwarted by topography, geopolitical borders, weather, equipment failure, and expenses. Peregrine Falcons *(Falco peregrinus)* tracked from an aircraft flew up to 330 km per day during autumn migration in North America. The average daily distance of three birds was 185 km (Cochran, 1975).

It has now been possible in this study to pinpoint all the overnight stopping-places of a raptor on migration. Their coordinates and further details are given in Table I. During its journey the bird spent four nights in France, four in Spain, two in Morocco, two in Algeria, five in Mali and four in Niger.

The relatively high number of night-time locations is remarkable, making it possible to calculate the distances covered each day (Tab. I & Fig. 1). The Short-toed Eagle flew a daily average of 234 km.

From its departure up to the 14th day the daily flight distances increased steadily, culminating on the 14th day in the maximum stretch of 467 km. From then on the length of each daily stage decreased almost continuously (Tab. I).

Overall, the bird covered less than 100 km on three days, and on five days 100-200, 200-300 and 300-400 km respectively. On two days (8 and 9 October) it flew the greatest distances of 467 and 401 km while crossing the Sahara in northern Mali.

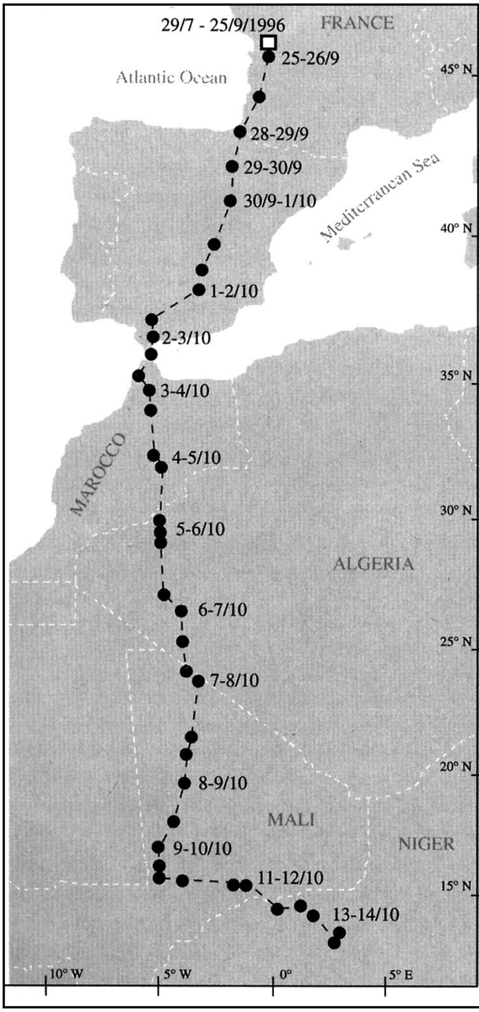


FIG. 1. – Autum migration route of the adult Short-toed Eagle *Circaetus gallicus.* Dates of most over-night roosting-places are given.

La voie de migration automnale de l'adulte de Circaète Jean-le-Blanc Circaetus gallicus *avec les dates de la plupart des localisations nocturnes.*

The shortest distance was on 27 September with a mere 17 km covered in the Landes Regional Park (France). This was plainly due to the bad weather, when it rained almost throughout the day.

Cross-country speed

In spite of permanent messages from the PTT relatively few precise daytime locations were obtained, probably resulting from the method of locating through the Doppler effect, whereby there is almost no scope for pinpointing a relatively fast-moving object. Accordingly we received only few good locations in succession over a short space of time, permitting the speed on migration to be calculated.

The most accurate estimate of mean cross-country migration speed was made possible by two good locations in quick succession on 8 October. 85 km were covered between 13.20 and 15.00 hrs, i. e. 51 kph. Between 08.00 and 13.20 hrs on that day 235 km were covered, i. e. a speed of 44 kph (FIG. 2). On 6 October the bird covered 248 km, i. e. 37 kph, between 08.42 and 15.25 hrs. These calculations agree well with the values given by BRUDERER and SPAAR (pers. comm.), who were able with

Table I. – Details of overnight roosting-places during migration and daily flight distances covered.

1 - roosting dates; 2 - time (UTC) of first location at roosting place in the evening; 3 - time of last ineation at roosting-places in the moming; 4 - number of locations from roosting-place; 5 & 6 - co-ordinates of roosting-places; 7 - further details on locations of roosting-places; 8 - distances covered in km from previous roosting-place (daily flight distance).

1 = Datum der Übernachtung, 2 = Uhrzeit der ersten Ortung am Übernachtungsplatz, 3 = Uhrzeit der letzten Ortung am Übernachtungsplatz, 4 = Zahl der Ortungen am Übernachtungsplatz, 5 und 6 = Koordinaten des Übernachtungsplatzes, 7 = weitere Angaben zur Lokalisation des Übernachtungsplatzes, 8 = Seit der letzten Übernachtung zurückgelegte Entfernung in Km.

Données sur les dortoirs utilisés lors de la migration et les distances journalières parcourues.

1 - dates pour chaque site; 2 - heure (en Temps Universel) de la première localisation au dortoir en soirée; 3 - heure de la dernière localisation au dortoir le matin; 4. - nombre de localisations recues en provenance du dortoir; 5 & 6 - latitude et longitude du site du dortoir; 7 - brève description du site du dortoir; 8 - distance parcourue (en km) depuis la nuit précédente.

1	2	3	4	5	6	7	8
25 - 26.09	14.07	–	2	45° 36’ N	0° 19’ W	9 km S of Cognac, central Western France	38
26 - 27.09	–	06.51	1	44° 34’ N	0° 44’ W	Parc Rég. des Landes, 31 km SSW of Bordeaux, SW France	121
27 - 28.09	–	08.11	3	44° 25’ N	0° 37’ W	Parc Rég. des Landes, 48 km 55W of Bordeaux, SW France	17
28 - 29.09	17.53	06.09	5	43° 21’ N	1° 32’ W	15 km SSE of Biarritz, SW France	137
29 - 30.09	17.30	03.26	4	42° 15’ N	1° 53’ W	Near River Ebro, 52 km SE of Logrono, N Spain	127
30.9 - 1.10	–	08.47	2	41° 09’ N	1° 56’ W	103 km SW Zaragoza, N Spain	123
1 - 2.10	18.27	08.25	4	38° 12’ N	3° 17’ W	Upper Guadaiquivir valley, 61 km NE of Jaen, 5 Spain	355
2 - 3.10	18.04	09.44	6	36° 32’ N	5° 19’ W	46 km N of Gibraltar, 5 Spain	297
3 - 4.10	16.01	07.42	5	34° 44’ N	5° 25’ W	123 km SSE of Tanger, N Morocco	228
4 - 5.10	17.19	07.22	3	31° 59’ N	4° 53’ W	Haut Atlas, 294 km E of Marrakech, Morocco	317
5 - 6.10	18.37	06.59	3	29° 43’ N	4° 54’ W	Sahara, 110 km NW of Djebel Ben Tadjine, W Algeria	257
6 - 7.10	18.16	08.19	6	26° 31’ N	4° 00’ W	Sahara, near Oued Chenachane, W Algeria	397
7 - 8.10	17.50	06.19	2	23° 50’ N	3° 18’ W	Sahara, 150 km NE of Taoudenni, N Mali	323
8 - 9.10	19.11	07.35	5	19° 43’ N	3° 56’ W	Sahara, 103 km NNW of Araouane, N Mali	467
9 - 10.10	17.08	07.17	4	16° 18’ N	4° 57’ W	211 km SW of Tombouctou, Mali	401
10 - 11.10	18.24	06.53	5	15° 44’ N	3° 55’ W	Central part of Delta of river Niger, 140 km NNE of Mopti, Mali	181
11 - 12.10	18.00	06.32	5	15° 33’ N	1° 02’ W	135 km SW of Gao, S Mali	309
12 - 13.10	17.38	12.22	6	14° 46’ N	1° 11’ E	172 km NW of Niamey, SW Niger	283
13 - 14.10	17.20	07.29	5	14° 20’ N	1° 49’ E	98 km NNW of Niamey, SW Niger	84
14 - 15.10	16.55	07.06	6	13° 35’ N	3° 01’ E	101 km E of Niamey, SW Niger	223

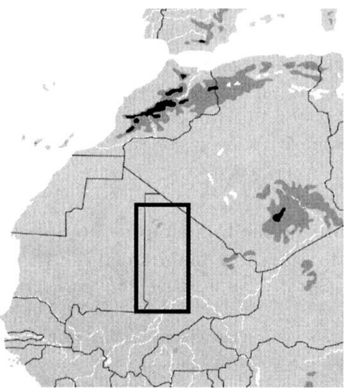
the help of radar to measure an average speed of 39.6 kph (29.9-49.3) (N = 9) in Israel.

Following migrating flocks of Broad-winged Hawks *(Buteo platypterus)* by a motor glider flying 40 to 150 km during autumn migration revealed cross-country speeds of 37.5 to 44 kph (HOPKINS 1975, HOPKINS *et al.,* 1979, WELCH, 1975). Steppe Eagles *(Aquila nipalensis)* tracked by radar had an average cross-country speed of 44.6 (± 17.7) kph during migration in Israel (SPAAR & BRUDERER, 1996). Lesser Spotted Eagles followed by a motorised glider in Israel migrated with an average velocity of 50.9 kph (± 6.7) (LESHEM & YOM-TOV, 1996).

Daily rhythm

Due to the time lapse of ca. 1.5 to 2 hours between passages of the satellites, the times of arrival at a roosting-place and departure the next morning could be estimated only very approximately. As shown by Table I, the bird had often already arrived at its roosting place by 17.20 hrs. In two cases it was already located there at 14.07 and 16.01 hrs. Throughout the whole migration the sun set between 17.46 and 18.02 hrs, and rose between 05.53 and 06.18 hrs. In all likelihood the bird often broke off its journey long before the first locations from its roosting-place.

Thus, for example, on 5 October it was located on the move at 15.38 hrs. Thereafter it covered only 27 km to its roosting-place, so must have arrived there around 16.10 hrs. On 6 October it was located at 15.25 hrs still 106 km from its roosting-place, so must have arrived there around 17.30 hrs, the first location from there being at 18.16 hrs. On 9 October it was located at 14.47 hrs only 84 km from its roost, where it was first located at 17.08 hrs. It must have arrived there at approximately 16.30 hrs.



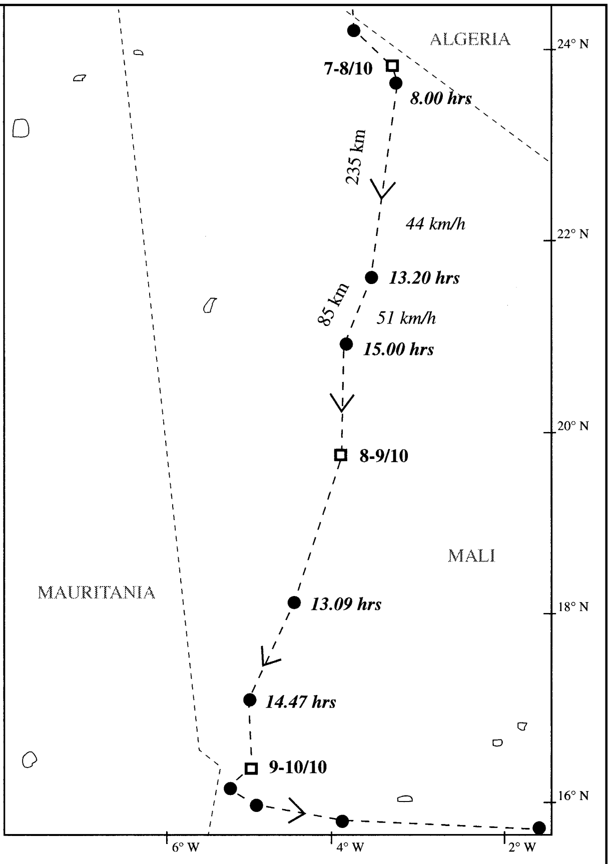


FIG. 2. – Daily flight distances covered on 8 and 9 October 1996 in Mali, the two days with the greatest distances covered, showing the overnight roosting-places (squares) and further locations (round spots) with the time of location, distance and average speed.

Migration du circaète les 8 et 9 octobre 1996 au Mali, les deur jours oû les distances parcourues ont été les plus longues. Les sites des dortoirs sont indiqués par des carrés, les autres localisations par des points, avec l'heure de la localisation, ainsi que les distances pour lesquelles les vitesses de migration ont été calculées.

On 11 October the bird was located at 14.25 hrs only 60 km from its roosting-place, which it must have reached at approximately 15.40 hrs.

lt must therefore be concluded that the bird arrived at its roosting-place ca. 30 mins to 2 hrs before sunset.

In the mornings the bird was repeatedly located for the last time at its roost between 07.00 and 08.00 hrs. The latest times were 08.25 hrs on 2 October and 08.19 hrs on 7 October. On several days locations in the forenoon showed the bird to be already some distance from its roosting-place, so that the time of departure could be estimated.

On 6 October the bird was located at 08.42 hrs 43 km distant from its roosting-place, and so must have set off between 06.50 and 07.00 hrs, since at 06.49 hrs it was still located at its roost. On 8 October it must have started around 07.40 hrs, being located still at its roost at 06.19 hrs and at 08.00 hrs 16 km distant from it. On 10 October the eagle must have moved off around 08.00 hrs; at 07.17 hrs it was still at its roost while at 08.54 hrs it was 36 km away. Thus the bird must have left in the morning between ca. 45 mins and 2 hrs after sunrise.

The foregoing reveals very variable lengths of time spent on migration and probably to some degree foraging. The species is known to sometimes bunt insects during migration (Kraft, 1987). On 8 October (length of day 11 hrs 49 mins) – the day with the greatest distance (467 km) covered – the bird must have spent about 10 hours, from ca. 07.40 hrs (1 hr 33 mins after sunrise) to 17.40 hrs (17 mins before sunset), on its flight across the Sahara in northern Mali. This calculation is based on an average speed of 44-51 kph, as calculated for two major stages covered on that day (see also Fig. 2).

On 6 October even 10½ hours must have been spent in flight (length of day 11 hrs 45 mins), when 397 km were covered over the Sahara in western Algeria. However, since between 08.42 and 15.25 hrs an average speed of only 37 kph was recorded, the question arises as to whether a search for food was not also indulged in during this time.

For 9 October, the day with the second longest daily distance of 401 km, we estimated that only around 8 hours, from ca. 08.50 to 16.50 hrs were spent travelling. Sunrise was at 06.09 hrs, sunset at 18.00 hrs.

Correspondingly less time must have been spent travelling on days when only ca. 120 or 130 km were covered. In these cases the bird can have spent only 3-5 hours on migration. On 10 October, for example, in Mali, 36 km were covered in the morning up to 08.54 hrs, after which only a further 38 km up to 14.38 hrs and thereafter still only 107 km to the overnight roosting-place.

At the Straits of Gibraltar in 1976 and 1977 Short-toed Eagles passed through between 06.00 and 17.00 hrs with the majority between 08.00 and 14.00 hrs, peaking between 09.00 and 10.00 hrs (Bernis, 1980). Bijlsma (1991) observed migrating Short-toed Eagles at Suez (Egypt) mainly between 09.00 and 16.00 hrs and to a smaller degree up to 17.00 hrs.

Dependence on weather

The distances covered each day reflect a marked dependence on the weather. On sunny days the eagle accomplished on average three times more (311 km) than it did on overcast, or on rainy days (92 km). Indeed, the dependence of migrating raptors on meteorological conditions has long been presumed, on the grounds of their use of thermals, but hitherto there has been little evidence of the daily flight distances depending on weather conditions.

For the first six days of the migration there were prevailing low level stratus clouds and partly rain, during which the bird covered an average daily stretch of only 94 km (max. 137 km). From 1 October on, the eagle moved into the subtropical region and had, apart from one day (13 October), fine, warm weather conditions on its journey. The development of mainly convective clouds indicates high temperatures and generates strong thermals, which the eagle used beside the general southerly wind direction on migration. The cloud cover estimated from Meteosat 5 satellite images was two eighths. The daily distance covered suddenly increased to an average of 311 km. On 11 October the eagle left the arid subtropical region and crossed the border to the more humid savannah. Therefore, the cloudiness increased and the wind direction changed westerly. Again, the bird heading towards Niger used the general wind direction for migration. Despite the cloud cover of 5/8 to 8/8 and occasional showers, the eagle flew 309 km on 11 October and 283 km on 12 October.

On 13 October the weather conditions became worse as seen on the satellite images. The whole southern part of West Africa was almost overcast. On that day only 84 km were covered.

COCHRAN (1975) observed that there was a large variation in flight time with different weather conditions. A migrating Peregrine Falcon *(Falco peregrinus)* ceased migration by 12.00 hrs on days when winds were opposed to the migratory direction. He followed this immature male fitted with a conventional radio transmitter by aircraft during its autumn migration from Wisconsin (USA) to Mexico, 2,620 km in 15 days. The average cross-country speed was 33 kph and the daily distance averaged 175 km.

An adult male Bald Eagle *(Haliaeetus leucocephalus)* was tracked from an aircraft by HARMATA (1984) during spring migration from Colorado to Saskatchewan in North America. During its 15 day migration the eagle spent 6 days "sitting out bad weather" and averaged about 220 km on the days it migrated.

DISCUSSION

These are the first published results of a migrating bird which was fitted with a solar-powered PTT so programmed that, given an adequate supply of energy, it could permanently send out signals. The results clearly show that, in the given conditions, apart from a brief spell of bad weather at the time of the bird's departure at the end of September, the degree of light was sufficient for the transmitter to be kept permanently charged, thereby yielding a mass of data hitherto inconceivable with battery-powered transmitters.

Whilst the very restricted life-span of the batteries was the limiting factor of satellite telemetry when using battery-powered transmitters, this energy problem has, given sufficient light conditions, been solved by the introduction of solar-powered PTTs.

In this case the limiting factor now is the restricted number of times the satellite passes each day. A greater mass of data together with more detailed information must be expected from the launching of more satellites. There are future plans for four satellites to be simultaneously in operation, whereby the number of locations will probably be doubled.

Comparison with the behaviour of other migrating birds tracked by satellite is only relatively possible since to date no results from other migrating individuals fitted with permanently operating transmitters have been published. Since it is now clear how widely the daily flight distances vary from one day to the next, there can be no true comparison of this valuable finding with the results obtained from other eagles fitted with battery-powered transmitters (MEYBURG *et al.*, 1995 a, b, c) since, in order to save energy, the latter were so programmed that they only emitted signals for a few hours spaced out over several days. For example, a Lesser Spotted Eagle fitted with a battery-powered transmitter gave an average of 166 km per day throughout the whole of its autumn and spring migrations (MEYBURG *et al.* 1995 a).

With the highest daily flight distance of 550 km, the maximum day's stage of this Short-toed Eagle falls only a little short of those covered by a Lesser Spotted Eagle and an Osprey which we likewise fitted with permanently operating solar-powered PTTs. According to our as yet unpublished findings this Lesser Spotted Eagle covered a maximum of 537 km in a single day on its autumn migration through the Sudan. We calculated an average cross-country speed of 46-60 kph on two occasions during this day. The Osprey covered 550 km crossing the Mediterranean on 4 September 1996.

Compared with the first, immature Short-toed Eagle tracked by satellite telemetry, this adult bird in general travelled clearly faster, covering a daily average of just over 100 km more. The first bird required 30 days for 4,045 km, compared with the individual here described, which covered 4,685 km in 20 days. Possibly this is connected with the adult bird's wide experience in finding food on unfamiliar terrain, thus spending less time hunting for it. More comparative research is needed. The routes taken by both Short-toed Eagles to southern Mali were rather similar.

More Short-toed Eagles in both West and East Europe need to be tracked in order to clarify the different migration strategies of the populations which bypass the Mediterranean at its western and eastern ends, and also the way in which the migratory strategies of juveniles, immatures and adults differ. In this connection it would be interesting to equip both birds of a pair or a whole family, if possible, as we have already done with Ospreys in three cases and Greater Spotted Eagle in one.

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ZUSAMMENFASSUNG

Zugstrategie eines adulten Schlangenadlers *Circaetus gallicus:* Satellitentelemetrische Untersuchungen

Erstmalig konnte das Zugverhalten eines adulten Schlangenadlers mit Hilfe der Satelliten-Telemetrie untersucht werden. Der im zentralwestlichen Frankreich (Département Charente-Maritime) gefangene Brutvogel wurde mit einem solarbetriebenen Sender versehen, der permanent sendete, so daß sein Herbstzug bis in den Südwesten des Niger auf einer Strecke von 4685 km, für die er 20 Tage benötigte, sehr detailliert dokumentiert werden konnte (FIG. 1).

Der Abzug aus dem Brutgebiet erfolgte am 25. September 1996, die Ankunft im Überwinterungsgebiet am Abend des 14. Oktober. Die Straße von Gibraltar wurde am 3. Oktober überflogen. Da alle Übernachtungsplätze geortet werden konnten (TAB. I), war es möglich, die täglich zurückgelegten Strecken zu berechnen, deren Länge zwischen 17 und 467 km (Mittel 234 km) schwankte (TAB. I). An drei Tagen wurde jeweils weniger als 100 km weit gezogen. An je fünf Tagen betrug die zurückgelegte Entfernung zwischen 100 und 200, 200 und 300 bzw. 300 und 400 km. Die beiden größten Tagesstrecken bewältigte der Vogel beim Durchqueren der Sahara im nördlichen Mali mit 467 und 401 km am 8. und 9. Oktober.

Es konnte eine sehr deutliche Abhängigkeit der täglich zurückgelegten Entfernungen vom Wetter festgestellt werden. An überwiegend sonnigen, warmen Tagen bewältigte der Adler im Durchschnitt mehr als das Dreifache (311 km) als an bedeckten, regnerischen Tagen (92 km).

Täglich wurden bis zu etwa 10 1/2 Stunden bei einer Tageslänge von 11 Stunden und 45 Minuten, oftmals jedoch wesentlich weniger, auf dem Zuge verbracht. Die Schlafplätze wurden abends etwa 1/2 bis zwei Stunden vor Sonnenuntergang aufgesucht und morgens eine 3/4 bis zwei Stunden nach Sonnenaufgang wieder verlassen. Aufgrund genauer Ortungen konnten durchschnittliche Zuggeschwindigkeiten von 37, 44 und 51 Km pro Stunde auf verschiedenen Teilstrecken errechnet werden.

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