Satellite tracking of two Lesser Spotted Eagles, *Aquila pomarina*, migrating from Namibia

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One immature and one subadult Lesser Spotted Eagle, *Aquila pomarina*, were followed by satellite telemetry from their non-breeding areas in Namibia. Both birds were fitted with transmitters (PTTs) in February 1994 and tracked, the immature for six months and three weeks, the subadult for eight months and two weeks, over distances of 10 084 and 16 773 km, respectively. During their time in Namibia both birds' movements were in response to good local rainfall. The immature eagle left Namibia at the end of February, the subadult at the end of March. They flew to their respective summer quarters in Hungary and the Ukraine, arriving there 2.5 and 1.5 months later than the breeding adults. The immature eagle took over two months longer on the homeward journey than a breeding male followed by telemetry in a previous study. On returning, the immature eagle followed the narrow flightpath through Africa used by other Lesser Spotted Eagles on their outward migration. It reached this corridor, which runs roughly between longitudes 31° and 36° East from Suez to Lake Tanganyika, veering from the shortest route in a direction east-northeast through Angola and Zambia to the southern end of Lake Tanganyika. The route taken by the subadult bird on its return migration differed markedly from that of all Lesser Spotted Eagles tracked to date, running further west through the Democratic Republic of Congo where, level with the equator, it flew over the eastern rainforest of that country. The outward migration, however, followed the same corridor and coincided in time with the migration of adults. [A German translation of the abstract is provided on p. 40.]

INTRODUCTION

Ringing, with a recovery rate of only *c.* 2.5%, has so far produced little concrete information regarding migration and wintering behaviour of the Lesser Spotted Eagle, *Aquila pomarina* (Danko *et al.* 1996). As a rule, this method merely provides the place of ringing and that of the bird's death as well as the age it attained. Knowledge of the migration dynamics, the route taken, speed of travel and resting-places can be acquired only by means of satellite telemetry. Owing to ever-increasing reduction in size and other improvements to satellite transmitters, technically called platform transmitter terminals (PTTs), it has, in recent years, become possible to track medium-sized birds of prey (Meyburg *et al.* 1993, 1996, 1998). Despite the considerable expense, satellite telemetry ranks as a cost-efficient way of studying bird migration (Hedenström 1997).

To investigate more fully the Lesser Spotted Eagles' movements outside the breeding season, we have fitted transmitters to birds in various breeding areas in Europe (Germany, Latvia, Slovakia). Four nestlings and four adults were equipped with battery-powered transmitters in 1992–1994. The results of the tracking of these eight birds have already been published (Meyburg *et al.* 1993, 1995a). In another on-going study begun in 1997, 11 adults have so far been fitted with solar-powered PTTs which have only very recently become available. Owing to the limited, one year maximum life of the 30–50 g battery-powered PTTs available at the time of this study, it was not possible to investigate the migratory strategies of immature Lesser Spotted Eagles, which were believed not to return to the breeding range of the species until they reach sexual maturity (Meyburg 1991, 1994, 1996), since they are observed only extremely rarely in Europe. The only way to solve the question of where these birds spent the time prior to becoming adult was to equip them with transmitters in Africa. Whether solar-powered PTTs last long enough to study this problem by fitting them to nestlings remains to be seen.

METHODS

On 9 February 1994, an immature Lesser Spotted Eagle was trapped with a bal-chatri in northern Namibia near Tsumkwe (Otjozondjupa Region) (19° 32'S, 20° 17'E) and fitted with a PTT. The bird weighed 1650 g and its entire body was more than usually covered with the typical whitish-yellow spots of juvenile and immature Lesser Spotted Eagles. The rust-yellow spot on the nape, typical at least for juveniles, was already missing. The iris was already almost as yellow as in adult birds. We estimated its age to be almost two years.

Another Lesser Spotted Eagle was similarly trapped with a bal-chatri on 11 February, near Tsintsabis (18° 42'S, 17° 33'E) in Oshikoto Region and fitted with a PTT. This bird weighed 1920 g with a crop full of frogs. It was a subadult female; it was virtually adult, as evidenced by its uniform brown plumage, including just a few isolated lighter patches. The iris was already completely yellow. We estimated it to be almost three years old, but possibly older.

To achieve as long a life as possible, the transmitters were programmed to remain inactive for 4.33 and 5.6 days between each 8-hour active phase. Further details regarding satellite tracking of raptors can be found in e.g. Meyburg *et al.* (1993, 1995b, 1996, 1998).

For the tracing of the birds' movements and computer calculation of distances covered between Argos locations we used an integrated global mapping system displaying a true mercator projection. The migration routes were also traced by a variety of CD-ROM-Atlases which included satellite photographs, in order to ascertain dependence on variables such as habitat types and altitude. For plotting the summering areas in Ukraine and Hungary, coloured maps of the Russian ordnance survey with a scale of 1:50 000 were used.

RESULTS

The immature eagle was tracked for six months and three weeks over a total distance of 10 084 km (107 fixes), the subadult for eight months and two weeks over 16 773 km (57 fixes). The

subadult bird spent only five months outside Africa during the northern hemisphere breeding season.

Movements in Namibia

The immature eagle remained in Namibia for about two weeks, until at least 22 February. Following capture, it flew some 300 km north to the Okavango River and then due west some 700 km to the Kunene Region where it lingered from 13 to 22 February at 17° 42′S, 14° 4′E. The minimum distance in Namibia was 997 km (Fig. 1).

The subadult remained in Namibia some seven weeks after having been trapped. It first moved about 400 km south, and then also flew to the Kunene region, moving about 900 km in a northwesterly direction to do so. From here, it moved back to the area where it had been caught and stayed in the vicinity from 10 to 27 March. Its nomadic movements over seven weeks covered at least 1277 km (Fig. 1).

The two birds were caught in areas that had between 150 and 220% more rain than average by the end of January 1994. The Kunene area to which both birds moved between 13 and 27 February had not had particularly good rains before the third week of February. During this time, the area received a total of 120 mm of rain, a very good fall for that part of Namibia, and NDVI (normalized difference vegetation index) analysis of NOAA images showed that the entire area to which both eagles had moved had a massive growth of vegetation. The area of increased vegetation growth in the northwest of Namibia covered about 4500 km^2.

The Kavango/Bushmanland area consists to a very great extent of broad- leafed savanna woodland growing on Kalahari sands. Clay soils in lower-lying local depressions occur locally and these soils support a variety of acacia species. The topography is very flat however. Rains fall almost entirely in the southern-summer months, and almost all primary production is dependent on rain. The first rains fall in October and November with sporadic falls lasting until March and April the following year. The sporadic nature of rainfall results in food production being extremely localized, both spatially and temporally. For Lesser Spotted Eagles, good rains result in the appearance of food such as termites, grasshoppers and frogs. Average annual rainfall amounts to 450–500 mm, but year-to-year falls vary substantially with the coefficient of variation of annual totals being in the region of 30–40%.

The Kunene area is more varied topographically than the Kavango, but is considerably more arid. Rains fall even more sporadically with annual totals of 250–350 mm being characterized by coefficients of variation of 45–50% in annual rainfall. Again, almost all the rain falls during the southern summer months. Much of the vegetation is dominated by mopane *Hardwickia (Colophospermum) mopane* and shrubs. Both the Kavango and Kunene are very sparsely populated by people.

Migration route of the immature eagle

The immature eagle left Namibia in a northeasterly direction. It was located first in Angola (16° 11′S, 15° 14′E) on 26 February. From there veering east-northeast it crossed Angola and Zambia in an almost straight line. On 11 March, south of the southern end of Lake Tanganyika (at 10° 10′S, 30° 45′E), it abruptly changed direction about 45° to the north. Then, heading almost due north between longitudes 31 and 33, its migration continued through western Tanzania and Uganda, eastern Sudan and Egypt, reaching the Red Sea (27° 22′N, 33° 18′E) on 27 April on a level with the southern tip of the Sinai Peninsula (Fig. 2).

The migration then followed the known route for these eagles (Meyburg *et al.* 1995a) along the Mediterranean coast, through Israel, Lebanon, Syria and across Turkey. The Gulf of Iskenderun was overflown on 6 May and the Bosphorus on May 12 (Fig. 3).

Thereafter the migration continued, heading northwest through Bulgaria and Rumania until, on 26 June the eagle reached its boreal summer quarters (47° 1′N, 21° 11′E) in eastern Hungary in the neighbourhood of the village of Szeghalom, near the Rumanian border.

Migration route of the subadult eagle

The subadult Lesser Spotted Eagle stayed in Namibia up to the end of March. On 1 April it was fixed in southern Angola (16° 7′S, 18° 4′E). Unlike the immature bird its route led almost directly north-east, through eastern Angola and the Democratic Republic of Congo. On 17 April the eagle had arrived in southern Sudan (5° 30′N, 28° 2′E) near the border of the Central African Republic. After crossing Sudan it reached southeastern Egypt (23° 10′N, 34° E) by 28 April (Fig. 2).

From then on it followed the established eastern route (Meyburg *et al.* 1995a) along the Mediterranean to the Bosphorus (see Fig. 3). In Syria and southern Turkey it covered only 571 km between 3 and 19 May. The Bosphorus was crossed on about 23 May, after which the bird flew along the west coast of the Black Sea. It arrived in its boreal summer quarters on 30 May

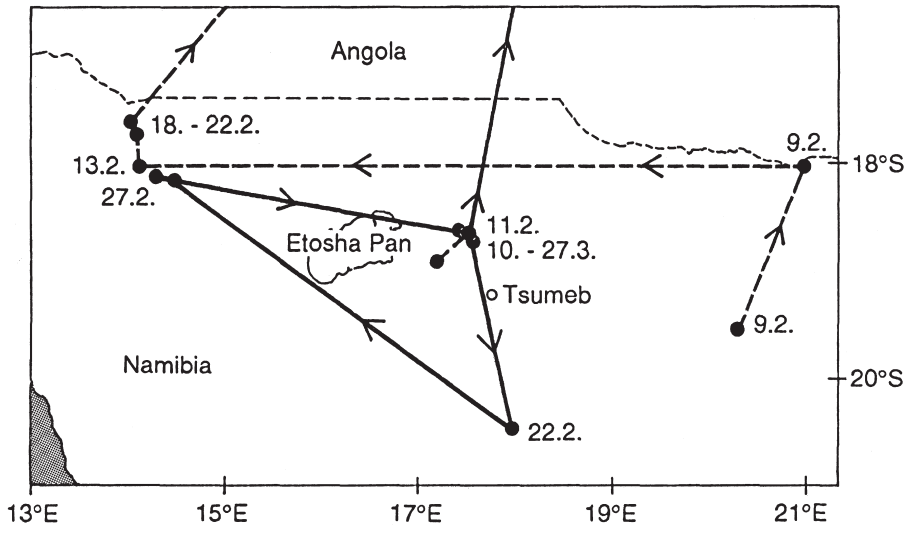

Fig. 1. Movements of the subadult (solid line) and immature (broken line) Lesser Spotted Eagle in Namibia.

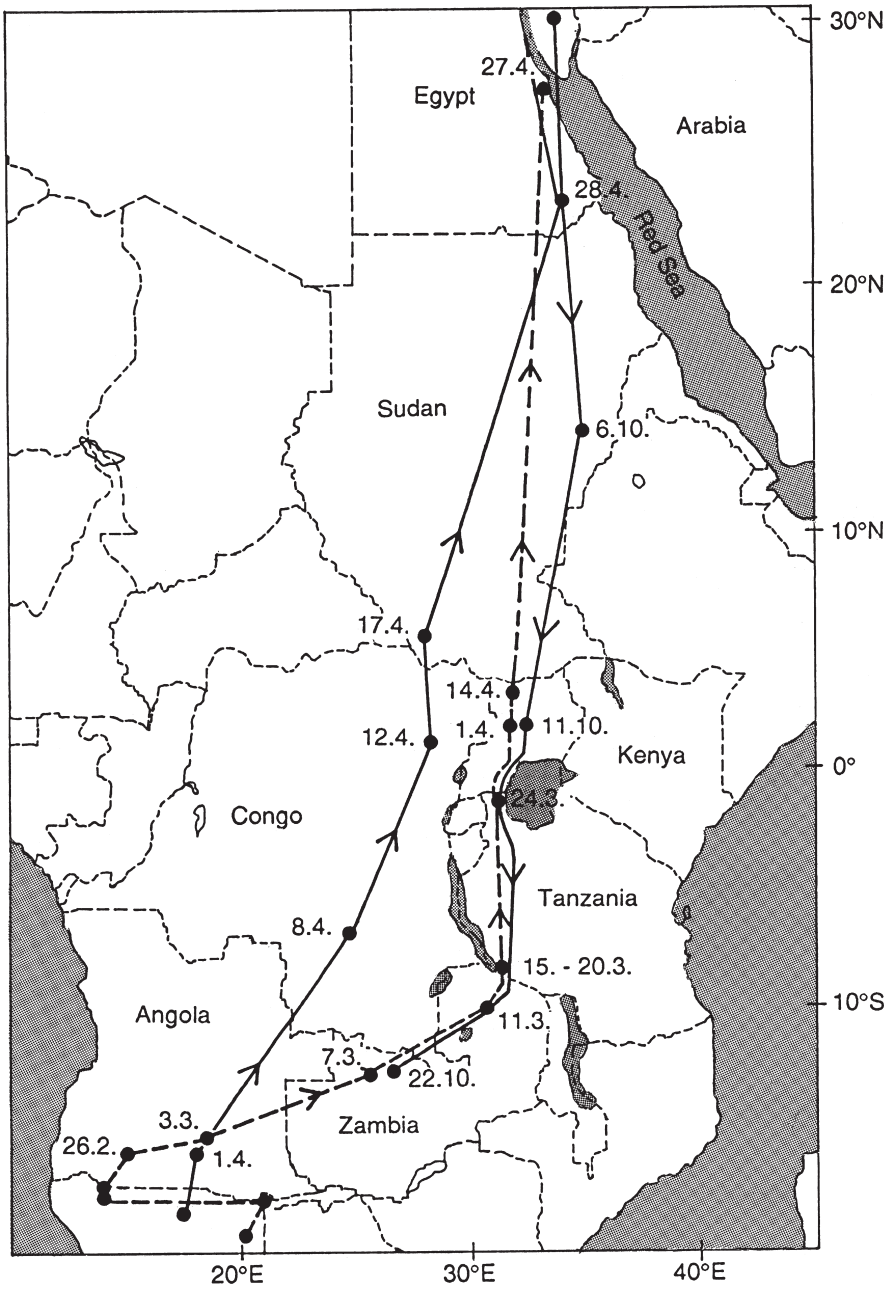

FIG. 2. Movements of the subadult (solid line) and immature (broken line) Lesser Spotted Eagle in Africa during the spring and autumn migrations, showing dates of arrival at selected points en route.

in southern Ukraine.

The outward migration to Africa four months later followed the same route round the Mediterranean, but unfortunately due to lack of locations the date of departure could not be determined. This must, however, have taken place roughly around 10 September, considering the overall migration speed of this bird during outward migration. On 30 September it had reached the Sinai Peninsula (30° 5′N, 33° 42′E) and on 6 October it was on the Blue Nile in the Sudan near Wadi Medani (13° 57′N, 34° 52′E). Here the bird was *c.* 425 km east of its springtime route. Its journey continued almost parallel with the White Nile. On 11 October the eagle was located in Uganda (1° 43′N, 32° 32′E), about 450 km east of its return migration route. From there it continued in its southern direction passing west of Lake Victoria and then through western Tanzania to Zambia (12° 44′S, 26° 38′E), where it was located for the last time on 22 October. This location showed that it was *c.* 670 km east of its return migration route. The distance from there to the place where it had been equipped with a transmitter was 1170 km.

Resting places and duration of rests

As far as could be judged from the locations, the immature bird broke its journey at least four times and for a total of six weeks. It remained from around 15 to 20 March about 15 km north of the Zambia/Tanzania border (8° 32′S, 31° 32′E) and from 1 to 14 April in northern Uganda (1° 42′N, 31° 57′E). A further pause on the migration ensued in southeastern Bulgaria (42° 29′N, 26° 17′E) from 18 May to 9 June. In southwestern Rumania (44° 55′N, 22° 10′E) it covered only 77 km between 13 and 17 June, so it can be concluded that the eagle rested there as well.

For the subadult eagle it can only be assumed in one case that it interrupted its migration. In this case it covered only 571 km between 3 and 19 May in southern Turkey.

Northern hemisphere

Both Lesser Spotted Eagles spent the northern hemisphere summer in areas where there were no breeding adults. The immature bird, up to the last location on 29 August, stayed in Hungary near the village of Szeghalom (47° 1′N, 21° 11′E) in

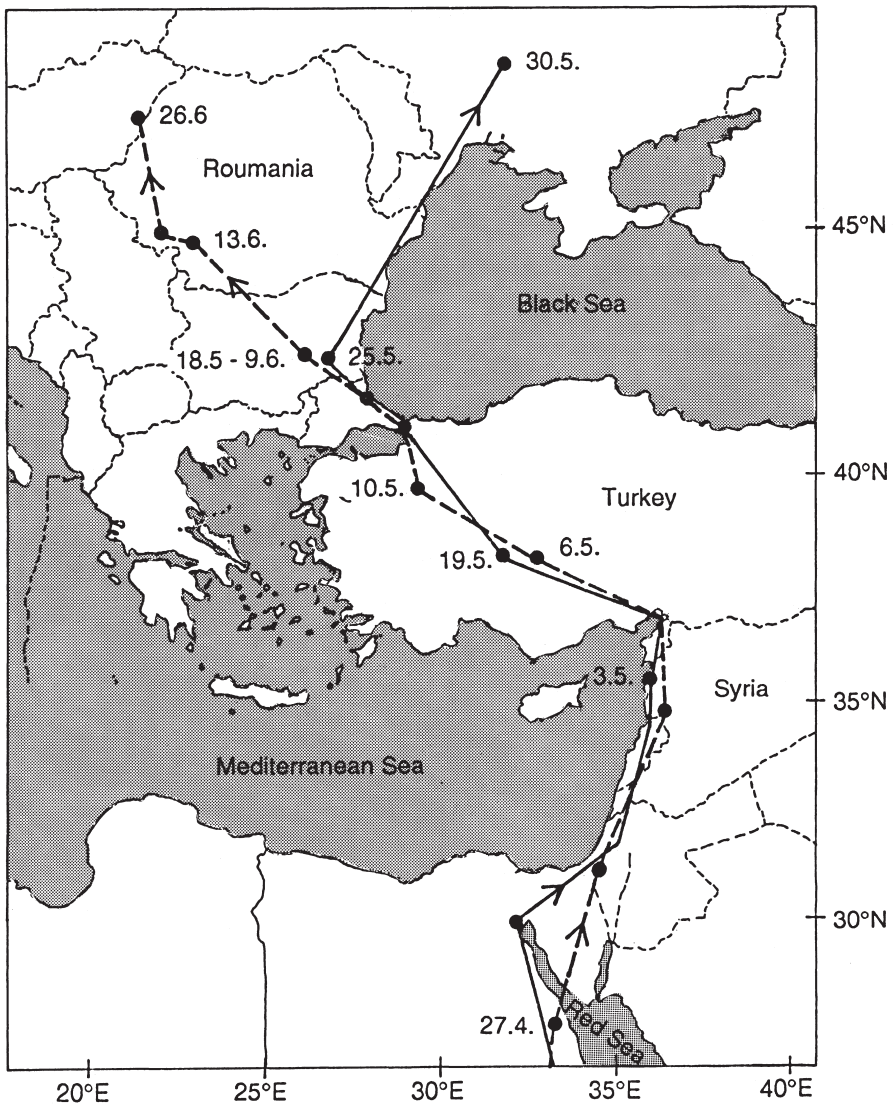

FIG. 3. Movements of the subadult (solid line) and immature (broken line) Lesser Spotted Eagles in Europe and the Middle East during the spring migration, showing dates of arrival at selected points en route.

the Puszta. Its home range extended over an area of 915 km^2. This area is rather grossly estimated due to the limitations in accuracy of satellite fixes. The region is characterized by a wide, open, absolutely flat landscape with only small stands of trees.

The boreal quarters of the subadult eagle (48° 5′N, 31° 57′E) in southern Ukraine, about 50 km south-southwest of Kirovograd, consisted of open, cultivated steppe, widely interspersed with small patches of woodland. Here the bird confined its activities to a home range of *c.* 610 km^2. Breeding adult males have home ranges of 22–34 km^2 (Scheller & Meyburg, unpubl.).

Migration speed of the immature eagle

The length of each day's travel varied considerably: in Angola and Zambia a daily average of 206 km (3–7 March) and 141 km (7–11 March) was travelled, respectively, and in east Tanzania 197 km (20–24 March). In Uganda progress was very slow, including a rest period, taking over three weeks to cross the entire country (540 km – 25 March–15 April). For the passage through the Sudan and Egypt (*c.* 15–27 April) a daily average of 207 km was covered, so that northern Sudan and Egypt must have been crossed much more rapidly. Most of the Lesser Spotted Eagles we have tracked have rested in southern Sudan during their autumn migration (Meyburg *et al.* 1995a). While crossing the Sinai Peninsula, Israel, Lebanon and southern Turkey (27 April–6 May) a daily average of 182 km was covered, and 86 km while crossing central Anatolia (6–10 May).

On the final stages of the journey through Bulgaria and Rumania (9–13 June) the daily average was 88 km; in western Rumania (17–26 June) up to arrival in northern quarters 31 km per day were travelled.

For the entire northward journey, totalling 10 084 km, this bird took four months, including the four rest periods in Tanzania, Uganda, Bulgaria and Rumania, making a daily distance covered of 83 km. Excluding these rest periods, it covered a daily average of *c.* 133 km.

Migration speed of the subadult eagle

With this bird the length of each daily stage varied considerably. In Angola and southern Congo (1–6 April) a daily average of 209 km was covered; in east Congo (6–12 April) 195 km; in northeastern Congo (12–17 April) 88 km; in the Sudan (17–28 April) 206 km; in Egypt, Israel, Lebanon and Syria (28 April–3 May) 207 km; in Turkey (19–25 May) 157 km; and in Bulgaria, Rumania and the Ukraine (25–30 May) at least 136 km.

For the entire 8252 km of its northward migration this bird took eight weeks (including a rest period of two weeks in southern Turkey). Discounting this rest period it covered on average about 147 km per day. If one includes the time spent resting, the daily distance flown was 118 km.

DISCUSSION

With satellite telemetry it was possible to record in detail the migration strategies of two nonbreeding Lesser Spotted Eagles and we can now compare these with those of breeding adults in another study. Their tracking within Namibia shows that the birds' movements were in response to good local falls of rain and the ensuing increased production of vegetation as supposed by Steyn (1982).

Migration period and migration speed

The immature eagle left its wintering grounds at the same time (end of February) as an adult male (i.e. 26 February 1995; Meyburg *et al.* 1995a). The subadult bird stayed on in Namibia for another month.

The immature eagle took about twice as long for the homeward migration as an adult male, which bred successfully in Germany after arrival on 22 April, about a week later than usual (Meyburg *et al.* 1995a). Probably owing to weather conditions in breeding areas in Europe in 1995, the arrival of all other breeding Lesser Spotted Eagles in Germany that year was later than the normal 10–15 April. The tracked adult had taken 7.5 weeks overall on its homeward journey from Zambia, covering a daily average of 166 km (Meyburg *et al.* 1995a). The subadult bird took hardly longer than the adult.

At the usual time of arrival in the breeding territory in mid-April the immature eagle was still in Uganda and the subadult eagle in northeastern Congo. The passage through the eastern Mediterranean at the beginning of May occurred a whole month later than the peak of the migration in this region (Christensen & Sorensen 1989), at a time when adults were already breeding. The arrival of the subadult eagle in its summer quarters at the end of May only just preceded hatching of chicks, while that of the immature bird at the end of June was at a time when the nestlings were already about two weeks old.

To breed successfully, adult Lesser Spotted Eagles must reach their breeding sites not later than about 15–20 April. A delayed arrival of adults of even one or two weeks apparently leads to non-breeding (Meyburg *et al.* unpubl.). Non-breeding immatures can dally and take advantage of food resources during migration and avoid competition with the breeding adults.

The subadult eagle's outward migration was faster than the homeward and almost synchronous with that of the breeding birds tracked by us in another study (Meyburg *et al.* 1995a). One adult tracked by us arrived on 28 October in its winter quarters in Zambia. The northern end of the Red Sea was bypassed by the subadult during the normal peak period of the migration here (i.e. at the end of September), while the last location in Zambia on 22 October was slightly earlier than the arrival there of the tracked adult mentioned before.

The *c.* 4,680 km stretch from Sinai to Zambia was covered by the subadult in *c.* 20 days, making daily stages of 234 km on average. On certain stretches an average of 359 km was reached (30 September – 6 October) in Egypt and the Sudan, at least 250 km (6–11 October) in Sudan and Uganda, and at least 173 km (11–22 October) in Tanzania and Zambia.

Migration routes

All Lesser Spotted Eagles tracked to date have migrated within Africa along a remarkably narrow corridor or migratory pathway, starting at Suez and proceeding almost due south along a line between the Red Sea and the Nile, through Uganda, and finally on through Tanzania, between its western border and Lake Victoria, to the southern end of Lake Tanganyika (Meyburg *et al.* 1995a, unpubl.). What is interesting is the marked deviation on the return migration of the subadult, when it took the more direct and shorter route from Namibia through Angola and Congo where, in the north, it had to cross rainforest.

Homing and orientation

On 6 April, the subadult was located at 6° '58S, 24° 48'E in southern Congo, *c.* 780 km west of its autumn route. On 12 April it was located at 1° 8'N, 28° 18'E in northeastern Congo about 440 km west of its southward migration route. From this marked distance between both routes we conclude that, to orientate, the eagle was not dependent during its homeward journey upon following the outward route. Retracing of the outward route can therefore be eliminated as being the only home-orientating mechanism.

Unlike the subadult, the immature eagle on its return journey flew to the southern point of the corridor, at the southern end of Lake Tanganyika, where it veered quite considerably away from the ideal shortest route to Suez and made an evident detour. Possibly less experienced immatures are more dependent on landmarks for orientation and follow familiar routes on their way home.

Whereabouts of juveniles and immatures

The migration of the immature eagle to Europe was surprising. We had expected it to remain somewhere in Africa. Although the senior author has extensively observed this species over the last 30 years and collected all the relevant literature, we are only aware of a single observation of immatures of this eagle within the breeding range. In this instance several immature Lesser Spotted Eagles were observed roosting together in Eastern Slovakia (J. Švehlik, pers. comm.). There is no other mention of it, as far as we are aware, in the world literature. We therefore still believe that the large majority of one-year and two-year-old Lesser Spotted Eagles do not return to Europe, so where they go remains a mystery.

The age at which young Lesser Spotted Eagles return to the breeding range and where they remain before their return needs to be determined. Whether solar-powered transmitters last long enough to solve this question by being fitted to nestlings remains to be seen, but it would be a worthwhile exercise.

ACKNOWLEDGEMENTS

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ZUSAMMENFASSUNG

Ein immat. und ein subad. Schreiadler wurden im Februar 1994 in Namibia mit Satelliten-Sendern versehen und über Zeiträume von sechs Monate und drei Wochen bzw. acht Monate und zwei Wochen und über Distanzen von 10.084 bzw. 16.773 km telemetriert. Während des Aufenthalts in Namibia erfolgten erhebliche Ortsveränderungen. Die Adler suchten Gegenden mit überdurchschnittlichem Niederschlag auf. Der immat. Adler verließ Namibia Ende Februar, der subad. Ende März. Sie zogen in Übersommerungsgebiete in Ungarn bzw. in der Ukraine, wo sie zweieinhalb bzw. eineinhalb Monate später als brütende Altvögel ankamen. Der immat. Schreiadler nahm sich über zwei Monate mehr Zeit für den Heimzug als ein in einer anderen Studie untersuchter männlicher Brutvogel. Er folgte der bei anderen Schreiadlern auf dem Herbstzug festgestellten recht engen Zugschneise durch Afrika und erreichte diesen Korridor, der etwa zwischen dem 31. und 36. Längengrad E von Suez bis zum Tanganyika-See verläuft, indem er zunächst stark von der kürzesten Route abweichend in Richtung ENE durch Angola und Sambia bis zum Südende des Tanganjika-Sees zog. Die Route des subadulten Vogels auf dem Heimzug unterschied sich hingegen stark von der aller anderen bisher telemetrierten Schreiadler und verlief deutlich weiter westlich durch den Kongo, wobei in Höhe des Äquators Regenwaldgebiete im Osten des Landes überquert wurden. Der Wegzug verlief hingegen ebenfalls innerhalb des Korridors und etwa zeitgleich mit adulten Adlern.

Book Review

Ecology and conservation of grassland birds of the western hemisphere

Peter D. Vickery & James R. Herkert (Eds)

1999. Studies in Avian Biology No. 19. Cooper Ornithological Society. 299 pp. Soft cover $25.00, hard cover $39.50 (includes shipping and handling). ISBN 1-891276-08-5 (soft cover). ISBN 1-891276-11-5 (hard cover)

Many grassland bird species' populations are declining throughout the world, and in particular in the western hemisphere. This book presents a diversity of information on grassland birds and their conservation arising from 34 papers presented at a two-day conference held in Tulsa, Oklahoma, in October 1995. Although the conference had a regional focus (western hemisphere), many of the lessons are relevant to grasslands in the Old World. Collectively, the papers help to diagnose the causes of grassland bird population decreases, and help to identify the most effective conservation actions.

An introduction gives an overview of research and conservation of grassland birds in the western hemisphere. There are descriptions of grassland habitats, their birds, and the threats they face. Following the introduction, 33 papers are presented in three sections: general ecology (8), breeding biology (18) and a section on Latin America (7).

The section on ecology focuses on population status of North American grassland birds, examining the factors responsible for trends in abundance and distribution (ranging from habitat destruction, fragmentation and degradation, to mortality from toxic chemicals, adverse weather, demographic and species-specific factors). The general conclusion is that populations of most grassland birds have decreased throughout North America. There are interesting papers on the evolution and origin of the present grasslands and birds of eastern North America, and on threats and conservation plans for grassland birds in the eastern United States.

The breeding ecology section has subsections covering habitat selection, effects of fire, grassland management, conservation in reserves, and data collection and analysis. Highlights include papers on the effect of habitat type and edge effects on nest predation and other life history traits, thermal aspects of nest-site location, and the effects of fire (extent and frequency), grazing regimes and herbicides on avian life histories.

Most grassland birds occur outside protected areas. Conservation of birds on privately owned land requires trade-offs between economic losses and retention of birds. This approach is applied in one paper, which assessed the most practical and ecologically-friendly grassland management regime that accommodates the needs of grazing animals while promoting the long-term persistence of grassland birds. Other conservation-related papers reported the value of restored habitats for grassland birds. The data collection and analysis section includes papers on a monitoring technique that can be used to identify and quantify nocturnal flight-calling to assess population trends and migration pathways, and practical advice for adequate experimental design.

Together, the book treats virtually all aspects of grassland bird conservation biology. Many of the papers report significant new information. However, several papers suffered from poor experimental design, including lack of adequate controls, unreplicated experiments, inadequate sample sizes, and especially the paucity of manipulative experiments with pre- and post-treatment. As pointed out by one of the authors, these shortcomings can lead to inaccurate conclusions and misdirected conservation efforts. The authors call for further studies to understand the factors affecting grassland bird populations to provide effective management strategies and conservation programmes, but there is a need for well-designed, controlled ecological experiments to isolate the effects of single factors. We need to measure the effects of specific causes rather than speculate about the possible causes of observed effects.

The papers on Latin America reported on bird species richness, population status, distribution, demographic characteristics and conservation needs of some of the region's grassland birds. But they lacked depth relative to the papers on north American grassland birds, suggesting that Latin American grasslands require more research and conservation attention.

Overall, this is a useful volume that will be welcomed enthusiastically both by grassland ornithologists and the interested novice. It should help to promote interest in grasslands and their birds. I recommend it to nature conservationists, ornithologists, government planners, decision-makers, wildlife managers, and the research community.

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