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MIGRATION ROUTES OF STEPPE EAGLES BETWEEN ASIA AND AFRICA: A STUDY BY MEANS OF SATELLITE TELEMETRY

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Abstract. We trapped 16 Steppe Eagles (*Aquila nipalensis*) on migration and on their wintering grounds and fitted them with satellite transmitters, 15 of them in Saudi Arabia and one in South Africa. Seven of the 14 Steppe Eagles trapped in Arabia in autumn did not migrate to Africa but spent the winter in the Arabian Peninsula. One adult migrated to southern Africa. The other six wintered in northeastern Africa, in some cases north of Bab-el-Mandeb, the straits at the southeastern end of the Red Sea, which they had crossed to reach the African continent. On their spring migration all eagles wintering in Africa migrated via the Suez, Egypt–Eilat, Israel, area at the northern tip of the Red Sea. This loop migration around the Red Sea is probably caused by east winds that blow from October until April, making the return migration difficult via Bab-el-Mandeb. This finding should help to explain the difference in eagle numbers between spring and autumn at such migration bottlenecks as Eilat, Suez, and Bab-el-Mandeb. Unlike eagles coming from Sudan and Ethiopia, eagles wintering in southern Africa must make a considerable detour of over 1200 km to complete this loop. The increase in Steppe Eagles overwintering in Arabia has probably contributed to the decline in the number of birds passing through Eilat in spring during recent years.

Key words: Aquila nipalensis, *migration, satellite telemetry, Steppe Eagle, wintering sites.*

Rutas Migratorias de *Aquila nipalensis* entre Asia y África: Un Estudio por Medio de Telemetría Satelital

Resumen. Atrapamos 16 águilas (*Aquila nipalensis*), incluyendo aves migratorias e invernantes (15 en Arabia Saudita y una en Sud África) y les colocamos transmisores satelitales. Siete de las 14 águilas atrapadas en Arabia durante el otoño no migraron hacia África, sino que invernaron en la Península Arábica. Aparte de un adulto que migró hacia el sur de África, las restantes seis invernaron en África oriental, en algunos casos al norte de los estrechos al extremo sureste del Mar Rojo (Bab-el-Mandeb) los cuales cruzaron para alcanzar el continente africano. Durante la migración primaveral, todas las águilas que invernaron en África migraron vía Suez y vía el área de Eilat, alrededor del extremo norte del Mar Rojo. La migración alrededor de este cuerpo de agua siguiendo una ruta diferente a la invernal, es probablemente causada por el viento que provenie del este entre octubre y abril, dificultando la migración de retorno vía Bab-el-Mandeb en febrero y marzo. Este descubrimiento debe ayudar a explicar la diferencia en los números entre primavera y otoño en sitios como Eilat, Suez y Bab-el-Mandeb, que actúan como cuellos de botella. La migración siguiendo dos rutas diferentes significa un desvío considerable de 1200 km para aquellas águilas que invernan en el sur de África, pero no para las que vienen desde Sudán y Etiopía. El incremento de aves que inviernan en Arabia probablemente ha contribuido durante los últimos años a la disminución en los números de aves que pasan a través de Eilat en primavera.

INTRODUCTION

The Steppe Eagle (*Aquila nipalensis*) breeds from southeastern European Russia to Manchuria in eastern China (Meyburg 1994). Next to the White Stork (*Ciconia ciconia*), the Steppe Eagle, with a weight of 2.4 to 3.9 kg, is the largest Palearctic bird species to overwinter regularly and in large numbers in Africa south of the equator. During the last 35 years of research into raptor migration through the Middle East, the Steppe Eagle has proved an intriguing species. Although each year well over 100 000 individuals must travel to Africa, very little is known of the course and dynamics of their journey, or of their behavior on their wintering grounds (Welch and Welch 1991a, Meyburg 1994, Shirihai et al. 2000). Whereas counts have

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been carried out at certain concentration points such as Suez, Egypt, Eilat, Israel, (summarized in Bijlsma 1987, Shirihai et al. 2000) and the straits of Bab-el-Mandeb, at the southern end of the Red Sea (Welch and Welch 1988, 1989, 1991b), they provide no information on the migration routes. Band recoveries are almost completely lacking (Mikhelson 1982).

In recent years satellite telemetry has proved to be a highly appropriate new method of recording the migration routes and dynamics of individual birds (Grubb et al. 1994, Meyburg et al. 1995, 2000, Brodeur et al. 1996, Fuller et al. 1998, Ueta et al. 1998, 2000, Martell et al. 2001, McGrady et al. 2002). We report here on the movements of 16 Steppe Eagles of different ages and both sexes equipped with satellite transmitters (PTTs) and tracked by means of the Argos system.

METHODS

TRAPPING TECHNIQUE

From 1993–1998 we captured 15 Steppe Eagles of varying ages in west-central Saudi Arabia and fitted them with satellite transmitters. We worked at two rubbish dumps near Taif (21°37′N, 40°43′E) and at an overnight roost site on the beach of the Red Sea near Mecca (20°3′N, 40°25′E). One other bird (No. 11) was captured in January 1995 in Kruger National Park, South Africa, (25°03′S, 31°37′E) using a bal-chatri trap (Table 1).

In Saudi Arabia we captured the Steppe Eagles by vehicle pursuit. The capture team was composed of a driver and an onboard observer, who caught the birds. We often used two teams simultaneously, capturing birds shortly before and after sunset (±15 min) when thermals were much less active. We chased the flying eagles with one or two four-wheel-drive vehicles. We singled out a bird and cut off its flight path three to five times, at which time it would land on the ground. During pursuit, we drove as closely as possible to the eagle, forcing it to make erratic flight maneuvers, which we could easily match. After the eagle landed, it was crucial to secure it quickly, as birds would fly or run several dozen meters farther if missed. Once the eagle was running, pursuit by the observer was necessary but never lasted more than 30 sec. We then threw a blanket over the bird and the observer seized it, with gloved hands, by the wings and legs. We then hooded the bird and allowed it to recover prior to handling.

We recorded the time between initial take-off and final capture (capture time) with a stopwatch. We abandoned chases when birds were not captured within 15 min because we presumed that longer chases could be detrimental to them. The capture rate was very high (92%) and demonstrated the efficiency of this method. The mean capture time in our study was less than 10 min and was comparable to helicopter pursuits of Golden Eagles (Ellis 1975). We observed no mortality during the 18–22 hr following capture. Three Steppe Eagles that were not fitted with PTTs were recaptured more than one year after their first capture using the same method. In another study an Imperial Eagle (*A. heliaca*) was similarly trapped three times in different years (Meyburg et al., unpubl. data). Although survival of birds not captured by this technique is unknown, these data suggest that capture stress did not jeopardize postrelease survival.

We measured wing length, tail length, beak length, wingspan, and weight of each bird and banded each with a National Commission for Wildlife Conservation and Development band (Riyadh, Saudi Arabia). Age was determined by referring to Clark (1996) and sex by size and weight. All captured birds received a thorough medical check by a veterinarian and were evaluated for degree of cardiovascular stress (Ostrowski et al. 2001).

Because of the dark of night following handling, birds could not be released the same day. Also, we kept birds in total isolation in a shaded aviary, even though this was stressful to them, to document any immediate postcapture mortality. For these two reasons, we released the birds at the pursuit site 18 to 22 hr after capture. During capture and handling, we followed the animal welfare guidelines of the National Commission for Wildlife Conservation and Development of Saudi Arabia.

This technique permits capture and recapture of selected individuals and has been useful for other large raptors, such as Imperial Eagle, Greater Spotted Eagle (*A. clanga*) and Lappet-faced Vulture (*Torgos tracheliotus*). Although very effective in catching wintering and migrating eagles, efficient use of this technique is limited to open desert and steppe habitats, free of obstructions.

TABLE 1. Details of 16 Steppe Eagles tracked with satellite transmitters between 1993 and 1998 in Asia, Arabia, and Africa. Northernmost and southernmost locations are provided for birds tracked during the breeding and wintering seasons, respectively. Age: juveniles are ≤1 year old; adults are ≥4 years old. Places of capture: Taif and Mecca, Saudi Arabia; Kruger National Park, South Africa.

Eagle	Age	Sex	Weight (kg)	Place of capture	Tracking dates	Tracking period (days)	Northernmost location	Southernmost location
E1	adult	M	2.45	Taif	2 Nov 1992–10 Mar 1993	129		21°35′N, 40°52′E
E2	juvenile	F	2.75	Mecca	20 Oct 1993–9 Dec 1993	47		6°31′N, 40°05′E
E3	immature			Taif	17 Mar 1993–10 Jun 1993	86	50°31′N, 52°48′E	21°24′N, 40°51′E
E4	adult	F	3.00	Taif	24 Oct 1993–30 Jun 1994	319	46°26′N, 58°12′E	18°05′N, 44°31′E
E5	adult	F	2.95	Taif	24 Oct 1993–24 Mar 1994	152	44°00′N, 53°09′E	24°07′S, 27°22′E
E6	juvenile	M	2.25	Mecca	20 Oct 1993–17 Mar 1994	133		3°33′S, 35°45′E
E7	adult	F	3.05	Taif	24 Oct 1993–15 Mar 1994	145		21°33′N, 40°46′E
E8	juvenile	M	2.45	Mecca	20 Oct 1993–26 May 1994	215		2°10′S, 34°25′E
E9	immature (2 years)	F	2.80	Mecca	20 Oct 1993–27 Oct 1994	373	50°27′N, 47°08′E	9°14′N, 25°18′E
E10	adult	F	3.30	Taif	22 Oct 1993–3 Sep 1994	361	49°18′N, 60°35′E	11°47′N, 40°36′E
E11	adult	M	2.25	Kruger	02 Jan 1995–31 Mar 1995	89	46°39′N, 55°22′E	25°03′S, 31°37′E
E12	adult	F	3.20	Taif	27 Oct 1996–11 Aug 1997	289	49°50′N, 63°16′E	21°08′N, 40°54′E
E13	immature (1.5 years)	F	3.25	Taif	23 Oct 1996–23 Apr 1997	183	46°44′N, 55°35′E	12°45′N, 44°13′E
E14	immature (3 years)	F	3.25	Taif	26 Oct 1996–8 Dec 1996	44		20°50′N, 40°46′E
E15	adult	F	3.45	Taif	27 Oct 1996–7 Mar 1997	132		21°00′N, 41°46′E
E16	adult	M	2.30	Taif	21 Oct 1997–13 Dec 1998	419	47°36′N, 58°51′E	11°38′N, 34°50′E

THE TRANSMITTERS

Eleven transmitters were battery powered; the last five transmitters fitted in 1996 and 1997 were solar powered. The weight of the transmitters, all supplied by Microwave Telemetry (Columbia, Maryland), was 50–80 g. In order to prolong battery life while adequately recording the migration route, these transmitters were programmed to emit signals for 8 hr every 2.3 days (in two cases) and every 4.3 days (in eight cases). The transmitter fitted to eagle 11 (E11) was programmed with different cycles to conform to the eagle's expected movements (8 hr every day during migration, 8 hr every 6 days during wintering and breeding). The solar-powered transmitters fitted to eagles 12–15 were programmed to emit signals for 12 hr every 5.3 days. The transmitter fitted to eagle 16 was programmed with different cycles to conform with the eagle's expected movements (to send signals continuously during migration and 8 hr every 6 days during wintering and breeding). The transmitters were fitted like backpacks using teflon ribbon to attach them to the birds just prior to release.

DATA ANALYSIS

All location data were analyzed individually and entered into databases. We used the computer program Mapit (Allison 1997) to plot Argos locations, measure distances between the locations, and trace the migration routes. This program is an integrated global mapping and digital display system which computes the great-circle distance from one point to another while dynamically displaying both great-circle and constant-compass-bearing (rhumb) lines. (Great-circle distances are the physically shortest distances on a globe.) Distances between wintering and summering areas and between segments of this were calculated as the sum of the great-circle distances between all accepted neighboring Argos locations (LC1 = 350–1000 m, LC2 = 150–350 m, and LC3 $<$ 150 m location accuracy).

RESULTS

The eagles were tracked for up to 13.7 months and for up to 17 100 km, leaving aside local movements. A total of 3734 locations was used in this study. From the 11 birds (E1–11) equipped with battery-powered transmitters we obtained 1219 locations, between 18 and 394 per eagle (mean 111 $\pm$ 108). The length of time between fixing the radio and last location ranged from 47 to 373 days with an average of 186 $\pm$ 109 days; in some instances the transmitters continued to send signals after the birds had either lost them or perished. From the five birds with solar-powered PTTs (E12–16) a total of 2510 locations was obtained (mean 502 $\pm$ 834). The time between fitting and last location was between 44 and 419 days (mean 213 $\pm$ 129 days).

Discounting one bird (E3) that was trapped in the spring and thus presumably had wintered in Arabia, seven of the 14 Steppe Eagles trapped in Arabia never left the peninsula for wintering, whilst the other seven crossed the Bab-el-Mandeb straits at the southeastern end of the Red Sea to Africa. Of these, six birds remained in eastern and northeastern Africa (Kenya, Tanzania, Chad, Sudan, and Ethiopia), thus partly wintering even north of Bab-el-Mandeb. One adult female traveled as far as southern Africa (24°07′S, 27°22′E). All eagles wintering in Africa conducted a loop migration around the Red Sea. Birds on their southward migration moved along the east coast of the Red Sea; on their return journey they traveled up the west coast of the Red Sea (Fig. 1).

Nine eagles which could be tracked to their summering areas spent the summer in Russia and Kazakhstan, just east of Lake Aral (63°16′E). Two adults, however, possibly bred in east Kazakhstan or even west Mongolia, as indicated by the direction of their northward migration until loss of contact. Only one bird (E9) migrated over the land between the Black and Caspian Seas; the others migrated between the Caspian and Aral Seas. Eagle 10 summered north of Lake Aral and performed a loop around this body of water, passing east of it on its southward migration (Fig. 1).

Figures 2 and 3, based on analysis of the data obtained from tracking 16 Steppe Eagles, our own field observations in Saudi Arabia, Kenya, Tanzania, Zambia, Botswana, Namibia, South Africa, and Israel, as well as data from other studies, show, in general terms, our conclusions regarding the routes followed by these birds on spring and autumn migration between Eurasia and Africa, excluding individuals wintering in Arabia.

DISCUSSION

Satellite telemetry transmitters require considerable energy to communicate with satellites,

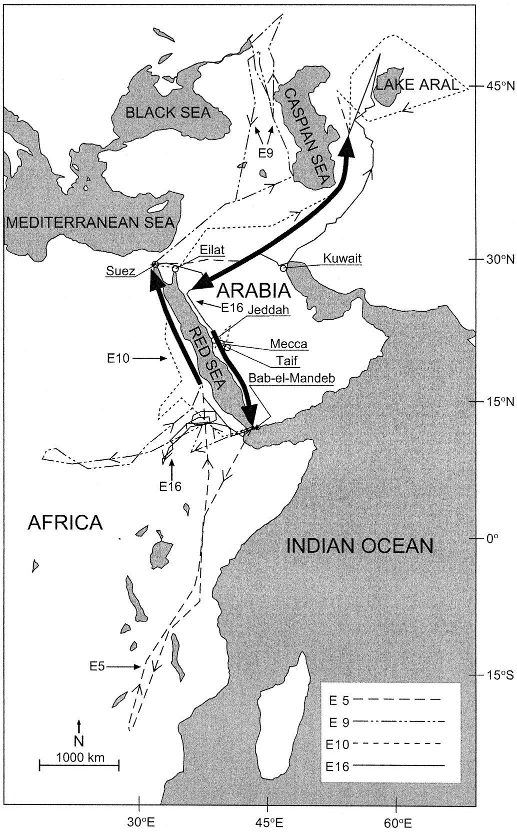

FIGURE 1. Migration routes of four Steppe Eagles (E5, 9, 10 and 16) tracked from Arabia to Africa via the straits of Bab-el-Mandeb in autumn, and back to Arabia and Asia in spring via Suez, Egypt, and Eilat, Israel. All tracked eagles using Bab-el-Mandeb to reach Africa and returning to Arabia and Asia showed this pattern of loop migration around the Red Sea.

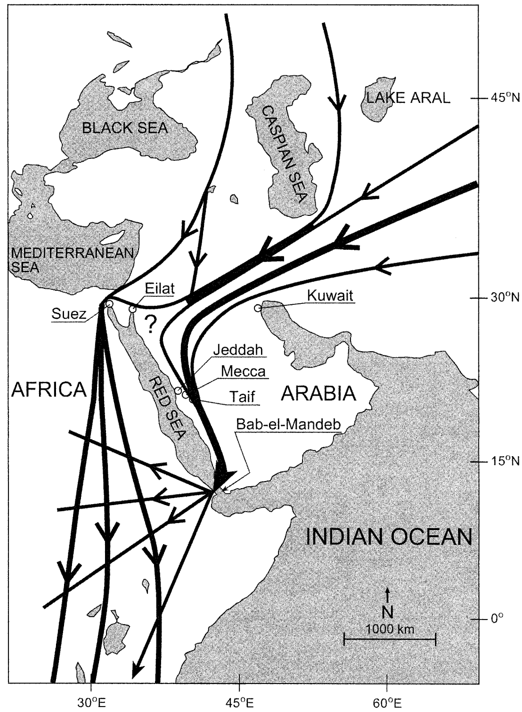

FIGURE 2. General conclusions about Steppe Eagle autumn migration routes between Eurasia and Africa, excluding individuals wintering in Arabia. Conclusions are based on our data from 16 satellite-tracked Steppe Eagles and other studies (Christensen and Sorensen 1989, Welch and Welch 1991a, Shirihai et al. 2000). It remains unclear why a considerable number of eagles make their way to Africa north of the Red Sea via Eilat and Suez (unless there is a migratory divide in the area indicated by a question mark).

and we found that lifespan of the batteries was the fundamental weakness of the system using battery-powered transmitters. The number of locations received using solar-powered transmitters was substantially higher, so that, particularly with E16, the route could be plotted far more accurately than with transmitters operating on batteries.

MIGRATION ROUTES AND ORIENTATION

One of the most interesting points to emerge from this study must surely be the loop migration, described here for the first time, taken round the Red Sea by all the birds that wintered in Africa. This should help to explain the difference in numbers between spring and autumn at such migration bottlenecks as Eilat, Suez, and Bab-el-Mandeb. Yom-Tov (1984, 1988) discussed this phenomenon at length, maintaining that following mortality in winter, especially of young birds, the number of eagles on spring migration over Eilat should essentially be smaller than in autumn. However, the opposite is the case. He further pointed out that a similar phenomenon is to be observed, not only in the case of other raptor species, in particular Steppe Buzzard (*Buteo buteo vulpinus*), Honey Buzzard (*Pernis apivorus*) and Black Kite (*Milvus migrans*), but also many small bird species.

For the Steppe Eagle population between the Aral and Caspian Seas the shortest route to their wintering grounds in Arabia and Africa runs past the southeast end of the Caspian Sea and northwest end of the Arabian Gulf. Joining these two points in a straight line and extending it, one

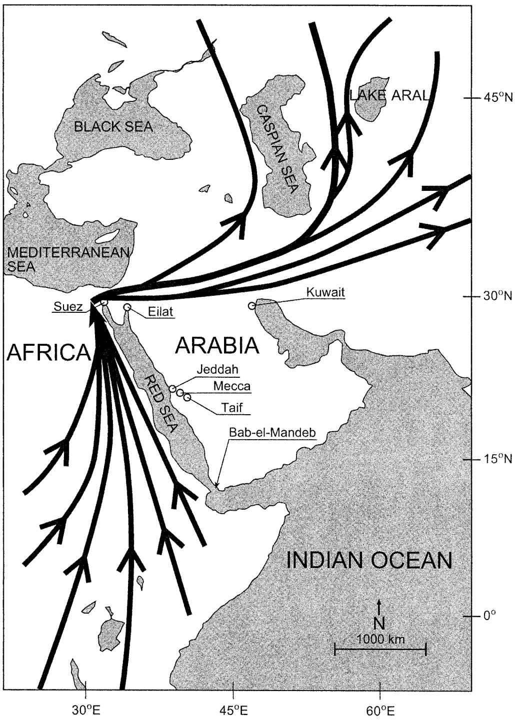

FIGURE 3. General conclusions about Steppe Eagle spring migration routes between Africa and Eurasia, excluding individuals wintering in Arabia. Conclusions are based on our data from 16 satellite-tracked Steppe Eagles and other studies (Christensen and Sorensen 1989, Welch and Welch 1991a, Shirihai et al. 2000).

ends up near Jeddah, on the Red Sea (Fig. 2). This shortest route from the Caspian Sea to the Arabian Gulf is apparently taken by many Steppe Eagles, and they do not seem to change direction very much from there on, so that they end up far too far north to accomplish the shortest route to Bab-el-Mandeb within the Arabian Peninsula. It remains unclear why a considerable number of eagles make their way to Africa north of the Red Sea via Eilat and Suez (24 246 observed near Eilat in the autumn of 1980, Shirihai et al. 2000; 64 900 observed near Suez in the autumn of 1981, Christensen and Sorensen 1989, Zalles and Bildstein 2000). Perhaps there is a migratory divide somewhere south of Eilat that serves as the deciding factor in route choice. This possibility, and the question of how the different migration routes developed, remain to be determined.

In this regard the autumn migration of E16 was particularly interesting. It was surprising that E16 reached the Red Sea only 314 km south of Eilat and then flew on southward following closely the east coast of the Red Sea. Judging from its route across Arabia one would have expected it to continue over Eilat. In view of the large number of Steppe Eagles passing over Eilat in autumn (Christensen and Sorensen 1989, Welch and Welch 1991a) other birds arriving on a similar route from the east and northeast must turn north. This would also explain the frequent arrival during autumn at Eilat of eagles on passage from the southeast (Welch and Welch 1991a). Birds migrating through Eilat in autumn need to be equipped with transmitters there and tracked for at least one year thereafter to elucidate these questions.

We suppose that for unknown reasons some birds turn northwest toward Eilat, possibly by following other birds, while others turn south at some point to arrive at Bab-el-Mandeb. Tracking Lesser Spotted Eagles (*A. pomarina*) over more than one year showed the development of migration routes of individual birds including astonishing detours of hundreds of kilometers (Meyburg et al. 2002). E16 was tracked twice following the Red Sea coast to Bab-el-Mandeb and the same wintering area in 1997 and 1998, suggesting that Steppe Eagles may adopt the same route year after year out of tradition.

For the eagles wintering in southern Africa the loop around the Red Sea involves a considerable detour (in the case of E5 this meant an extra 1250 km). For eagles wintering in the Sudan and Ethiopia (e.g., E10), the loop route does not entail a detour. Since Welch and Welch (1991b) by direct observation also found no evidence of migrating Steppe Eagles crossing Bab-el-Mandeb in spring we assume that all Steppe Eagles entering Africa via this migration bottleneck follow the loop migration around the Red Sea.

The wind blowing from the east during the cool season (October to April) helps the migrants coming from the east to cross the straits in autumn. The average wind speed is 14.5 km hr^{-1} according to the weather database for the last 14 years in the Bab-el-Mandeb area (Weatherbase 2002). This same easterly wind probably prevents them from crossing the straits again when returning to their breeding grounds in February and March, thus leading to the evolution of this migration loop.

FLIGHT OVER WATER

According to our direct observations on the Red Sea coast near Jeddah, many Steppe Eagles are obliged to roost on the shore in the evening. Many days of such observations led us first to conclude that some eagles elect to cross the Red Sea from here. We watched some individuals disappear from sight across the water. Data from satellite telemetry, however, show that on reaching this barrier Steppe Eagles change direction and follow the coastline south to the Bab-el-Mandeb Straits.

Whereas high mountains and deserts clearly present no insurmountable ecological barriers for a migrating Steppe Eagle, it, like other large users of thermals, avoids crossing large expanses of water, which can lead to considerable loss of life (Zu-Aretz and Leshem 1983, Kerlinger 1985, Spaar and Bruderer 1996). Those eagles flying to southern Arabia and continuing to Africa must, however, cross the 22-km-wide straits of Bab-el-Mandeb. Locations from all the birds we tracked showed that in nearly every case they lingered in Yemen for several days before attempting the crossing. We do not know whether they were reluctant to fly over the sea or whether (more likely) they were waiting for more favorable weather conditions.

The movements of E13 even led to the conclusion that this bird was prevented from making the crossing. It first flew in typical fashion down the Red Sea coast to the vicinity of the straits. Unfortunately the small number of locations received made it impossible to tell exactly how long the eagle stayed there. It can, however, be presumed that for some reason, perhaps due to weather conditions, E13 was deterred from crossing over to Africa. At that time the weather was predominantly bad, with heavy rain. Subsequent locations indicated that the bird spent the winter in various parts of the Arabian Peninsula until 1 April. During this time it was tracked over a total of 5537 km. In early April it left, migrating north through Kuwait and Iran.

After being equipped, E10 stayed from 24 October to 15 November relatively close to the Red Sea coast before migrating to wintering grounds in the Sudan. Its local back-and-forth movements to and from the coast and the fact that its wintering grounds were more or less on the opposite side of the Red Sea led us to presume that it was waiting for favorable weather conditions to make the crossing. Only after three weeks did it fly farther down the coast to make the detour over Bab-el-Mandeb. Similarly, E5 avoided flying over the ca. 45-km-wide Lake Malawi, thereby deviating slightly from the shortest route.

WINTER DISTRIBUTION

Brooke et al. (1972) advanced the theory on ecological grounds that adult and immature Steppe Eagles have different wintering grounds. This theory has found its way into relevant summarizing works (Brown et al. 1982, Steyn 1982, Shirihai et al. 2000), according to which adult birds overwinter in eastern Africa and young birds in southern Africa. The birds we tracked gave this idea little support as did our own field observations in Kenya, Tanzania, Zambia, Namibia, and South Africa (Meyburg et al., unpubl. data). Only relatively few individuals flew to southern Africa, and these did so independent of their age. A greater number spent the winter in East Africa. In Tanzania we observed the species in December and January, in large concentrations consisting of adults, juveniles and immature birds.

That a plainly substantial part of the population overwinters in Arabia was not previously known or has at least not been well documented. It may well be that the use of wintering grounds in Arabia by an increasing part of the Steppe Eagle population is a new development resulting from an improved supply of food. In recent years the number of herds of domestic ungulates has increased dramatically owing to substantial artificial feeding (Shobrak 1996), so that a plentiful supply of food is at hand for the eagles. At such places, where the Steppe Eagle is by far the commonest bird of prey, it is not unusual to see 50 to 100 birds together. This may have resulted in fewer birds migrating as far as eastern or southern Africa. The ecological reason for some individuals to undertake such long migrations remains obscure. The possible increase in overwintering in Arabia has perhaps contributed to the decline in the number of birds passing through Eilat in spring (Shirihai et al. 2000) during the past 10 years.

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LITERATURE CITED

ALLISON, J. B. 1997. Mapit. Version 2.0. Allison Software, Apollo, PA.

BIJLSMA, R. G. 1987. Bottleneck areas for migratory birds in the Mediterranean region: an assessment of the problems and recommendations for action. International Council for Bird Preservation, Cambridge, UK.

BRODEUR, S., R. DECARIE, D. M. BIRD, AND M. FULLER. 1996. Complete migration cycle of Golden Eagles breeding in northern Quebec. Condor 98:293–299.

BROOKE, R. K., J. H. GROBLER, M. P. S. IRWIN, AND P. STEYN. 1972. A study of the migratory eagles *Aquila nipalensis* and *A. pomarina* (Aves: Accipitridae) in southern Africa, with comparative notes on other large raptors. Occasional Papers of the National Museum of Rhodesia B5(2):61–114.

BROWN, L. H., E. K. URBAN, AND K. NEWMAN. 1982. The birds of Africa. Vol. I. Academic Press, London.

CHRISTENSEN, S., AND U. G. SORENSEN. 1989. A review of the migration and wintering of *Aquila pomarina* and *Aquila nipalensis orientalis*, p. 139–150. *In* B.-U. Meyburg and R. D. Chancellor [EDS.], Raptors in the modern world. World Working Group on Birds of Prey, Berlin.

CLARK, W. S. 1996. Ageing Steppe Eagles. Birding World 9:268–274.

ELLIS, D. H. 1975. First experiments with capturing Golden Eagles by helicopter. Bird-Banding 46: 217–219.

FULLER, M. R., W. S. SEEGAR, AND L. S. SCHUECK. 1998. Routes and travel rates of migrating Peregrine Falcons *Falco peregrinus* and Swainson's Hawks *Buteo swainsoni* in the Western Hemisphere. Journal of Avian Biology 29:433–440.

GRUBB, T. G., W. W. BOWERMAN, AND P. H. HOWEY. 1994. Tracking local and seasonal movements of wintering Bald Eagles *Haliaeetus leucocephalus* from Arizona and Michigan with satellite telemetry, p. 347–358. *In* B.-U. Meyburg and R. D. Chancellor [EDS.], Raptor conservation today. World Working Group on Birds of Prey and The Pica Press, Berlin.

KERLINGER, P. 1985. Water-crossing behaviour of raptors during migration. Wilson Bulletin 97:109–113.

MARTELL, M. S., C. J. HENNY, P. E. NYE, AND M. J. SOLENSKY. 2001. Fall migration routes, timing, and wintering sites of North American Ospreys as determined by satellite telemetry. Condor 103: 715–724.

MCGRADY, M. J., L. T. MAECHTLE, J. J. VARGAS, W. S. SEEGAR, AND M. C. PORRAS PEÑA. 2002. Migration and ranging of Peregrine Falcons wintering on the Gulf of Mexico coast, Tamaulipas, Mexico. Condor 104:39–48.

MEYBURG, B.-U. 1994. 209. Steppe Eagle *Aquila nipalensis*, p. 194. *In* J. del Hoyo, A. Elliott, and J. Sargatal [EDS.], Handbook of the birds of the World. Vol. 2. Lynx Edicions, Barcelona.

MEYBURG, B.-U., J. M. MENDELSOHN, D. H. ELLIS, D. G. SMITH, C. MEYBURG, AND A. C. KEMP. 1995. Year-round movements of a Wahlberg's Eagle *Aquila wahlbergi* tracked by satellite. Ostrich 66: 135–140.

MEYBURG, B.-U., W. SCHELLER, AND C. MEYBURG. 2000. Migration and wintering of the Lesser Spotted Eagle *Aquila pomarina*: a study by means of satellite telemetry. Global Environmental Research 4:183–198.

MEYBURG, B.-U., J. MATTHES, AND C. MEYBURG. 2002. Satellite-tracked Lesser Spotted Eagle avoids crossing water at the Gulf of Suez. British Birds 95:372–376.

MIKHELSON, K. A. 1982. Steppe Eagle, *Aquila nipalensis*, p. 92–95. *In* K. A. Mikhelson and Y. A. Viksne [EDS.], Migrations of birds of eastern Europe and northern Asia. Falconiformes-Gruiformes. ''Nauka'' Press, Moscow.

OSTROWSKI, S., E. FROMONT, AND B.-U. MEYBURG. 2001. A capture technique for wintering and migrating Steppe Eagles in south-western Saudi Arabia. Wildlife Society Bulletin 29:265–268.

SHIRIHAI, H., R. YOSEF, D. ALON, G. M. KIRWAN, AND R. SPAAR. 2000. Raptor migration in Israel and the Middle East: a summary of 30 years of field research. International Birding and Research Center, Eilat, Israel.

SHOBRAK, M. 1996. Ecology of the Lappet-faced Vulture *Torgos tracheliotus* in Saudi Arabia. Ph.D. dissertation, University of Glasgow, Glasgow, UK.

SPAAR, R., AND B. BRUDERER. 1996. Soaring migration of Steppe Eagles *Aquila nipalensis* in southern Israel: flight behaviour under various wind and thermal conditions. Journal of Avian Biology 27:289–301.

STEYN, P. 1982. Birds of prey in southern Africa. David Philip Publishers, Cape Town.

UETA, M., F. SATO, E. G. LOBKOV, AND N. MITZA. 1998. Migration route of White-tailed Sea Eagles *Haliaeetus albicilla* in northeastern Asia. Ibis 140: 684–686.

UETA, M., F. SATO, H. NAKAGAWA, AND N. MITA. 2000. Migration routes and differences of migration schedule between adult and young Steller's Sea Eagles *Haliaeetus pelagicus*. Ibis 142:35–39.

WEATHERBASE [ONLINE]. 2002. Historical weather for Djibouti. ⟨http://www.weatherbase.com⟩ (20 January 2003).

WELCH, G. R., AND H. J. WELCH. 1988. The autumn migration of raptors and other soaring birds across the Bab-el-Mandeb straits. Sandgrouse 10:26–50.

WELCH, G., AND H. WELCH 1989. Autumn migration across the Bab-el-Mandeb Straits, p. 123–126. *In* B.-U. Meyburg and R. D. Chancellor [EDS.], Raptors in the modern world. World Working Group on Birds of Prey, Berlin.

WELCH, G., AND H. WELCH. 1991a. The autumn migration of the Steppe Eagle *Aquila nipalensis*. Sandgrouse 13:24–33.

WELCH, G., AND H. WELCH. 1991b. Spring raptor observations from Djibouti. Ornithological Society of the Middle East Bulletin 26:25–27.

YOM-TOV, Y. 1984. On the difference between the spring and autumn migrations in Eilat, southern Israel. Ringing and Migration 5:141–144.

YOM-TOV, Y. 1988. Bird migration in Israel, p. 497–514. *In* Y. Yom-Tov and E. Tchernov [EDS.], The zoogeography of Israel. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

ZALLES, J. I., AND K. L. BILDSTEIN [EDS.]. 2000. Raptor watch: a global directory of raptor migration sites. BirdLife International and Hawk Mountain Sanctuary, Cambridge, UK.

ZU-ARETZ, S., AND Y. LESHEM. 1983. The sea—a trap for gliding birds. Torgos 5:16–17.