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Migration, wintering and breeding of a lesser spotted eagle (*Aquila pomarina*) from Slovakia tracked by satellite

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Abstract In northern Slovakia an adult male Lesser Spotted Eagle (*Aquila pomarina*) occupied the same nest site for 11 years running (1992–2002), where it was ringed and fitted with two satellite transmitters. In six of these years it successfully reared a young. In 1994 and 2000–2002 its behaviour during migration could be followed in detail by means of satellite telemetry. The eagle took the known route for this species to South Africa. In 2001, it spent 43% of the year at its breeding site, 33% in its winter quarters, the remaining 24% being spent on migration. In three cases the autumn migration took 40, 48 and 61 days respectively. In two cases the spring migration took 49 days. All five recorded autumn and spring migrations averaged a daily flight distance of 178 km. In spring the daily flight distance was in general slightly greater than in autumn. The longest was recorded from 30 March to 2 April 2001, between Uganda and the Red Sea, during which the bird covered a total of 1,650 km, averaging 412 km per day. In 2001, the spring migration from the wintering grounds was 2 weeks later than in 2002. The wintering grounds, where in 2 years the bird spent around 3.5 months, covering at least 1,666 and

2,269 km, respectively, comprised a large part of Zimbabwe together with the Kruger National Park in South Africa and neighbouring parts of Mozambique. The annual journeys flown, including movements around the wintering grounds, amounted in 2000–2001 to at least 20,396 km and in 2001–2002 to 19,041 km. Except during its crossing of the Sahara, the eagle must have taken food on nearly all its days of migration.

Keywords *Aquila pomarina* · migration · nest site fidelity · satellite telemetry · wintering

Introduction

Satellite telemetry (ST) has in recent years established itself as a highly effective method of investigating the migration of raptors (e.g. Grubb et al. 1994; Meyburg et al. 1995a, 1995b, 1998, 2003; Brodeur et al. 1996; Kjellen et al. 1996; Ueta et al. 1998, 2000; Martell et al. 2001) and other animal species.

The Lesser Spotted Eagle (*Aquila pomarina*) (LSE), a typical long-distance migrant, has by this means been monitored since 1992 (Meyburg et al. 1993, 1995a, 2001, 2002). Up to 1994, only battery-powered transmitters were available, so the routes on migration taken by individual birds could not be compared over several years. This first became possible with the introduction of solar-powered transmitters.

We here describe the migration and breeding behaviour of an adult male LSE from northern Slovakia, the breeding success of which could be recorded from 1992 to 2002. In parallel, its migrations and overwintering behaviour were studied by means of ST from 26 May 1994 to 17 January 1995 and from 12 July 2000 to 12 April 2002. The 1994 autumn migration route has already been briefly described by Meyburg et al. (1995a).

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Methods

T.B., O.S. and J.V. have been studying the breeding population of the LSE since 1989 in an area of 630 km² in the Spisská Magura mountains of northern Slovakia (Stara Lubovna district). Not only is the annual breeding success of ca. 50 pairs recorded, but their young, together with a number of adults, have also been ringed.

On 27 July 1992, an adult male, with a nest site observed since 1990 on Skolka hill near Luckova (49°19'N, 20°34'E) about 40 km north-east of Poprad, was trapped by the Dho-gaza method and ringed. On 26 May 1994 this male was again trapped and equipped with a battery-powered satellite transmitter (PTT) (ID No. 22692) supplied by Microwave Telemetry, USA. This transmitter provided 95 locations up to 17 January 1995. On 12 July 2000, the bird was captured for a third time, the old transmitter was removed and replaced by a solar-powered one (ID No. 23952). In addition, the bird was fitted with a colour ring. For the trapping, a live Eagle Owl (*Bubo bubo*) was used as a decoy on the first two occasions, but the eagle ignored this in further catching attempts between 1995 and 2000; the substitution of a stuffed Golden Eagle (*A. chrysaetos*) eventually led to a successful third recapture.

The eagle's return and breeding success were continuously monitored in the field and the young were ringed. This bird's nests were only a short distance apart, between 720 and 800 m above sea level, its hunting area being in the nearby meadows and fields 570 m above sea level.

The transmitters were fitted like backpacks (by B.U.M.), using teflon ribbon to attach them to the bird. All location data were analysed individually and entered into databases by B.U.M. and C.M. We used a computer program to plot Argos locations, measure distances between locations and trace the migration routes. This program is an integrated global mapping and digital display system which computes the great-circle distance between one point and 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 these were calculated as the sum of the great-circle distances between all accepted neighbouring Argos locations.

Results

Breeding success

Since it was ringed in 1992, this bird bred successfully for 6 years, rearing a young to fledging each time. If the assumption is correct, that this same male was already in occupation of this nest site in 1990 and 1991, then it had bred successfully in 8 out of 10 years (see Table 1). In 2002, the bird met its end shortly after arriving in its breeding territory; it was located for the last time on 12 April. Afterwards, the nest site was unoccupied and the male in question seen no more.

Annual time budget

The length of each of four phases of the year could be established. Clearly the longest was the time spent at the breeding site, followed by the overwintering period. For the year 2001, the annual time budget could be exactly defined. The bird spent one-third in its wintering

grounds, barely a quarter on migration and nearly half in its breeding territory (see Table 2).

Migration

Migration routes

The eagle followed a route, already known from other adult LSEs tracked by ST (Meyburg et al. 1995a, 2001), round the eastern Mediterranean as far as Suez and then in a more or less straight line to Zimbabwe and South Africa. The outward and return routes from and back to the breeding area differed relatively little as far as the northern border of Zambia. In northern Uganda, for instance, the distance between the most western and eastern routes was only 155 km. Only in Zambia did wider divergences first appear. Here the most western and eastern routes were 645 km apart.

Distances covered on migration and annual journeys

The distances covered in autumn and spring varied between 8,540 and 9,314 km. This was due only to a small extent to somewhat different routes of unequal length.

Table 1 Breeding success of a Lesser Spotted Eagle (*Aquila pomarina*)

Year	Breeding success	Remarks
1990	Yes	
1991	Yes	
1992	Yes	The offspring was shot on Zakynthos Island, Ionian Islands, Greece, on or shortly before 25 September 1992
1993	Probably no	Old nest destroyed, no new nest found and no adult carrying prey to the forest
1994	Yes	
1995	Yes	
1996	No	On 10 July, the ca. 35-day-old chick found dead below the nest without head
1997	No	Reasons for failure unknown
1998	Yes	
1999	Yes	
2000	Yes	
2001	No	On 13 June, the male carried prey to the nest, but on 6 July the nest was empty
2002	No	The pair was not observed during the nestling period

Table 2 Time budget for the year 2001

Period	Length in days	% of year
Overwintering	60	16%
Spring migration	49	13%
Stay in breeding territory	155	43%
Autumn migration	40	11%
Overwintering	61	17%

The main differences were the respective final points reached in the wintering grounds in autumn as well as the starting points in spring. As final points we regarded those at which the bird, clearly south of the equator following previous migrations, lingered a while and then proceeded no further south for a longer period.

As starting point of the return migration in spring we considered those points in the wintering area from which the bird suddenly began to migrate north after having been there for some time without moving much. The final points of the outward journey and corresponding starting point on the homeward journey lay far apart, due to the bird's large wintering area. The southernmost point lay 8,400 km distant from the breeding site.

Including the bird's movements while in its wintering grounds, the yearly overall distances flown amounted in 2000-2001 to at least 20,396 km and in 2001-2002 to at least 19,041 km.

Duration and speed of migration

The time spent and average speed during the three autumn migrations differed more widely than on the returns in spring (Table 3). Overall, the eagle flew fastest on its autumn migration in 2001. Over all five recorded autumn and spring migrations, a daily average of 178 km was flown. On the spring migration the average was slightly higher (185 km/day, both years combined) than in autumn (174 km/day, all three years combined). Figs. 1, 2, 3 illustrate distances covered each day.

The speed varied not only from one year to another, but also showed distinct differences between the various stages during both annual migrations.

Autumn migration

The course of the outward journey has already been described (Meyburg et al. 1995a). In 2001, the speed varied much less than in 2000, as also on the spring migration.

In autumn 2000, during the first 10 days to the Bosphorus (19–28 September), only ca. 100 km were covered daily. On the stretch from the Bosphorus to shortly beyond Suez (30 September to 7 October) this increased to an average of 250 km/day. While crossing the Sahara (8–12 October) to the 13th parallel in

Table 3 Duration of migration, total distances flown and average daily flight distances

Year	Length in days	Total distance covered	Average of the daily flight distances (km)
Autumn 1994	48	8,534	178
Autumn 2000	61	8,813	144
Autumn 2001	40	8,540	213.5
Spring 2001	49	9,314	190
Spring 2002	49	8,835	180

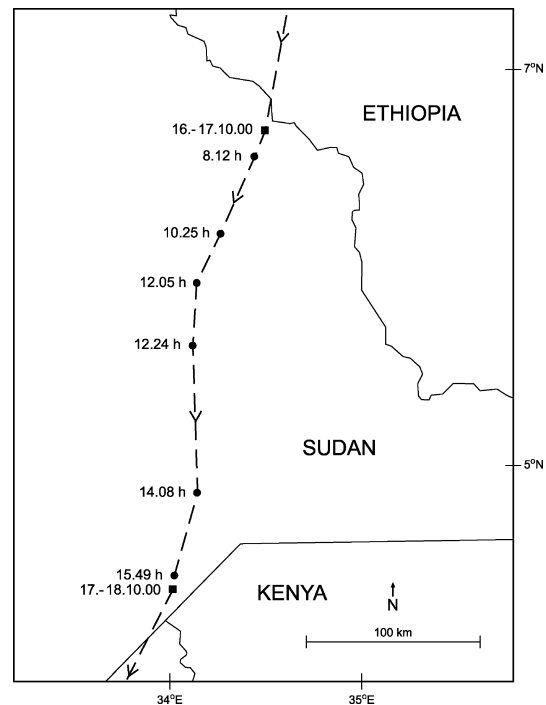


Fig. 1 Distance (268 km) covered by a Lesser Spotted Eagle (*Aquila pomarina*) on 17 October 2000 during outward migration in south-eastern Sudan, showing the overnight roosting-places (squares) and further locations (round spots). During this day the eagle flew 118 km in 2 h 3 min (1205–1408 hours GMT), giving an average of 57 km/h

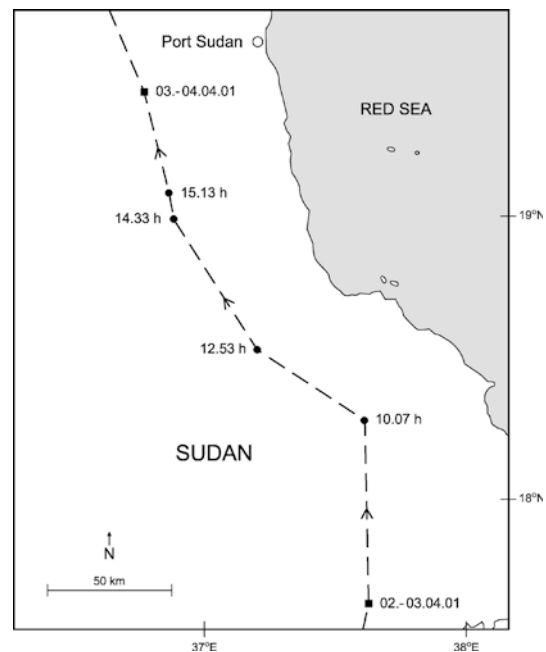


Fig. 2 Distance (235 km) covered on 3 April 2001 during return migration in eastern Sudan, showing the overnight roosting-places (squares) and further locations (round spots)

northern Sudan the mean daily distance rose to nearly 350 km/day. It seemed likely that during this stage no food was taken. In Ethiopia, southern Sudan and

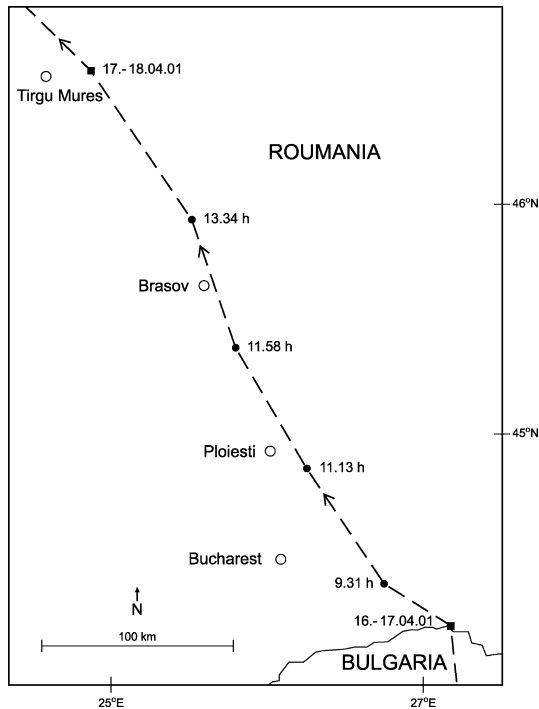


Fig. 3 Distance (327 km) covered on 17 April 2001 during return migration in Romania, showing the overnight roosting-places (*squares*) and further locations (*round spots*)

northern Uganda (13–22 October), the speed slackened to only 170 km/day.

Southern Uganda and northern Tanzania (22–26 October) were then crossed slowly, at only 60 km/day, so the bird must have spent most of the time resting. On the following 4 days (27–30 October) most of Tanzania and northern Zambia were quickly crossed (average daily stretch over 250 km). The next day, 31 October, was the only day on which no progress was recorded. From 1 to 18 November, only ca. 50 km were flown daily until arrival at the wintering grounds, so again much time was spent resting.

In autumn 2001, on the other hand, the daily distance covered remained relatively constant throughout. Apart from 25 October, when a little over 50 km were covered, the daily stretch varied between 165 and 271 km. During the first 13 days, up to 4 October and shortly before Iskanderun in southern Turkey, an average of 165 km was covered, after which between 220 and 270 km/day were maintained throughout the whole journey.

Spring migration

The daily flight distances during the spring migrations of 2001 and 2002 were quite different. In 2001, during the first half of the journey up to 29 March in northern Uganda, the speed was very modest, wavering around 100 km per day. From 11–15 March, in northern Zambia, an average of only 24 km/day was covered, with the bird resting a great deal. Also in Uganda, between 25 and 29 March, much time was spent resting

and only 70 km were flown. Thereafter the bird abruptly gathered speed: from 30 March to 2 April its highest overall progress was recorded on the stage from northern Uganda through Ethiopia and Eritrea to the Red Sea. On four successive days the bird flew over 400 km per day, in all 1,650 km. Thereafter its daily average gradually diminished until arrival at the breeding site on 19 April. Up to 12 April, however, a constant 315–365 km were covered daily.

The spring migration in 2001 from the wintering grounds was around 2–2.5 weeks late in comparison with 2002. It is unclear why the bird set out 2 weeks later from its winter quarters (on 2 March 2001 as against 19 February 2002).

Thus the eagle on 16 March 2001 was still at the northern border of Zambia, as opposed to the northern border of Eritrea on 16 March 2002, 3,270 km ahead. In 2001, it reached the Red Sea 17 days later than in 2002, and similarly for the Lebanon. It eventually crossed the Bosphorus 14 days later. Despite this late arrival at the nest site on 19 April, eggs were laid and one young hatched.

During most of the 2002 spring migration ca. 150 km were covered daily. Only in Uganda (3–9 March) did the eagle rest a great deal, covering only 50 km per day. From northern Uganda to Israel, however, some 270–350 km were covered daily (10–22 March). Then, from the Lebanon to the breeding territory, the daily average was again 150 km.

Cross-country speed

On 2 days, the exact speed could be calculated thanks to good locations in quick succession. On 8 October 2000, the eagle flew 247 km along the Red Sea at a speed of 36.5 km/h. On one segment of 184 km it reached an average of 44 km/h. On 17 October 2000, it flew 118 km in south-east Sudan in 2 h 3 min, giving an average of 57 km/h (Fig. 1).

Overwintering

The winter quarters, in which the bird spent ca. 3.5 months in each of the 2 years, encompassed parts of Zimbabwe and the Kruger National Park in South Africa and nearby Mozambique (see Fig. 4; Table 4). Both regions A and D, in which the eagle spent nearly 2 months at the end of 1994 and the whole of November 2001, were adjacent to each other (see Fig. 4; Table 4).

The winter of 2000–2001 was to begin with spent by the eagle in north-west and then in south-east Zimbabwe, where it exploited larger areas. Not until shortly before the end of the wintering period, from mid-February to early March, did it move to the Kruger National Park in South Africa, where it proceeded only as far as 23° 32'S.

In the winter of 2001–2002, however, it stayed only 1 month in Zimbabwe, up to the beginning of

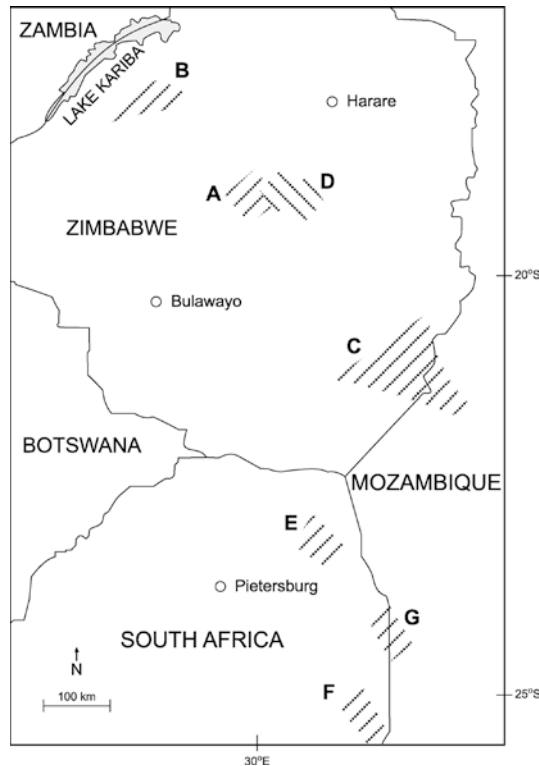


Fig. 4 Main wintering areas in southern Africa (see also Table 4)

December, followed by 2 months in the Kruger National Park and across the border into Mozambique, then finally spending the last 2 weeks back in Zimbabwe.

Altogether seven principal wintering zones were identified, covering varied extents and where the bird spent varied lengths of time (see Table 4; Fig. 4).

Within its total wintering area the eagle roamed extensively, at least 2,269 km in 2000–2001 and 1,919 km in 2001–2002. It did not reach the southernmost points until January (17 January 1994 and 14 January 2002, respectively) and February (20 February 2001), when in 2001 it only went as far south as 23°32'S, but to 25°20'S in 1994 and 2002. The southernmost point which could be recorded by sufficiently good locations lay at 25°20'27"S, 31°44'01"E in South Africa in the southern Kruger National Park.

Discussion

There have been a number of studies from different countries on the LSE's breeding success, for example from Slovakia by Švehlik and Meyburg (1979). Equally, in recent years its behaviour on migration has been investigated by means of ST (Meyburg et al. 1993, 1995a, 2001, 2002). Hitherto, however, it has not been possible to analyse both breeding success and behaviour on migration of one individual over a long space of time. With the male described here it has been possible for the first time to record its breeding over at least 10 years and at the same time document its migration routes over 2.5 years. Thereby knowledge of its life history has been gained to a degree hitherto unknown.

Nest site fidelity and longevity

It has long been presumed that the LSE has a strong site fidelity, returning each year to its old nest site. Proof of this, particularly over longer periods of time and recorded for individually marked birds, is nevertheless extremely scarce.

The LSE studied here, ringed in 1992 and fitted with a transmitter in 1994, returned regularly to its breeding site up to 2002. From 1994 onwards, it was constantly recognisable from its transmitter and from 2000 also by its colour ring. If the assumption is correct, that it occupied its nest site in 1993 and that in 1990 and 1991 it was also there, then it returned for at least 13 years to the same place. It definitely did so for 11 years.

Such incontrovertible proof, established by marking, of a LSE at its nest site is unknown to us in the literature. Assuming that this eagle first bred at the age of four, it was born at the latest in 1988, so it had reached an age of at least 15 years. As the nest site was already occupied in 1990 and 1991, and perhaps before, the bird could even have been substantially older.

Since it certainly returned in April 2002, whereas the nest was not subsequently occupied and nor was the bird observed, it is presumed that it must have perished soon after its arrival.

Table 4 Main wintering areas in Zimbabwe, South Africa and Mozambique (see also Fig. 4)

Region	Co-ordinates	Dates of stay	Situation	Home range in km ² ^a
A	19°00'S, 30°20'E	7 Nov to 31 Dec 1994	Central Zimbabwe ^b	11,730
B	17°56'S, 28°10'E	19 Nov to 26 Dec 2000	NW Zimbabwe	2,800
C	21°03'S, 31°57'E	5 Jan to 11 Feb 2001	SE Zimbabwe	22,500
D	19°02'S, 30°10'E	1–28 Jan 2001	Central Zimbabwe	1,350
E	23°13'S, 31°04'E	11–18 Jan 2001	Central Kruger NP	450
F	25°15'S, 31°39'E	25 Dec 2001 to 14 Jan 2001	Southern Kruger NP	250
G	24°22'S, 32°06'E	21–28 Jan 2002	Kruger NP and neighbouring Mozambique	200

^a Calculated by the minimum convex polygon method

^b See also Meyburg et al. 1995a

Feeding on migration and cross-country speed

Overall, the eagle clearly flew fastest crossing the Sahara. Daily stages of up to and over 400 km may lead to the assumption that the bird at this time took no food. If one accepts an apparently high average speed of 50 km/h, this would have meant 8 h/day spent on the wing, leaving in effect hardly any time to search for food. The eagle started migrating at the earliest around 0800 hours and began to roost at about 1600 hours (GMT) during days with great daily flight distances (see Figs. 1, 2, 3). During all the other stages of the migration, especially in Uganda and Zambia, the short distances covered provided ample time for hunting.

The cross-country speed calculated for this bird in two instances (44 and 57 km/h) agrees quite well with LSEs followed by a motorised glider in Israel, which migrated with an average velocity of 50.9 km/h (± 6.7) (Leshem and Yom-Tov 1996). A Short-toed Eagle (*Circaetus gallicus*), which is about the same size, migrated with speeds of 44 and 51 km/h when crossing the Sahara (Meyburg et al. 1998).

Annual journeys, duration of migration, daily flight distances and winter home ranges

For comparison of the annual routes followed on migration, the literature contains only one account of an adult male LSE from Germany (Meyburg et al. 1995a). The data are, however, far less detailed due to the much lower performance of the transmitter.

Compared to the Slovakian bird, the German male bred about 740 km further northwest and the southernmost point of its winter quarters was about 1,140 km further north in Zambia. The length of the migration was roughly similar (8,986 km for the German male as compared to 8,540–9,314 km for the Slovakian). Also, with both birds the yearly distance flown approximated to 20,000 km. The German LSE stayed somewhat longer (4 months) in its wintering grounds than the Slovakian (3.5 months), while the duration of the migration was roughly the same for both (7.5 weeks and 7–9 weeks, respectively). The Slovakian bird travelled slightly faster (178 km/day) than the German one (166 km/day). The Slovakian eagle, which in all three winters went to the Kruger National Park in South Africa and neighbouring parts of Mozambique, had several home ranges which were far from each other. The German bird confined itself to one region of Zambia, comprising ca. 25,000 km².

Feeding in the wintering grounds

It has been suggested that LSEs on their wintering grounds follow the rain fronts (Steyn 1982) in order to

find a good source of food throughout their stay. This could be confirmed in the case of two individuals overwintering in Namibia (Meyburg et al. 2001). 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 after good rain falls. For LSEs, good rains result in the appearance of food, such as termites, grasshoppers and frogs. This would probably also account for the peregrinations of the Slovakian LSE in southern Africa.

The substantially smaller areas frequented in the Kruger National Park as compared with Zimbabwe perhaps point to a better supply of food in the Park. An estimated 1,000 LSEs were observed in the Park feeding at a 16 km² nesting colony of Red-billed Quelea (*Quelea quelea*) during 18–21 February 1997 (Kemp 2001). The timing and availability of concentrated food sources (termite alates, quelea, locust) may be an important component in the migratory strategy of this raptor.

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