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First record of Eurasian Griffon Vulture *Gyps fulvus* from the Balkans migrating to South Sudan revealed by GPS tracking

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Summary

Adult Griffon Vultures *Gyps fulvus* are mostly resident but the juveniles and immatures are mostly nomadic and migratory. Significant numbers of young vultures from Eurasia migrate every autumn to the Middle East and Africa but little is known about their migration routes and wintering grounds. We tracked one juvenile Griffon Vulture on its south migration from Bulgaria to South Sudan. This is the first confirmed occurrence of the species in South Sudan. The overall travelled distance on migration was 5727 km with a migration speed of 136 km/d. In the wintering grounds in Sudan and South Sudan this bird inhabited mostly arid savannah and desert habitats up to 600 m altitude. The overall wintering home range (MCP) was 47 781 km^2.

Keywords: dispersal, satellite telemetry, wintering, home range

Introduction

The Eurasian Griffon Vulture *Gyps fulvus* is an obligate scavenger with a large range (Ferguson-Lees & Christie 2001). Its breeding distribution extends from Kazakhstan and Nepal in the east, throughout the Caucasus, southern Europe and the Iberian Peninsula to the west. The species is now considered extinct as a breeding species from Algeria, Morocco and Tunisia in North Africa but still occurs in good numbers in the Middle East, south to Saudi Arabia and Yemen (BirdLife International 2019). Spain holds more than 95 % of the European population (Del Moral 2009). On the Balkan Peninsula the species breeds in Bulgaria, Greece, Macedonia, Serbia, and Croatia (Sušić 2004, Xirouchakis & Tsiakiris 2009, Grubač 2013, Sušić & Radek 2013, Velevski *et al.* 2013, Demerdzhiev *et al.* 2014). The Griffon Vulture population in Bulgaria hs steadily increased in the past 20 years as result of intensive conservation actions and reintroduction programmes (Demerdzhiev *et al.* 2014, Stoynov *et al.* 2018).

Adult Griffon vultures are mostly resident, while the juveniles are primarily nomadic, with some are migratory, overwintering in Africa and the Middle East (del Hoyo *et al.* 2004, McGrady & Gavashelishvili 2006). There is an increasing number of records, mostly in the spring and summer, of nomadic Griffon Vultures wandering in Central and Northern Europe, e.g. Germany, Belgium, the Netherlands, Finland for example (Botha *et al.* 2017). Zuberogoitia *et al.* (2013) found that after being ringed as nestlings, the Griffon Vultures were re-sighted in the natal area only three or more years later suggesting that young vultures wandered around vast areas in the first years of their life. Donázar (1993) concluded that about 30% of the juveniles in Spain migrate. Some birds from France join the autumn migration of the Spanish vultures

and overwinter in Spain or Western Africa (Terrasse 2006). Sušić (2000) reported that in autumn 100 % of the Croatian juvenile, immature and subadult Griffon Vultures migrate south reaching Italy, Greece, Bulgaria, Israel and Chad. However, the wintering grounds of the Eurasian populations of the species are not well studied and only sporadic records could be found in the literature (Hogg *et al.* 1984, Mundy 1992, Jennings 1995, Strandberg *et al.* 2007, Henriques *et al.* 2017, Di Vittorio & Petrozzi 2018).

Here we present results of tracking a juvenile Griffon Vulture from Bulgaria to its wintering grounds in Sudan and South Sudan. We estimated the migration speed and distance travelled during its first fall migration and the size of its wintering home range.

Materials and Methods

We tracked a juvenile Griffon Vulture tagged in its nest in the Eastern Rhodopes, Bulgaria at approximately 100 days of age. The vulture was tagged in its nest located near the town of Madzharovo (41.65 N, 25.86 E). Based on a blood DNA sample, the vulture was sexed as female (BSPB unpubl. data). The following measurements were made: weight 7.1 kg, cranium length 139.2 cm, tarsometatarsus length 126.3 cm. The bird was marked with a colour wingtag, a standard metal ring, and colour plastic ring, to ease its identification after fledging. It was fitted with 70-g solar-powered GPS satellite transmitter (Microwave Telemetry www.microwavetelemetry.com). The unit was attached as a backpack with a 10-mm Teflon ribbon harness. The entire transmitter equipment, rings and wingtag did not exceed 3 % of the bird's body mass and it was unlikely to have had adverse effects on the individual's survival probability, or movement ecology (Kenward 2001). The transmitter was set to record the location of the bird every 2 h during the day and night. All data were automatically downloaded and incorporated into the Movebank database (www.movebank.org). Prior to analyses, the telemetry data were inspected and visualized in Movebank to check for outliers. Using the Movebank data filters, we removed erroneous GPS fixes (Walter *et al.* 2011).

We calculated the start and end dates of migration, the distance travelled and the migration speed based on GPS location fixes. The start of autumn migration was defined as the first day on which the bird moved over 100 km from its natal area, and the end of autumn migration was defined as the first day south of 30° N latitude when the bird started moving less than 50 km per day and remained in a confined area. Migration distance was calculated by summing the Eucledian distance between all subsequent locations during the migration period, and migration speed was the migration distance divided by the number of days spent migrating (Alerstam 2003). Stopover sites were considered to be those areas where the vulture stopped for more than 3 days during the migration.

We estimated the Griffon vulture's wintering home-range using kernel utilization distribution method with 95 % and 50 % kernel density contours (Worton 1989). We also calculated the overall foraging range as the Minimum Convex Polygon (MCP) encompassing all GPS locations (Worton 1989). For these calculations we used all the GPS fixes collected from the end of the migration until the transmitter became stationary, suggesting the death of the vulture or the removal of the unit. Home-range analyses were performed using Geospatial Modelling Environment software operating with R (Beyer 2012, R Core Team 2018). We used information on land cover types (from GlobCover 2009, http://due.esrin.esa.int/page_globcover.php) to char-

acterize the habitats within the home range of the Griffon Vulture. We combined land cover types into six discrete landscape types: cropland (composed of the GlobCover classes: 11, 14, and 20), savannah (GlobCover classes 30, 110, 130 and 180), grassland (GlobCover classes 120 and 140), sparse vegetation and desert (GlobCover classes 150 and 200), forest (GlobCover classes 40, 50, 60, 70, 90, 100, 160 and 170) and other landscapes, including all remaining GlobCover classes (190, 210, 220) (Buechley *et al.* 2018). Data were mapped and processed using QGIS software (www.qgis.org).

Results

The juvenile Griffon Vulture was tracked for 170 days in 2016 (17 July–1 December). It started the autumn migration on 19 September and arrived in the wintering grounds in Africa on 30 October. The overall distance travelled was 5727 km over 42 days, equaling 136 km per day. The longest distance travelled in a single day was 346 km on 28 October over the Sahara Desert in Sudan. The Griffon Vulture passed over four migratory bottlenecks for soaring birds: Burgas, Bulgaria (21 September), Bosphorus, Turkey (22 September), Iskenderun, Turkey (15 October) and Suez, Egypt (22 October). It stopped at two stopover sites, both in north Turkey, spending six days at each. The first stopover was in the area of Beypazari and the second was 60 km northwest of Cankiri.

The overall wintering home range, calculated as MCP was 47 781 km^2 extending from North and South Darfur states in Sudan to the Western and Eastern Bahr el Ghazal states in South Sudan, as far south as 8°80N. The 95 % kernel home range was 14 300 km^2 and the core area of the wintering home range (50 % kernel) was 2350 km^2 (Fig. 1). The Griffon Vulture primarily inhabited medium elevations between 450 and 600 m above sea level. Savannah landscape covered 52.5 % of the home range core area and 44.86 % was covered by sparse vegetation and desert. The other habitat types covered less than 3 % of the inhabited area.

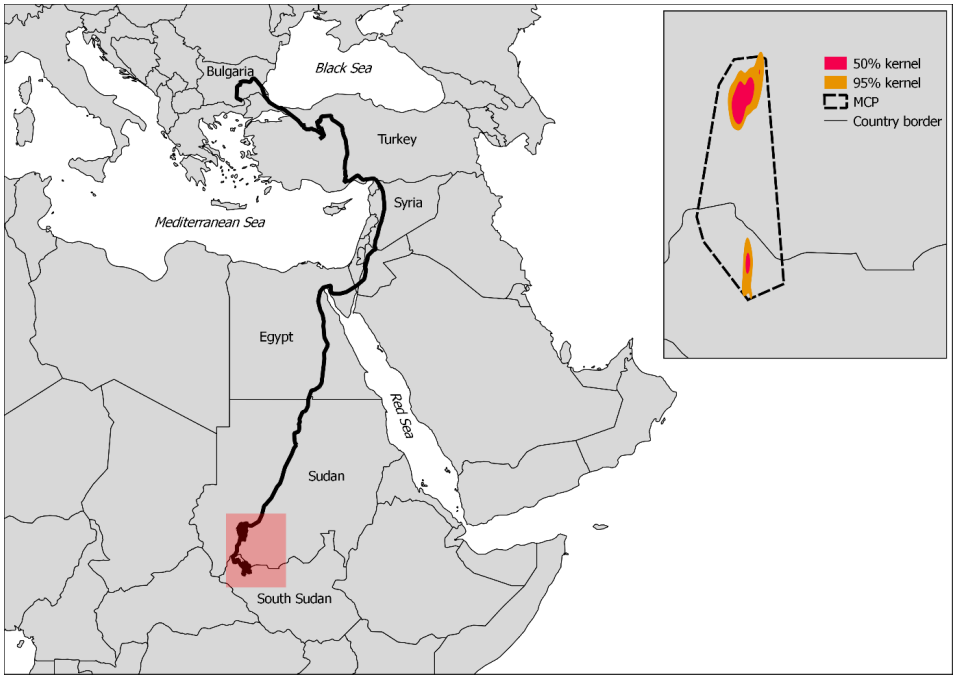

Figure 1. Map of the migration route and wintering home range of a juvenile Griffon Vulture

Discussion

This study provides the first documented record of Eurasian Griffon Vulture migrating from the Balkans to South Sudan, and it is also the first record of the species in South Sudan. There are no previous studies on the Griffon Vulture's wintering home range in Africa and our results can serve as baseline information for future studies it this field. However, it should be noted that the reported wintering home range size was estimated using data from only 32 days, and does not encompass the whole wintering season, so the estimate should be interpreted with caution. The transmitter became stationary from 1 December, but it continued sending GPS fixes, so we suspect that the bird had died or the unit had been removed.

On its southward migration, the tracked Griffon Vulture first moved north towards the Balkan Mountain in Bulgaria, then later passed over the soaring birds' migration bottleneck at Burgas, and a day later it had crossed the Bosphorus. We suppose that the majority of the migrating Griffon Vultures from the Balkans cross the Sea of Marmara either through the Bosphorus or through the Dardanelles like other raptors (Fulop *et al*. 2014, Panuccio *et al*. 2017). However, the species was not recorded during raptor migration counts at the Dardanelles in 1956 and 2010 (Nisbet & Smout 1957, Panuccio *et al*. 2017). In contrast, significant numbers were recorded at the Bosphorus during autumn migration counts—165 individuals in 1956 and 55 individuals in 2010 (Nisbet & Smout 1957, Fulop *et al*. 2014). Based on these records and our unpublished tracking data of migrating individuals (n = 5), we suggest that Griffon Vultures from the Balkans migrate mostly through the Bosphorus where the sea crossing is shortest. Observations made at Gibraltar confirm that the sea crossing takes much longer for Griffon Vultures in comparison to other soaring birds, and some vultures even fall exhausted into the sea (Mundy 1992). However, more in-depth studies need to be carried out to confirm this pattern.

Migrant Griffon Vultures, like other soaring birds, only use a few main migration bottlenecks to cross to Africa: the Strait of Gibraltar (between Spain and Morocco), the Strait of Bab-el Mandeb (between Yemen and Djibouti) and Suez (Mundy 1992). Our tracked Griffon Vulture crossed into Africa through Suez in the second half of October. The first record of migrating Griffon Vultures through Suez was in 1947 when over 3800 individuals were counted for one week in October (Goodwin 1949). In 1981, during a two-month survey, 1284 vultures were recorded and 97 % of them were classified as juveniles or immatures (Bijlsma 1983, Goodman & Meininger 1989). The number of migrating vultures through Gibraltar has been constantly increasing over the last 40 years reflecting the increase of the Iberian population (Ramirez 2017). In 1970 only 600 Griffon Vultures were recorded during the autumn migration count at Gibraltar but in 2015, on a single day, 2362 vultures were observed, and it is estimated that over 8000 migrate through the strait every autumn (Pineau & Giraud-Audine 1974, Ramirez 2017). Migration raptor counts at Bab el Mandeb suggest that the number of Griffon Vultures crossing the strait towards Africa is very low. No Griffon Vultures were recorded during migration counts in 1985, and only three individuals were observed in 1987, which was the first published record of the species in Djibouti (Welch & Welch 1988). In contrast, twelve Griffon Vultures were observed for one week of observations in northern Yemen in 1985. The same number was recorded for nine days of observations in 1987 (Porter & Christensen 1987). These records are evidence that some migrating Griffon Vultures reach Yemen but very few cross to Africa, so probably they remain in the southern parts of Yemen for the winter.

The migration speed of our tracked Griffon Vulture was significantly lower that the speed of an adult Griffon Vulture tracked from Spain to Senegal; this bird travelled 2682 km with a migration speed of 206 km/d (Munoz *et al.* 2016). Both vultures travelled their longest daily distances when crossing the Sahara. The core area of the wintering home range (50 % kernel) of our tracked vulture was five times larger than the home range of adult and subadult non-breeding Griffon Vultures in Spain (Garcia-Ripolles *et al.* 2011). These differences in the home range size could be explained by the availability of food and suitable foraging habitat, and the age of the tracked birds. However, there are no previous studies on the wintering home range size of the species and our results can be used as baseline information for future studies and comparisons. The Griffon Vulture inhabited primarily arid areas covered by savannah and desert vegetation. These areas likely hold high numbers of livestock whose carcasses provide valuable and predictable food resource (Kendal *et al.* 2014). Egyptian Vultures *Neophron percnopterus* from the Balkans which overwinter in Sahel inhabit similar habitats and take advantage of these food resources as well (Meyburg *et al.* 2004, Oppel *et al.* 2015).

The wintering grounds of the Eurasian populations of the Griffon Vulture have not been thoroughly studied. Griffon Vultures, presumably originating from the Iberian population, were recorded as winter visitors in a number of West African countries — more frequently in Mauritania and Senegal but also in Mali, Gambia, Ghana, Nigeria and Niger (Mundy 1992, Barlow *et al.* 1997, Strandberg *et al.* 2007, Caucanas *et al.* 2018). An immature Griffon Vulture was observed in a rice field in Guinea-Bissau in 2011, only the second record of the species in the country (Borrow & Demey 2004, Henriques *et al.* 2017). The first record of a Griffon Vulture from the Balkans wintering in Africa was a juvenile ringed in Croatia and re-sighted a few months later in Chad (Sušić 2000). There are few other records of the species from Central and East Africa. Two specimens were obtained in the 1920s in the Lake Chad basin (Mundy 1992). In Sudan the species was reported as "uncommon" along the Red Sea and "rare" as far south as 13° N during the Palaearctic winter, but there were no previous records in South Sudan (Hogg *et al.* 1984, Nikolaus 1989, Mundy 1992, de Bont 2009, Mallalieu 2013). Our results indicate that some Griffon Vultures may overwinter in South Sudan but due to the lack of observers these individuals have remained unreported. In Ethiopia the Griffon Vulture was considered an uncommon visitor between the Eritrean border and the West Highlands near Addis Ababa at 9° N, and it was never sighted further south in Somalia (Mundy 1992). The southernmost records of the species in Africa are from lake Langano in Ethiopia where two individuals identified as adults were observed in 1974 (Vittery 1983) and southern Kenya where one individual was observed feeding on an elephant carcass (Clark 2001). However, it should be noted that misidentifications with the rufous morph of immature Rüppell's Vultures *Gyps rueppelli* are possible (D. Forsman *in litt.*) and D. A. Turner (*in litt.*) in addition, mentioned the possibility of the occurrence of hybrids. Our record is one of the few proved records of the species further south than 9° N.

Three other Griffon Vultures tagged in Bulgaria were tracked to their wintering grounds in Israel and Saudi Arabia (BSPB unpubl. data) and one juvenile from Greece was tracked to Yemen (Tsiakiris *et al.* 2018). Furthermore, a subadult Griffon Vulture from the Caucasus, tracked with satellite transmitter overwintered in Saudi Arabia (McGrady & Gavashelishvili 2006). Presumably wintering Griffon Vultures were previously recorded in the northern parts of Saudi Arabia but the origin of these birds

remained unknown (Jennings 1995). The species is also considered a rare visitor on migration and in winter in Oman (Gallagher 1989). These records affirm that an unknown but possibly considerable number of the young Griffon Vultures from southeast Europe overwinter in vast areas in the Middle East but our results and records from raptor migration counts at migration bottlenecks suggest that some individuals continue further south to Africa.

A significant number of Griffon Vultures enter Africa every autumn through the main raptor migration bottlenecks, but little is known of their wintering areas and sojourns. Here we present tracking data from one juvenile Griffon Vulture migrating from Bulgaria to South Sudan. More studies on the Griffon Vulture's migration patterns, wintering distribution, home ranges and habitat selection in Africa are encouraged to understand their movements and and the threats they face better.

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