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Author(s): Beatriz Yáñez, Antonio-Román Muñoz, Keith L. Bildstein, Ian Newton, Albertus G. Toxopeus & Miguel Ferrer
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Individual variation in the over-summering areas of immature Short-toed Snake Eagles *Circaetus gallicus*

Beatriz YÁÑEZ[1], Antonio-Román MUÑOZ[1,2], Keith L. BILDSTEIN[3], Ian NEWTON[4], Albertus G. TOXOPEUS[5] & Miguel FERRER[6]

[1]Migres Foundation, N-340, Km. 96.2. Huerta Grande, Pelayo E-11390 Algeciras, Cádiz, SPAIN, e-mail: beatrizyv@gmail.com
[2]Department of Didactic of Mathematics, Social Sciences and Experimental Sciences, Faculty of Education Sciences, University of Malaga, E-29071, Málaga, SPAIN
[3]Acopian Center for Conservation Learning, Hawk Mountain Sanctuary, 410 Summer Valley Rd., Orwigsburg, PA 17961, USA
[4]Centre for Ecology & Hydrology, Benson Lane, Crowmarsh Gifford, Wallingford, OX10 8BB, UNITED KINGDOM
[5]Department of Natural Resources, Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, THE NETHERLANDS
[6]Department of Ethology and Biodiversity Conservation, Estación Biológica de Doñana, CSIC. C/ Américo Vespucio, s/n. E-41092 Sevilla, SPAIN

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Abstract. Satellite tracking is an invaluable tool in the study of bird movements. However, the normally small sample size it involves makes it difficult to obtain data spanning the entire range of migratory behaviour found in particular populations. We recently reported that Spanish immature Short-toed Snake Eagles leave their winter quarters in sub-Saharan Africa to occupy summering areas in northern Africa (north of the Sahara), in contrast to previously reported behaviour of a young French eagle which remained during the summer in the sub-Saharan wintering range. A more recent increase in the sample size of tracked young snake eagles further extends our knowledge of the summering behaviour of this species with one immature reaching the European range but occupying four widely-separated areas during the course of the summer. In the short-term, technology progress may provide the normal use of representative samples to increase accuracy in movement ecology studies.

Key words: delayed maturation, migration, raptor, satellite tracking, summering behaviour

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Elucidating all of the migration patterns in bird populations has sometimes proved difficult given the great variability exhibited by various species related to the age, sex, and breeding areas of the individual birds involved (Newton 2008). This information is important in increasing our knowledge about the ecology of such species and relevant to their conservation. Satellite tracking has greatly increased our understanding of bird movements in recent decades, especially for migratory species, enabling us to obtain movement-ecology data for the entire annual cycle. Birds of prey have been particularly well studied in this way (Hake et al. 2001, Thorup et al. 2006, Strandberg et al. 2010, Bohrer et al. 2012, Limiñana et al. 2012). Satellite tracking has clear advantages over other methods, but its main drawback is its cost, as a result of which almost all studies depend on small samples. Transmitter losses and failures together with the deaths of some fitted individuals further reduce the resulting data (Strandberg et al. 2009, Klaassen et al. 2010, Mellone et al. 2013). Unfortunately, the behaviour of small numbers of individuals is not always representative of their regional populations, and may reveal only a subset of the patterns that occur (Vardamis et al. 2011).

The Short-toed Snake Eagle *Circaetus gallicus* (herafter STE) is a migratory medium-sized raptor, which does not normally breed at least until the fourth calendar year (Campora & Cattaneo 2005). The distribution range of immature STE during summer, so-called summering behaviour, via the use of satellite tracking illustrates the potential impact of small sample sizes in assessing the variability in species movement ecology. Here we report how a gradual increase of the number of tagged individuals has expanded the range of known summering behaviour for this species. This study reports new information that complements the recently published notes by Mellone et al. (2011) and Jiguet et al. (2011), and describes for the first time a case of a yearling STE, marked with a satellite transmitter, spending the summer in Europe. Although the arrival of immature (second and third calendar year) STEs in the European breeding range was already reported on the basis of field observations (Garcia & Bensusan 2006, Premuda 2010, Premuda et al 2010, Pacuccio et al. 2012, Migres Foundation unpub. data), previous summering areas of yearling STEs using satellite technology had all been in the African continent, north or south of the Sahara (Mellone et al. 2011, Jiguet et al. 2011).

In 2010 three STEs nestlings were tagged with 45g Microwave Telemetry solar/GPS tracking units in the province of Cadiz, southern Spain, several days before fledging (see Pavón et al. 2010), and sexed by molecular methods. The tracking units were programmed to record one GPS position every hour from 5 to 22h GMT (one bird, #53725) and one position every two hours (two birds, #53726; #53728) from 5 to 21h GMT. To study the over-summering behaviour of these STEs, we analysed their locations above 31°N because beyond this latitude several of the tagged birds began to perform non-directional movements, indicating that migration had ended (Mellone et al. 2011). This latitude also roughly coincides with the southern limit of the breeding range of the species. We considered for analysis one position every two hours to avoid differences in the duty cycles of the transmitters. To prevent repetition of locations in roosting sites we selected locations from 9 to 17h GMT with 2 to 5 locations per bird per day. We used 50% fixed kernel density contours (KDC) (Worton 1989) to characterize summering areas with the Home Range extension for ArcGis 9.3 (Rodgers et al. 2005), using Equal Area Cylindrical transformation to estimate the sizes of over-summering areas in km^2. We calculated the centre in each of the summering areas as the harmonic mean and their ranging distance (RD) by measuring distances between this centre and locations included in each area (Mellone et al. 2011). We also used these centres to measure distances between different summering areas used by the same individual.

Two birds, #53725 (female) and #53726 (male), began migrating on 21 and 24 September, respectively, soon after leaving the nest, without performing pre-migratory movements. Both crossed to Africa via the Strait of Gibraltar, where important concentrations of the species occur during migratory periods (Bernis 1980, Muñoz et al. 2010), completed their migratory journey on 1 October, and spent the winter in Mali (#53725) and Mauritania (#53726). The third tagged eagle (#53728) was found drowned in a well just a few meters from the nest on 20 September before it could start its autumn migration.

During the summering period, a total of 365 and 330 GPS locations were obtained for birds #53725 and #53726, respectively. #53725 started northward from Mali on 24 April 2011, and stopped when it reached Northern Africa, on 8 May (see Fig. 1), taking 15 days to cover 2600 km. 50% KDC included a main area (35°40′44″N, 0°57′13″W) and a small patch centred 14 km south (see 5 and 6 Fig. 1) in Algeria (see Table 1 for more details). #53726 left Mauritania on 3 May 2011 and on 26 May crossed again the Strait of Gibraltar having reached the European breeding range for the species. After 24 days covering 2700 km, this eagle stopped its journey in central Spain, the first summering area detected by KDC analysis (40°24′37″N, 4°5′8″W, see 1 Fig. 1). Then the bird wandered more than 1000 km, with a two-day rest halfway to the smaller of the detected areas (42°17′8″N, 6°34′10″W, see 2 Fig. 1). After that, it occupied the main area (40°13′34″N, 5°39′W, see 3 Fig. 1) and finally moved south to occupy its last summering area (36°57′N, 3°23′33″W, see 4 Fig. 1), from where it started migration back to Sub-Saharan Africa (see Table 1 for more details). Both birds returned successfully to the wintering range on 20 September and 10 August respectively. #53725 took 13 days to travel 2100 km to occupy a wintering area 438 km north of that used the previous year and #53726 moved 2375 km southward to reach after 14 days the same wintering area from where it started the spring migration. The length of the summering period and the activity differed among birds, with #53725 remaining in a small area for 90 days, and #53726 displaying nomadic behaviour occupying

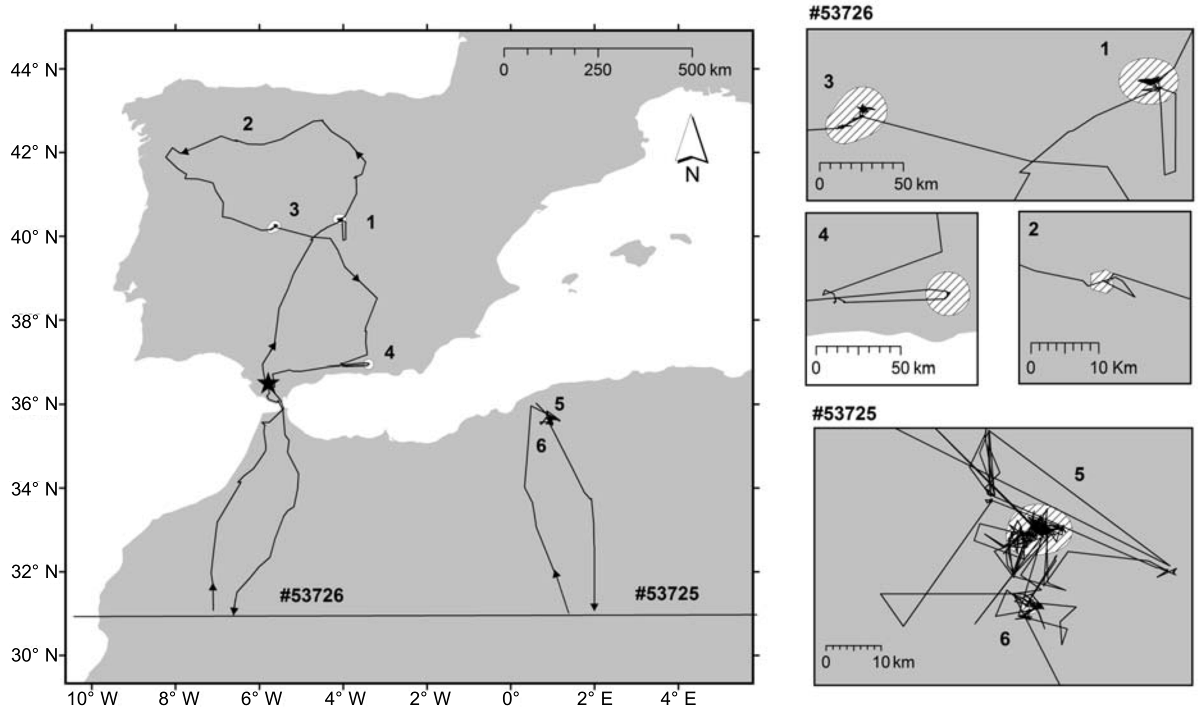

Fig. 1. Estimated summering areas of two second calendar year (non-breeding) Spanish Short-toed Snake Eagles, #53726 (male) and #53725 (female), in the Iberian Peninsula and northern Algeria, respectively, based on GPS locations. Dotted line shows Latitude 31°N (southernmost breeding range for the species) line with arrows indicates the movement of fitted STEs and arrows their direction, and the star shows the area where the eagles were hatched. Small figures on the right side detail in striped patches all six 50% Kernel Density Contours (KDC) shown in the figure on the left (see identification numbers to properly identify them).

different summering areas, during 44 days of the 99 days outside its wintering range (Fig. 1). Ranging distances between consecutive summer staging areas were around 1 km for #53725 and varied between 1 and 5.5 km for #53726 (see Table 1 for more information).

During this summering period both birds were within the breeding range for the species but made no obvious attempt to breed, as indicated by: (1) their age, they were yearling birds, but this species does not normally breed until after the fourth year, according to Campora & Cattaneo (2005); (2) their habitat, most summering areas detected in northern Africa (Mellone et al. 2011, this note) are in unfavourable areas for nesting, such as arid and deforested stony lands (Beatriz Yáñez and Antonio-Román Muñoz, pers. obs.); (3) their length of stay, due to the late arrivals of immatures and also, in some cases, early departures to wintering sites compared with breeding birds which are recorded arriving in breeding areas from the end of February (Migres Foundation unpub. data) and leaving from mid September (Meyburg et al. 1998, Migres Foundation unpub. data); (4) behaviour, breeding

Table 1. Details of summering areas in second calendar year Spanish Short-toed Snake Eagles detected by 50% Kernel Density Contours (KDC). RD — Ranging distance, Distance — the separation between consecutive used summering staging areas.

ID	Sex	Nº areas	site	Period (days)	size (km^2)	RD km (SD)	Distance (km)
#53726	M	4	1	30 May–14 June (15)	603.5	5.3 (1.5)	
			2	17 June–19 June (2)	7.0	1.7 (1.13)	295.9
			3	24 June–11 July (17)	601.9	5.5 (3.1)	243.8
			4	17 July–27 July (10)	424.6	1 (1.7)	413.5
#53725	F	2	5	31 May–20 August (81)	72.9	2.2 (1.3)	
			6	21 August–7 September (16)	7.5	0.8 (0.3)	13.7

requires that birds remain in fixed localities (Newton 2008) and in general, immatures used different roosting sites and sometimes several staging areas. Of course it is difficult to distinguish if the last two possibilities are causes for the lack of breeding or merely effects.

The bird summering in the Iberian Peninsula moved large distances and occupied four areas, which were quite distant from each other, while the eagle summering in northern Africa used two small areas, close together. These differences could be due to different food availability in the two areas, being higher in northern Africa (Cox et al. 2006). In the case of the bird that crossed to Europe, it could have been repeatedly expelled by breeding birds. This may not have held for those birds occupying areas of northern Africa where the species breeds in low densities.

The first data provided by satellite tracking on the summering behaviour of immature STEs (n = 1) (Cavallin et al. 2007) supported the hypothesis that individuals remained in the African wintering range during their first year. Delayed return migration sensu Bildstein (2006) occurs in several other raptors that exhibit delayed maturation, including Osprey *Pandion haliaetus* (Hake et al. 2001), Egyptian Vulture *Neophron percnopterus* (Meyburg et al. 2004), and Western Honey Buzzard *Pernis apivorus* (Panuccio & Agostini 2006). The relatively small sample size of tracked STEs (Mellone et al. 2011 and this note; in total n = 8) indicates considerable diversity in the migratory and over-summering behaviour of immature STEs. This is in line with behaviour described by Newton (2008) for delayed-maturation species in which some young remain in wintering areas and delay their initial return migration, whereas others migrate part of the way back to the species breeding area, and still others return to breeding areas but stay for a shorter time than breeding adults as in the one STE (#53726) described in this note. Summering strategies in immature STEs are therefore more diverse than previously assumed. Their behaviour may vary with the nutritional state of the individual (Newton 2008), in turn depending on food availability (Morrison et al. 2008, Mihoub et al. 2010, Buij et al. 2012), foraging experience (Gorney & Yom-Tov 2008), and/or carry-over effects from earlier in the life cycle (Yosef et al. 2002, 2003, Grande et al. 2009, Strandberg et al. 2010).

In juvenile STEs three studies were needed to describe the current known range of summering strategies in this species, all involving small samples. As these birds were from different parts of the breeding range (France and Spain), and were tracked in different years, further studies are needed to show whether all three forms of behaviour (deferred return, graded return or complete return) occur among birds from the same limited breeding or wintering localities, and to understand their significance in terms of risks, costs and survival. The existence of different migratory strategies among different geographical areas, and also between different birds within the same area, may have important implications in the regulation and viability of populations. Other developing methods such as integrated transponders (PIT) (Smith & Nebel 2013) or GPS-GSM telemetry (Duerr et al. 2012), eventually may offer ways to increase sample sizes more economically. In the meantime, care should be taken in generalising from the behaviour recorded in small samples of individuals.

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STRESZCZENIE

[Zmienność osobnicza w geograficznej lokalizacji terenów użytkowanych w okresie letnim przez niedojrzałe płciowo gadożery]
Pierwsze dane dla młodych, niedojrzałych płciowo gadożerów sugerowały, że spędzają one okres lata na terenach zimowisk w subsaharyjskiej Afryce. Nowsze dane pokazywały, że mogą one opuszczać zimowiska i okres wiosny i lata spędzać w północnej Afryce ponownie wracając jesienią na tereny zimowisk.

W pracy prezentowane są dane dla dwóch osobników pochodzących z Hiszpanii, które po okresie zimy wróciły na szeroko rozumiane tereny lęgowisk tego gatunku, wyznaczone w pracy przez 31 równoleżnik (Fig. 1). Młoda samica odleciała jesienią do Mali, a następnie na okres lata (3 miesiące) powróciła na północ — do Algierii. Młody samiec po spędzeniu zimy w Mauretanii wrócił do Europy przemieszczając się po półwyspie Iberyjskim, zatrzymując się na dłużej na czterech terenach (Tab. 1, Fig. 1). Jesienią oba ptaki wróciły ponownie na tereny zimowisk tego gatunku. Zwiększenie liczby ptaków śledzonych przy pomocy telemetrii satelitarnej, wskazuje, że strategie migracyjne tego i innych gatunków są bardziej złożone niż wydawało się do tej pory.