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SHORT REPORT

Migration routes and wintering areas of Booted Eagles *Aquila pennata* breeding in Spain

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Capsule Five Booted Eagles breeding in Spain were tracked by GPS during migration. Autumn routes were generally more eastern than spring routes, showing a typical loop migration. Birds covered on average ca. 200 km/day, and only one individual used a long-term stopover site (for up to 4 weeks). All but one used a single wintering area, located in Sub-Saharan Africa, at 2800–3500 km from their nests. Eagles were forced to stop migration at the Strait of Gibraltar for up to 6 days.

The Booted Eagle (*Aquila pennata*) is a summer resident in Southern Europe. Although some individuals winter in the Mediterranean basin (Martínez & Sánchez-Zapata 1999, Baghino *et al.* 2007), the majority of the population migrates to tropical Africa through the Strait of Gibraltar and the Bosphorus (Cramp & Simmons 1980). Migration routes remain poorly known, with only one study based on one individual tracked by satellite telemetry published to date (Chevallier *et al.* 2010). Therefore, our current knowledge on the location of wintering areas is rather limited and based on field observations (Thiollay 2006). Here, we describe the migration routes and wintering grounds of Booted Eagles breeding in Spain by means of remote GPS tracking, using both satellite transmitters and data-loggers.

During July 2011, five breeding adult Booted Eagles (two males and three females) were captured at several locations in Spain (Ávila, Madrid and Castellón) using a dho-gaza net placed close to their active nests (with chicks in the last period of development) and a live Eagle Owl (*Bubo bubo*) used as decoy. Four birds were equipped with Microwave Telemetry Inc. Argos/GPS solar satellite transmitters, and one with a Telemetry Solutions Quantum 4000 Enhanced GPS data-logger. All devices weighted 22 g and were attached as backpacks using a Teflon harness (Garcelon 1985). All birds successfully finished the breeding season after tagging. Transmitters were programmed to collect GPS locations on an hourly basis from 06:00 to 20:00 (GMT) during migrations, while the data-logger collected information in the same time window but every 2 hours. Data from satellite transmitters were retrieved through the Argos system and those collected with the data-logger by recapturing the bird in July 2012.

Daily distance was calculated as the distance covered (straight line) between consecutive roosting sites during migration (Mellone *et al.* 2012). No case of nocturnal migration was recorded. Days with daily distance < 50 km and days with direction opposite to the general migration direction were named 'non-travelling days' and were not used to compute average daily distances. All tracks were visually inspected in order to check when and where non-travelling days occurred and whether they were indicative of stopover or aberrant behaviour (*sensu* Strandberg *et al.* 2010).

The median departure date during autumn was 18 September, while the median arrival was 10 October. Birds spent on average 25 days to complete their journey (range: 13–50). During spring, median dates were 16 March (departure) and 7 April (arrival), with, on average, 29 days spent on migration (range 18–42). Eagles' routes were concentrated at the Strait of Gibraltar and spring tracks generally diverted more westerly than

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autumn ones as observed in four out of five tracked birds (Fig. 1). Average daily distances were 210.7 km (sd =± 30.4; $n = 5$) during autumn, and 191.7 (sd =± 43.1; $n = 5$) during spring, with a maximum value of 449 km (bird #68456 during spring). Only one individual (#91724211 on Fig. 1) used a clear stopover area located at roughly 250 km south of the Strait of Gibraltar, which was heavily used during both migrations (28 days during

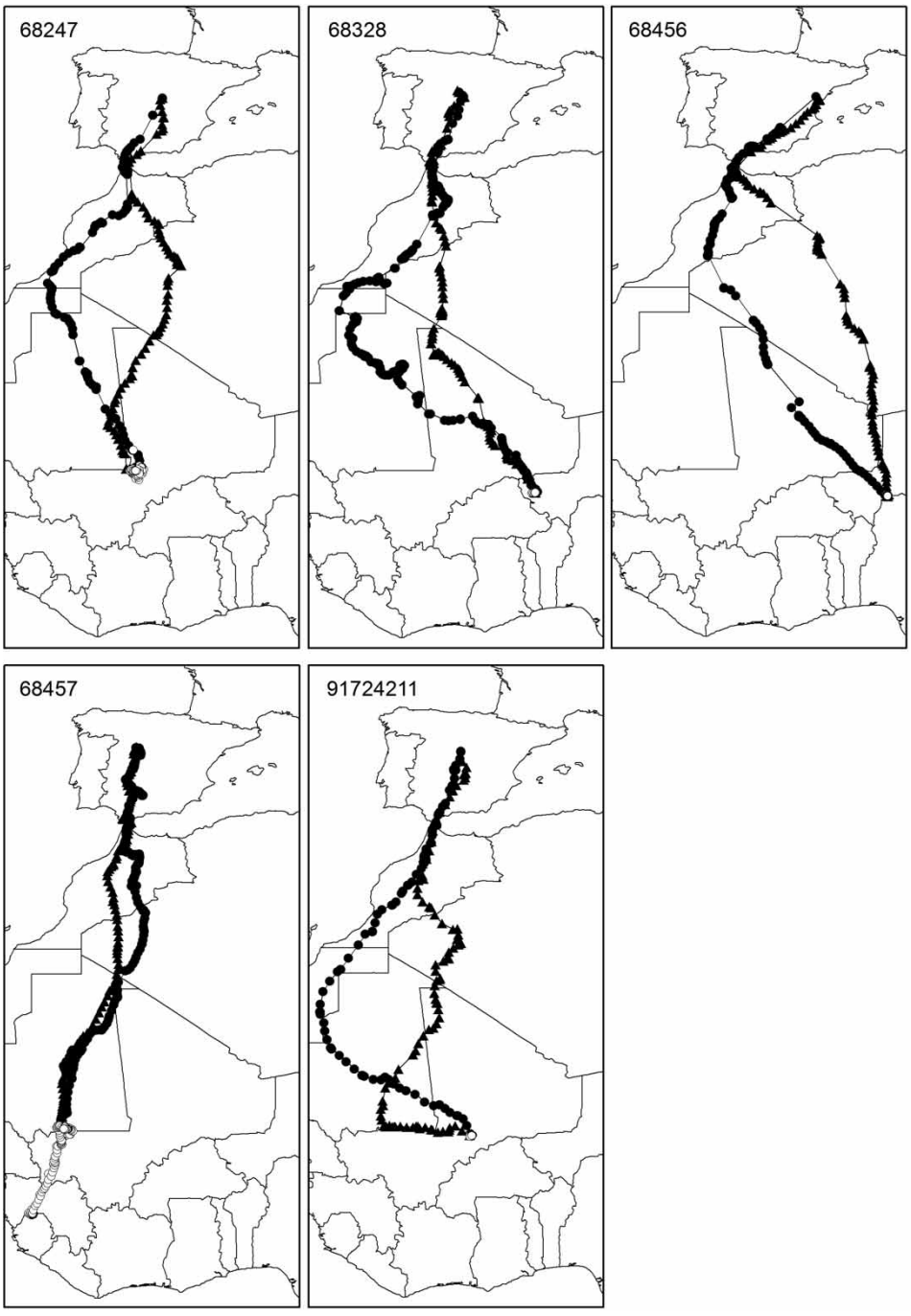

Figure 1. Routes followed by five Booted Eagles during autumn (triangles) and spring (circles) migration. White circles show winter locations. The upper left number indicates transmitter's number. Each symbol on the figure represents an hourly location during daytime (except #91724211 where data were collected every 2 hours).

autumn and 17 during spring). Of the non-travelling days of the other four individuals, 18 of 50 days occurred in the Strait of Gibraltar area, in particular during spring, on average, 33.3% (sd =± 45.6; $n = 4$), and during autumn, 53.3% (sd =± 50.3; $n = 4$) of non-travelling days were spent there. Overall, birds stopped in the Strait of Gibraltar area on average 2.4 days (sd =± 3.3; $n = 5$) during autumn and 1.4 days (sd =± 1.5; $n = 5$) during spring, showing conflicting behaviour such as aborted sea crossings and retreat flights (Fig. 2). Other non-travelling days mostly occurred in the desert with, for example, bird (#68457) flying for 2 days southwards for more than 200 km during spring. In addition, nine non-travelling days took place in Spain during spring. All but one bird used a single wintering area, located in a narrow latitudinal band (13.5–15.5°N) about 1500 km wide at 2800–3000 km from the nests. Only bird #68457 used two distinct areas: one at 15.5°N and the other one at about 670 km southwards, at 9.9°N (3500 km from the nest; Fig. 1), between 10 December 2011 and 6 March 2012.

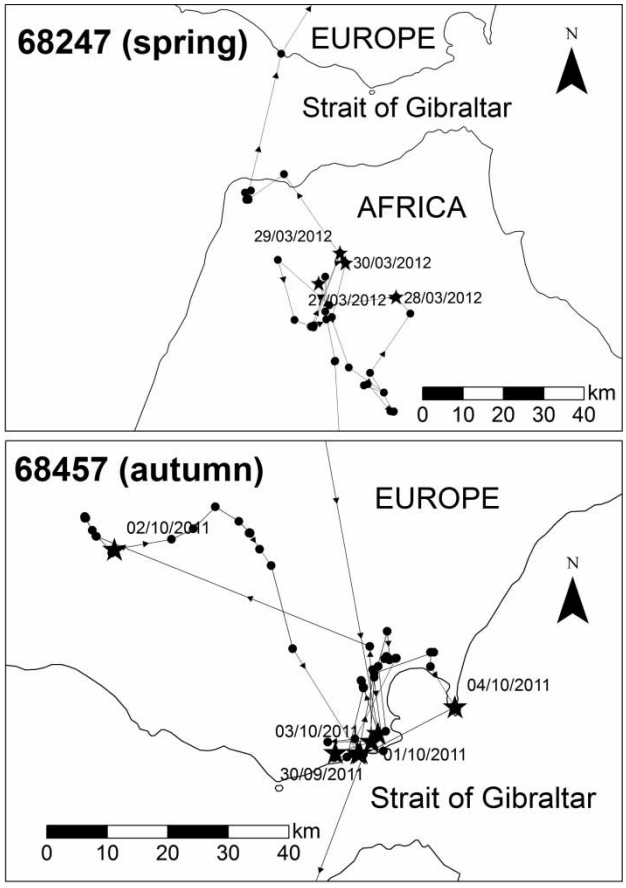

Figure 2. Two representative tracks of Booted Eagles approaching the Strait of Gibraltar in spring (27–31 March 2012; top) and autumn (28 September–4 October 2011; bottom). The upper left number indicates the satellite transmitter number. Each circle on the figure represents an hourly location, with stars indicating those collected at midday and the arrows the flight direction.

The observed loop migration could be probably due to wind drift (Klaassen *et al.* 2010, 2011), in agreement with the results obtained for other raptor species migrating across the same region (Klaassen *et al.* 2010, García-Ripollés *et al.* 2010, Limiñana *et al.* 2012a, 2012b). Average daily distances are also similar to those of other soaring birds using the same routes (Mellone *et al.* 2012). We found that at least one of the five individuals stopped during migration for a long period. This bird showed long stopovers in the same area during both migration seasons, possibly taking advantage of previous knowledge of optimal foraging grounds (Alerstam *et al.* 2006). Despite the low sample size, the results may suggest a stopover strategy in North Morocco for the species, highlighting again the possible importance of the belt between the Sahara and the Mediterranean Sea for European raptors such as immature Short-toed Eagles during the summer (Mellone *et al.* 2011b) and Lesser Kestrels stopping-over during spring migration (Limiñana *et al.* 2012a)

Soaring migrants frequently show a complex start–stop behaviour (i.e. beginning and aborting the crossing) when facing a sea crossing, due to the high costs of flight over water and associated mortality risk (Kerlinger 1989). This behaviour has been investigated by means of visual observations (Premuda *et al.* 2004, Agostini 2005) and radar tracking (Meyer *et al.* 2000), but satellite tracking studies are quite scarce (see Meyburg *et al.* 2002, 2003). Such costs force some species to do large detours to avoid long sea crossings, such as that reported for Short-toed Eagles flying around the Mediterranean Sea (Agostini *et al.* 2002, Mellone *et al.* 2011a, Panuccio *et al.* 2012). As shown in our study, even a small barrier like the Strait of Gibraltar (only 14 km; Fig. 2) can affect the whole migration duration. In this area strong crosswinds prevail, often for several days, sometimes associated with heavy rainfall. Therefore, soaring migrants are obliged to stop and wait for better soaring conditions (Bernis 1980; Muñoz *et al.* 2010), probably even without taking advantage of this obligated stopover for feeding and fuel deposition. The longest stopping episodes (6 days) occurred during continuous periods of easterly wind averaging 25 km/h (as reported by Gibraltar weather station; wunderground.com 2013). It is likely that non-travelling days occurring in the desert were also caused by bad weather conditions (e.g. Strandberg *et al.* 2010), but that the bird showing the

prolonged stopover (#91724211) must have been foraging. It is not possible to confirm that the 9 non-travelling days recorded in Spain were also used for foraging.

Booted Eagles' wintering grounds were located slightly south of those of other raptor species wintering in the Sahel (García-Ripollés *et al*. 2010, Mellone *et al*. 2011a, Limiñana *et al*. 2012a, 2012b). Bird #68457 used two wintering areas, with the main one located in the tropical rainforest, between Guinea and Sierra Leone. The individual tracked by Chevallier *et al*. (2010) also used two different areas during each winter. According to Thiollay (2006), while the Short-toed Eagle is found almost exclusively in the Northern part of the Sahel, the Booted Eagle is widely distributed between 11° and 20°N in West Africa. More data are needed to achieve a better understanding of the effects of conditions experienced, and the requirements for the species, during migration and wintering.

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REFERENCES

Agostini, N. 2005. Are earlier estimates of Accipitriformes crossing the Channel of Sicily (central Mediterranean) during spring migration accurate? *J. Raptor Res* **39:** 184–186.

Agostini, N., Baghino, L., Coleiro, C., Corbi, F. & Premuda, G. 2002. Circuitous autumn migration in the Short-toed Eagle (*Circaetus gallicus*). *J. Raptor Res* **36:** 111–114.

Alerstam, T., Hake, M. & Kjellén, N. 2006. Temporal and spatial patterns of repeated migratory journeys by ospreys. *Anim. Behav* **71:** 555–566.

Baghino, L., Premuda, G., Gustin, M., Corso, A., Mellone, U. & Cardelli, C. 2007. Exceptional wintering and spring migration of the Booted Eagle *Hieraaetus pennatus* in Italy in 2004 and 2005. *Avocetta* **31:** 47–52.

Bernis, F. 1980. *La migración de aves por el estrecho de Gibraltar. Vol. 1. Aves planeadoras*. Universidad Complutense, Madrid, España.

Chevallier, D., Jiguet, F., Nore, T., Baillon, F. & Cavallin, P. 2010. Satellite tracking of a Booted Eagle (*Aquila pennata*) during migration. *Ring. Migr* **25:** 62–64.

Cramp, S. & Simmons, K.E.L. 1980. *The Birds of the Western Palaearctic*. Oxford University Press, Oxford.

Garcelon, D.K. 1985. *Mounting Backpack Telemetry Packages on Bald Eagles*. Institute for Wildlife Studies, Arcata, CA.

García-Ripollés, C., López-López, P. & Urios, V. 2010. First description of migration and wintering of adult Egyptian Vultures *Neophron percnopterus* tracked by GPS satellite telemetry. *Bird Study* **57:** 261–265.

Kerlinger, P. 1989. *Flight Strategies of Migrating Hawks*. The University of Chicago Press, Chicago, IL.

Klaassen, R.H.G., Strandberg, R., Hake, M., Olofsson, P., Tottrup, A.P. & Alerstam, T. 2010. Loop migration in adult Marsh Harriers *Circus aeruginosus* as revealed by satellite telemetry. *J. Avian Biol* **41:** 200–207.

Klaassen, R.H.G., Hake, M., Strandberg, R. & Alerstam, T. 2011. Geographical and temporal flexibility in the response to crosswinds by migrating raptors. *Proc. R. Soc. Lond. B* **278:** 1339–1346.

Limiñana, R., Romero, M., Mellone, U. & Urios, V. 2012a. Mapping the migratory routes and wintering areas of Lesser Kestrels *Falco naumanni*: new insights from satellite telemetry. *Ibis* **154:** 389–399.

Limiñana, R., Soutullo, A., Urios, V. & Reig-Ferrer, A. 2012b. Migration and wintering areas of adult Montagu's Harriers (*Circus pygargus*) breeding in Spain. *J. Ornithol* **153:** 85–93.

Martinez, J.E. & Sanchez-Zapata, J.A. 1999. Invernada de aguililla calzada (*Hieraaetus pennatus*) y culebrera europea (*Circaetus gallicus*) en España. *Ardeola* **46:** 93–96.

Mellone, U., Klaassen, R.H.G., García-Ripollés, C., Limiñana, R., López-López, P., Pavón, D., Strandberg, R., Urios, V., Vardakis, M. & Alerstam, T. 2012. Interspecific comparison of the performance of soaring migrants in relation to morphology, meteorological conditions and migration strategies. *PLoS ONE* **7(7)**: e39833.

Mellone, U., Limiñana, R., Mallìa, E. & Urios, V. 2011a. Extremely detoured migration in an inexperienced bird: interplay of transport costs and social interactions. *J. Avian Biol* **42:** 468–472.

Mellone, U., Yáñez, B., Limiñana, R., Muñoz, A.R., Pavón, D., González, J.M., Urios, V. & Ferrer, M. 2011b. Summer staging areas of non-breeding Short-toed Snake Eagles. *Bird Study* **58:** 516–521.

Meyburg, B.-U., Matthes, J. & Meyburg, C. 2002. Satellite-tracked Lesser Spotted Eagle avoids crossing water at the Gulf of Suez. *Br. Birds* **95:** 372–376.

Meyburg, B.-U., Paillat, P. & Meyburg, C. 2003. Migration routes of Steppe Eagles between Asia and Africa: a study by means of satellite telemetry. *Condor* **105:** 219–227.

Meyer, K.S., Spaar, R. & Bruderer, B. 2000. To cross the sea or to follow the coast? Flight directions and behaviour of migrating raptors approaching the Mediterranean Sea in autumn. *Behaviour* **137:** 379–399.

Muñoz, A.R., Toxopeus, B., Elorriaga, J., Gonzalez, J.M. & Yáñez, B. 2010. First record of a communal roost of Short-toed Eagles *Circaetus gallicus*. *Ibis* **152:** 173–175.

Panuccio, M., Agostini, N. & Premuda, G. 2012. Ecological barriers promote risk minimization and social learning in migrating Short-toed Snake Eagles. *Ethol. Ecol. Evol* **24:** 74–80.

Premuda, G., Mellone, U. & Cocchi, L. 2004. Osservazioni sulla modalità della migrazione primaverile dei rapaci a Capo d'Otranto. *Avocetta* **28:** 33–36.

Strandberg, R., Klaassen, R.H.G., Hake, M. & Alerstam, T. 2010. How hazardous is the Sahara Desert crossing for migratory birds? Indications from satellite tracking of raptors. *Biol. Lett* **6:** 297–300.

Thiollay, J.M. 2006. The decline of raptors in West Africa: long-term assessment and the role of protected areas. *Ibis* **148:** 240–254.

Wunderground.com, 2013. http://www.wunderground.com, accessed 6 February 2013.

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