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Loop migration of adult European Honey Buzzards (*Pernis apivorus* Linnaeus, 1758) through the Central-Eastern Mediterranean

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Abstract
This study provides the first systematic survey of spring and autumn migration of adult European Honey Buzzards (*Pernis apivorus*) along the Central-Eastern Mediterranean flyway. Observations were done in 2007 and 2008 over the island of Antikythira (southern Greece), located 33 km NW of Crete. A total of 135 birds were counted during spring, 101 in 2007 and 34 in 2008. During post-reproductive movements, the passage of 2479 individuals was reported, 1131 in 2007 and 1348 in 2008. During both years an evident peak during the last ten-days of August occurred. These results clearly show differential spring and autumn migration of adult European Honey Buzzards through this region. Historical data concerning prevailing winds were used to reconstruct general wind patterns in the Central-Eastern Mediterranean region. It showed north-northwesterly winds between southern Greece and Libya during both spring and autumn, but very weak (<10 km/h) during the first period. We discuss two hypotheses to explain why the spring visible migration was so scarce: 1) a narrow migratory loop, with the European Honey Buzzards using a direct path between Libya and Peloponnesus during spring, bypassing Antikythira, and 2) a loop migration on a greater scale, involving a detour via the Bosphorus/Dardanelles' Strait and/or the Central Mediterranean, that would allow the European Honey Buzzards to minimise the water crossing but increasing the overall migration distance. In the light of previous studies on this species, the first hypothesis seems to be much more reliable than the second one.

Keywords: *European Honey Buzzard,* Pernis apivorus*, loop migration, geography, wind*

Introduction

The European Honey Buzzard (*Pernis apivorus* Linnaeus, 1758) breeds in Europe and winters in west-central equatorial Africa (Cramp & Simmons 1980; Hake et al. 2003). During migration, adult birds of this species use mostly soaring flight over land compensating the drift effect of crosswinds (Thorup et al. 2003; Panuccio et al. 2010). As a result they concentrate the passage at the main bottleneck areas of the Mediterranean Sea: the Strait of Gibraltar, the Bosphorus and the Channel of Sicily (Bildstein 2006). Thermals are almost absent over the open sea and thus these birds are reluctant to undertake long sea crossings to limit powered flight and to reduce energetic costs (Kerlinger 1989). Sometimes they have been observed to use, rarely successfully, soaring flight over the sea when passing close to the coastline, probably flying in thermals deviated over water by the wind or exploiting lee waves (Agostini et al. 2000, 2007). In addition, they do not use thermals, which precede frontal systems to cross the Mediterranean (Thake 1977; Agostini et al. 2000, 2005a,b, 2007). However, unlike at the Strait of Gibraltar or the Bosphorus, in the Central Mediterranean region adult European Honey Buzzards undertake long sea crossings sometimes flying hundreds of kilometres over water and showing curvilinear flyways using small islands to interrupt non-stop powered flights (Agostini & Panuccio 2005). Due to the scarcity of thermals, they

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tend to fly very low when migrating over these bodies of open water (Agostini et al. 2000). This allows for an accurate survey of the migration by direct visual observation when they reach small islands low to the ground. During the sea crossing several factors such as prevailing winds, geography and navigational abilities, interact shaping their paths (Agostini et al. 2005b, 2007; Panuccio 2011). Moreover, a larger number of adults use the Central Mediterranean flyway during spring compared to the autumn migration period (ca. 25,000 vs 5000; Agostini & Panuccio 2005). Recent preliminary observations made over Antikythira (southern Greece), a small island along the Central-Eastern Mediterranean flyway, reported the passage of European Honey Buzzards during both spring and autumn migration (Kominos unpublished data). In this Mediterranean area raptors have to fly hundreds of kilometres over water between Greece and Libya and, as in the Central Mediterranean, they can use small islands to interrupt the non-stop powered flight. The aim of this study was to investigate spring and autumn migration of adult European Honey Buzzards using data collected at Antikythira during systematic observations in 2007 and 2008.

Dominant wind patterns seem to play an important role in the evolution of migratory paths such as of narrow migratory loops (Kerlinger 1989; Newton 2008; Klaassen et al. 2010). In particular, the importance of weather conditions for birds during the crossing of large stretches of sea has been shown in several species (Gill et al. 2009; Saino et al. 2010; Mellone et al. 2011). It has been already shown that prevailing winds significantly affect pathways of adult European Honey Buzzards when migrating over water (Agostini et al. 2005b, 2007). In this framework, we analysed historical data concerning the direction and strength of the wind in the Central-Eastern Mediterranean region to reconstruct general wind patterns (see also Klaassen et al. 2010).

Materials and methods

Study area and methods

Antikythira (35° 52' N; 23° 18' E) is a small island (20 km^2; max. altitude 378 m), oriented in a NW-SE direction, located 32 km SE of the island of Kythira and 33 km NW of Crete, which in turn is located approximately 300 km NE of the Cyrenaica Peninsula (Libya; Figure 1). During spring, observations were made, aided with telescopes and binoculars, from 25 April to 15 May 2007 and from 19 April to 14 May 2008, each day between 08:00 and 17:30 h (solar time); during autumn, from 24 August to 20 September 2007 and from 21 August to 20 September 2008, each day between 08:00 and 17:30 h (solar time), covering peak periods of the passage of adult birds through the Mediterranean basin during both spring and autumn (Agostini & Panuccio 2005). Birds seen in reverse migration were subtracted from total numbers to avoid double counts. Generally, when European Honey Buzzards were very close to the ground (150 m) we were able to classify ages. In order to estimate the total number of adults and juveniles passing at the site during autumn migration, we divided the observation period into three ten-day periods (21–31 August; 1–10 September; 11–20 September). The total number of adults and juveniles was derived applying the age proportion in the sample of identified individuals to total counts during each period also to verify the existence of age dependent migration passage at the site (see also Agostini et al. 2004). In contrast, very few immatures (2nd calendar-year) are expected to reach Europe during spring since they mostly spend the second year of life in Africa (Panuccio & Agostini 2006).

Wind data were obtained from the ERA-40 Re-Analysis project (Uppala et al. 2005; http://www.ecmwf.int/research/era/do/get/era-40) of the European Centre for Medium Range Weather Forecasts (ECMWF). This project provides a high-quality historical archive of the state of the atmosphere in the past fifty years, reconstructed by variational assimilation of a comprehensive dataset of observations into a high-resolution atmospheric general circulation model. The data span the period from mid 1957 to mid 2002 and surface atmospheric variables are available at a spatial resolution of 2.5° . . . 2.5° in longitude and latitude, with a time resolution of 6 hours. From this archive we extracted daily average zonal and meridional surface (10 m above the ground) wind velocity components for the Central-Eastern Mediterranean region, at a resolution of 2.5°. The daily data are averaged over the 45 years of the dataset and over spring (21 April–20 May) and late summer (21 August–20 September) periods, producing maps of prevailing winds and average wind strength. Surface variables were used because European Honey Buzzards, as mentioned above, tend to fly very low when migrating over bodies of open water.

Results

During spring migration a total of 135 European Honey Buzzards were seen in 418 hours, 101 in 2007 and 34 in 2008 (max. one-day count was 32 birds on 5 May 2007). They reached the observation post from SE and disappeared towards NW.

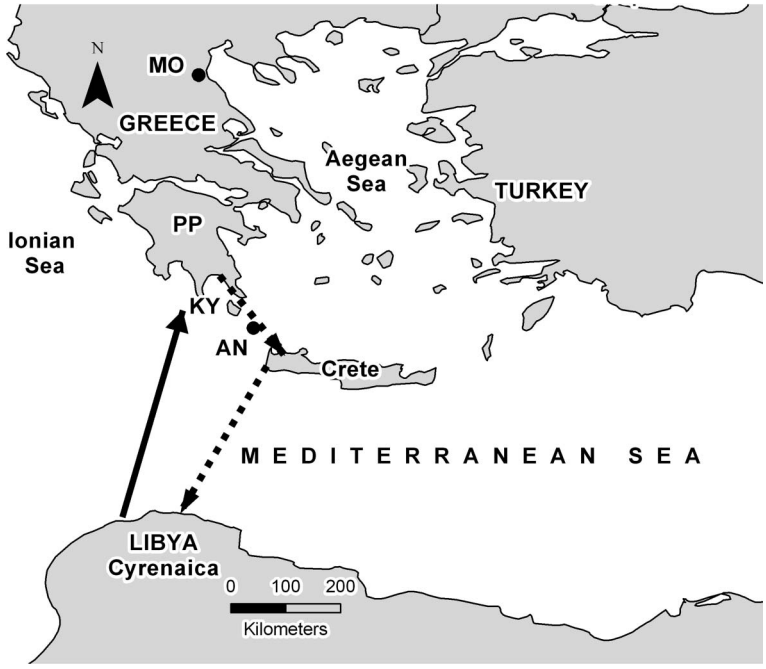

Figure 1. The study area (MO = Mount Olympus; AN = Antikythira; PP = Peloponnisos; KY = Kythira). Dotted arrows: observed autumn pathway between Peloponnisos and Crete via Antikythira and that expected between Crete and Libya; solid arrow: supposed spring pathway across the Central-Eastern Mediterranean according to the first hypothesis (narrow loop).

We recorded 63 (47%) European Honey Buzzards that migrated singly while flocks contained on average 3.4 ± 0.4 (SE; N = 21) birds. Among aged birds, 55 were adults and one was an immature (2nd calendar-year). During autumn migration the passage of 2479 European Honey Buzzards was recorded in 556.5 h, 1131 in 2007 and 1348 in 2008. Migrants reached the observation post from NW and disappeared towards SE. In both years an evident peak occurred, including 308 migrants on 29 August 2007, and 387 on 24 August 2008. A total of 2396 (97%) birds were seen migrating in flocks containing on average 14.5 ± 2.3 (SE; N = 76) and 12 ± 1.4 (SE; N = 108) birds during 2007 and 2008, respectively. Among aged birds (N = 719), 623 (86.6%) were adults and 96 (13.4%) juveniles, and using this proportion we estimated the passage of 2198 adults and 281 juveniles. The proportion of juveniles was higher late in the season, during the second ten-days of September (Figure 2). Among aged birds migrating singly (N = 39) juveniles outnumbered adults (24 vs 15).

By analysing dominant wind patterns in the Mediterranean region during spring and autumn migration of this species, north-northwesterly winds in both periods between southern Greece and North Africa occurred, but these were very weak (<10 km/h) in spring and stronger in autumn (Figure 3a, b).

Discussion

Migrating birds often follow different routes during spring and autumn, with one route being east or west of the other one. This phenomenon is called 'loop migration', and wind is one of the most important selective agents shaping this kind of strategy (Newton 2008; Klaassen et al. 2010). In agreement with previous studies, juvenile European Honey Buzzards behave differently from adults, concentrating late in the season during autumn (Agostini & Logozzo 1995; Hake et al. 2003; Agostini 2004) and being virtually absent during spring. Therefore, we will focus our discussion only on adult individuals.

The adult European Honey Buzzards counted here are likely to breed in Greece, which has an estimated breeding population of 1000–2000 pairs (BirdLife International 2004). Our results suggest that these birds use different flyways in spring and autumn. During autumn migration, adults choose the direct route between Greece and Libya, via Antikythira and Crete, exploiting the tail wind component of prevailing winds (Figure 1). Instead, visual observations revealed very scarce migration during spring. As mentioned above, previous studies made by satellite telemetry and visual observation showed that adult European Honey Buzzards are not susceptible of drifting by crosswinds during migration over land (Thorup et al. 2003; Panuccio

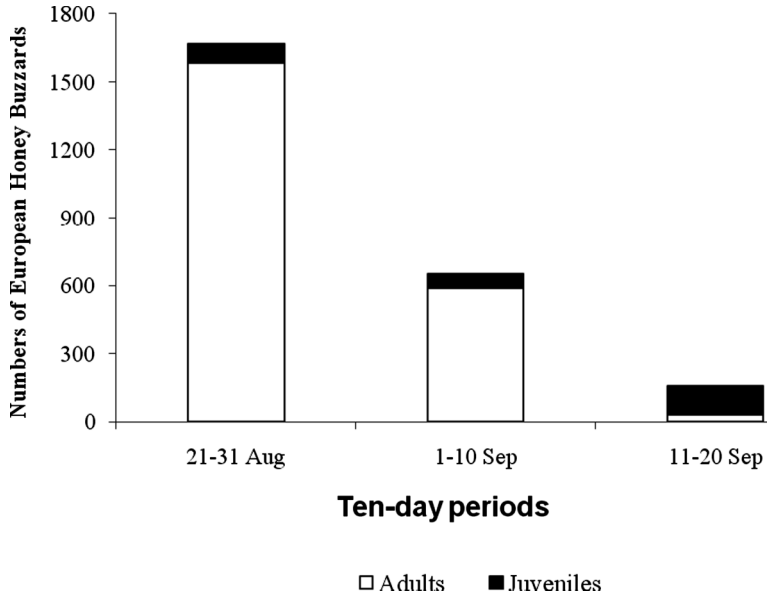

Figure 2. Estimated numbers of adult and juvenile European Honey Buzzards passing over the islands of Antikythira during the three ten-day periods in autumns 2007–2008.

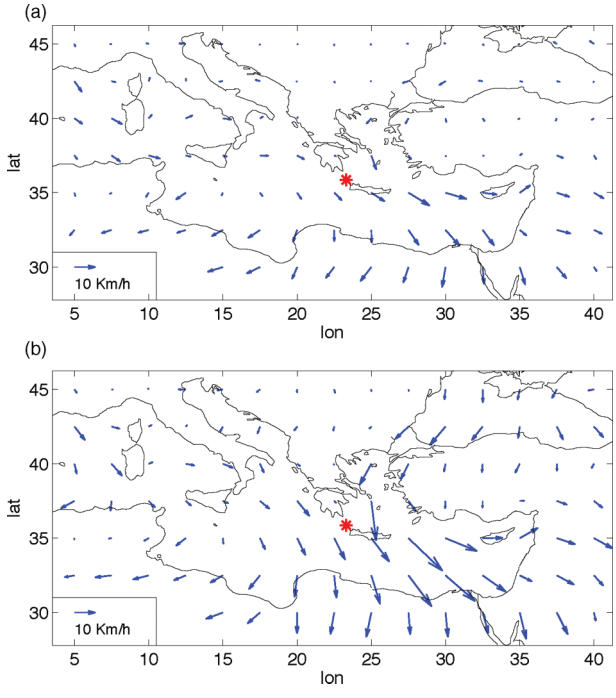

Figure 3. Average surface wind velocities and directions in spring (a) and autumn (b). The maps were obtained averaging daily data from the ECMWF ERA-40 archive in the periods 21 April–20 May and 21 August–20 September for the years 1957–2002 (Asterisk = Antikythira).

et al. 2010). For this reason, the seasonal difference that we found at Antikythira is not likely to depend upon wind conditions met during the crossing of the Sahara desert in spring. In addition, adult European Honey Buzzards are rather sedentary during the winter (Hake et al. 2003), and thus a loop migration in this species is unlike to be caused by movements performed during this season. Here we suggest two hypotheses to explain our results, the first one involving a narrow migratory loop and the second one a loop on a much larger scale: 1) most of European Honey Buzzards observed over Antikythira during autumn migration, may choose to fly in weak winds directly from Libya to Peloponnisos in spring, undertaking a longer water crossing in this period (approx. 400 km); in doing so they would bypass Antikythira and probably Crete (Figure 1), perhaps crossing the sea also during the night when winds tend to become weaker; 2) most of them may choose other flyways involving long detours, without attempting the direct crossing to avoid head winds in that region, and concentrating their passage via the Bosphorus/Dardanelles' and/or the Central Mediterranean (Figure 4). Through the Bosphorus and the Central Mediterranean at least 10,000 and 25,000 European Honey Buzzards are reported each spring, respectively (Corso 2001; Üner et al. 2010). The first hypothesis would agree with results of previous studies made in the Central Mediterranean region, where large numbers of adult European Honey Buzzards regularly undertake longer sea crossings (>300 km) during spring compared to autumn migration, mostly flying in weak (<20 km/h) or tail winds also during the night (Panuccio et al. 2004; Agostini et al. 2005a; M. Panuccio and G. Lucia unp. data). Wind patterns

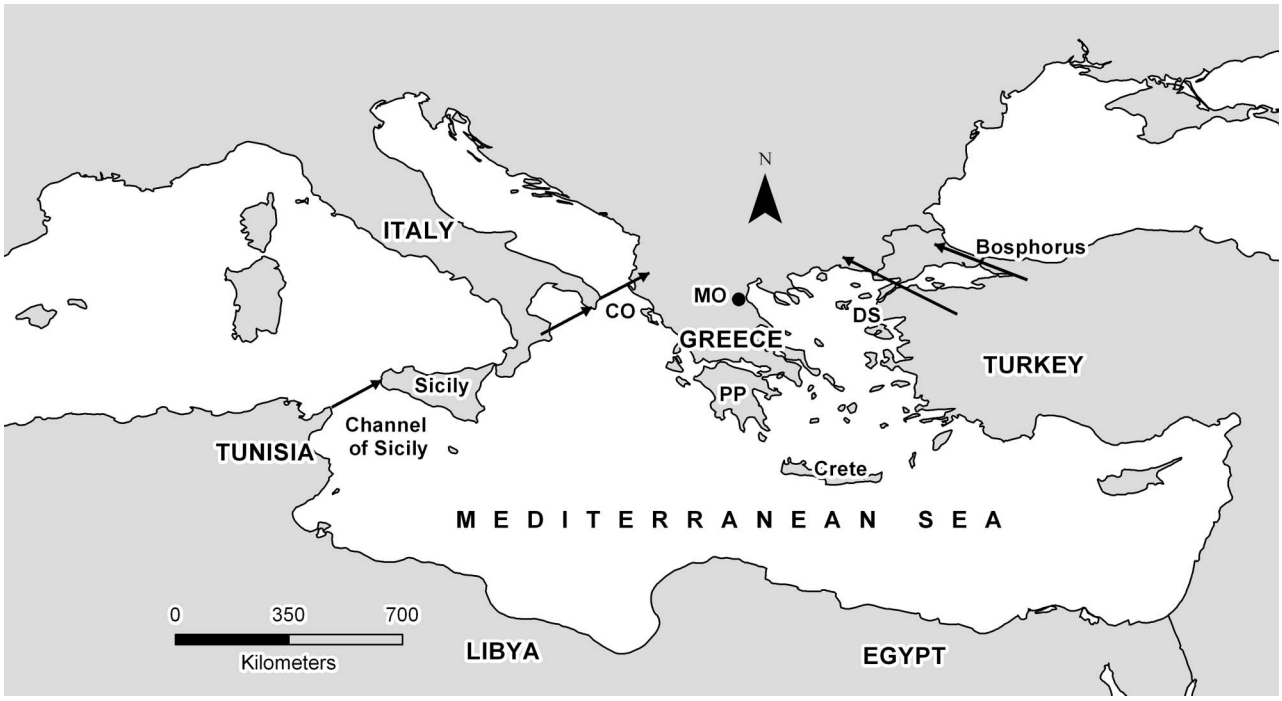

Figure 4. Spring migration routes according to the second hypothesis (large scale loop; CO = Capo d'Otranto; MO = Mount Olympus; PP = Peloponnisos; DS = Dardanelles).

show that head winds are very weak (<10 km/h) during spring between Libya and southern Greece (Figure 3). Moreover, as suggested in previous studies, migrants are expected to choose shorter routes during spring rather than autumn, crossing the sea on a broader front, perhaps to reach earlier their breeding areas (see Agostini & Panuccio 2005). In case of adverse weather for crossing, they can wait for better wind conditions along the coast of Northern Libya also for some days, as observed at the Cap Bon Promontory (Northern Tunisia; Agostini et al. 1994). In addition, in agreement with this hypothesis, a recent satellite study confirmed that European Honey Buzzards which know a shorter sea crossing through the Mediterranean (e.g. that through the Strait of Gibraltar) can decide to undertake longer sea-crossings in spring choosing more direct flyways between wintering and breeding areas (Meyburg et al. 2010). Instead, the second hypothesis resembles the results of recent satellite studies on the migration strategies of Oriental Honey Buzzards (*Pernis ptilorhyncus*) breeding in Japan, that also perform a loop migration, with adults undertaking the long crossing across the East China Sea (approximately 700 km) during autumn and returning via a different and longer overland route in spring to cross the sea between south Korea and Japan where it is only 50–100 km wide (Higuchi et al. 2005; Yamaguchi et al. 2008). The authors suggested that dominant wind patterns over the East China Sea could play a role in their behaviour since Oriental Honey Buzzards breeding in Japan would exploit tail winds during the longer crossing of the East China Sea in autumn but not during spring migration.

Previous counts at raptor migration watchsites in Japan and in the Korean Peninsula were in agreement with the results of these satellite studies (see Yamaguchi et al. 2008). However, it is unlikely that adult European Honey Buzzards breeding in central and southern Greece use the same migration strategy shown by adult Oriental Honey Buzzards breeding in Japan, increasing the overall migration distance during spring migration to reduce the over-water path (avoiding the 300 km between Crete and Libya that they cover during autumn). Sporadic observations made in southern Italy near Capo d'Otranto (Apulia; Figure 4) reported the passage of large numbers of European Honey Buzzards during spring migration (Premuda et al. 2004), but these probably reach breeding areas located north of Greece. Moreover, recent visual observations at a watchsite in NE Greece (Mount Olympus; Figure 4) during spring migration, did not report a passage of this species from the eastern corridor (Bosphorus and Dardanelles) towards central-southern Greece (Panuccio et al. in press). Finally, the fact that the second hypothesis (concerning the long detour during spring migration) does not

agree with the results of visual observations in the Central Mediterranean region such as with those of the first satellite study of pre-nuptial movements of the European Honey Buzzard (Agostini & Panuccio 2005; Meyburg et al. 2010), would confirm that the narrow migratory loop (first hypothesis, Figure 1) is more reliable than the large scale loop. Despite the tailwind support, we suggest that European Honey Buzzards would concentrate in higher numbers over Antikythira during autumn rather than spring migration since this island, together with western Crete, appears as a natural springboard towards Africa in this period. The populations of European Honey Buzzards breeding in Eastern Europe provide an excellent study system to investigate the differential use of routes by migrating birds in spring and autumn. Hopefully, studies made by means of satellite telemetry will clarify which one is the exact flyway used during spring by the birds observed in Antikythira during autumn.

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