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SHORT COMMUNICATION

Weather-influenced water-crossing behaviour of black kites (*Milvus migrans*) during migration

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Abstract

From 2014 to 2020, 32 black kites from various European countries were tagged with telemetry devices and tracked to study their spatiotemporal behaviour. Eleven birds which crossed the Mediterranean Sea and the Black Sea directly over large water bodies out of traditional migration routes over the Strait of Gibraltar, the Dardanelles/the Bosporus area and the east coast of the Black Sea were selected for this study. Ten birds attempted to cross the Mediterranean Sea and one attempted to cross the Black Sea. All black kites crossed the sea successfully but in one case the bird failed. The maximum water crossing length was recorded at 542 km. The average speed of the birds crossing the sea included a broad range from 27.7 to 97 kph. There was a correlation between average speed and tail-wind speed during the crossing. We conclude that the most favourable conditions for black kites when crossing large water bodies such as the Mediterranean and Black seas were sunny to partly cloudy weather with temperatures over 20 °C, the speed of the tailwind of 1.1–10.8 m/s and the air pressure over the standard value of 1013 hPa.

Keywords Raptors · Telemetry · Migration · *Milvus migrans*

Introduction

Black kites of the nominal subspecies *Milvus migrans migrans* (Boddaert, 1783) (hereafter 'black kites' are only birds of this nominal subspecies) breed in the Western Palearctic and Central Asia (Ferguson-Lees and Christie 2001). The European population is estimated at 162,000–218,000 mature individuals (BirdLife International 2015). Circannual variations including the migration of black kites have been extensively reviewed and it is known that black kites are summer residents in Europe and winter mostly in sub-Saharan Africa with a few remaining to winter in the

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Mediterranean region (Ortlieb 1998; Panuccio et al. 2013; Literák et al. 2017; Ovčiariková et al. 2020).

Previous research has focused on the migration behaviour of black kites but data regarding the crossing of large water bodies as challenging environmental obstacles for this species remain largely unknown (Panuccio et al. 2013). Firstly, Agostini and Duchi (1994) characterized water-crossing migration behaviour using direct observations of black kites migrating from Sicily to Tunisia and back. Recently, morphology, flight performance and water-crossing tendencies during the migration of 21 Afro-Palearctic raptor species including black kites were comparatively studied by Agostini et al. (2015). To date, the maximum water crossing length of black kites migrating over the Mediterranean Sea was 250 km (Panuccio et al. 2004; Agostini et al. 2015).

Since most of migrating black kites are reluctant to fly over large water bodies and cross transcontinental boundaries over the Strait of Gibraltar, the Bosporus Strait, the Dardanelle Strait and the Bab-al-Mandeb Strait (Panuccio et al. 2013; Ovčiariková et al. 2020; Santos et al. 2020), in this paper we characterize 11 black kites using unusual routes of migrating over large water bodies of the Mediterranean Sea and the Black Sea from Europe to Africa and from Europe to the Middle East. We reveal that black kites fly continually over water bodies for distances exceeding 250 km but in some cases their flight over large water bodies can be fatally unsuccessful.

Materials and methods

We tagged 30 black kite pulli on 19 nests with telemetry devices in Austria (2 birds/1 nest), Bulgaria (3/2), Czech Republic (18/11), Germany (1/1), Slovakia (5/3) and Ukraine (1/1) from 2014 to 2020 (for details see Ovčiariková et al. 2020). Moreover, we tagged one adult in Bulgaria in 2017 and one adult in Hungary in 2019. The birds were tracked for different periods from tagging but not later than on 31 September 2020. Eleven birds which crossed the Mediterranean Sea and the Black Sea directly over large water bodies out of traditional routes over the Strait of Gibraltar, the Dardanelles/the Bosporus area, the Bab-al-Mandeb Strait and the east coast of the Black Sea were selected for this study.

Loggers equipped with solar panels (20 g; Ecotone, Poland, or Ornitela, Lithuania) were used to track the birds. Loggers were fitted onto the backs of the birds using harnesses (backpacks) consisting of 6 mm Teflon ribbon encircling the body by two loops. The loggers function in GPS (Global Position System)/GSM (Global System for Mobile Communication) systems. The GPS positions of the birds were collected according to individual settings (usually one position fixed per 6 h) and were sent as SMS (Short Message Service) text messages by local mobile operators to the Ecotone and Ornitela Centers in Poland and Lithiuania, respectively, where they were saved and archived. Coordinates of bird positions were analysed using GIS (Geographic Information System) and the software ArcGIS 10.1 (Esri, Redlands, USA).

We analysed water-crossing flights of ten black kites and one black kite over the Mediterranean Sea and the Black Sea, respectively. The distances of the trajectories of direct water-crossing flights were calculated from GPS data. We investigated time periods, directions of their migration routes over water bodies, water crossing length, the velocity of black kites flying over water and the weather conditions during their flight over large water bodies. We also investigated the success rates of their flights over the large water bodies.

Weather records were downloaded from the web portals www.timeanddate.com and www.ncdc.noaa.gov. We worked with data from the nearest coastal cities to the bird's flight trajectories, in both Europe and Africa, and with weather data from the Mediterranean Sea recorded by ferries which travelled in similar directions to obtain reliable information about the weather conditions during the migration of individual birds over the sea.

Pearson correlation test (MS Excel) was used to determine if there is any connection between the speed of tail-wind and the average velocity of migrating birds.

Results

Ten birds attempted to cross the Mediterranean Sea and one attempted to cross the Black Sea (Table 1; Fig. 1). All black kites crossed the sea successfully but in one case, the bird failed. This black kite left mainland Greece to cross over the Mediterranean and died 66 km prior to reaching the Libyan coast where its body was later found by a local co-worker. We recorded the maximum water crossing length of a black kite at 542 km. The average speed of birds crossing the sea was in a broad range from 27.7 to 97 kph. Weather conditions during these crossings are provided in Table 1. There was a significant positive correlation between the average flight speed of the birds and tail-wind speed during the crossings ($r = 0.9$; $df = 14$; $p < 0.05$) (Fig. 2).

We were able to record the altitude fluctuation while sea crossing of BK11 (equipped with Ornitela logger) (Table 1). Rest of the studied birds were equipped with Ecotone loggers which lack the function of an altitude recording. B11 flew from Europe to Africa in three stages (Fig. 3). During the second stage, B11 left Italy heading south-east to Sardinia. Approximately 100 kilometres before reaching the eastern coast it changed its direction and flew south east to the direction of Sicily (Fig. 1). This change of flight direction was associated with the sudden change of a wind flow direction from N to SE. This change of wind direction caused exceptionally long sea crossing flight for soaring bird which lasted for 14 hours. Visible change in the altitude and

Table 1 Long flights of black kites over the sea and the weather conditions during the flights

Black kite	Direction of the flight	The sea	Flight date	Estimated age when crossing the sea	Flight time (hour)	Average speed (kph)	Average altitude (m)	Total distance (km)	Weather	Temperature of air (°C) max./min.	Wind speed (m/s)	Wind direction	Air pressure (hPa)
BK1	Italy (mainland)/Sicily	Tyrhennian Sea	2 Sep 2014	ND	7.7	64.4	-	495	Scattered clouds	27/23	9.7	NW	1007
	Sicily/Tunisia	Strait of Sicily	11 Sep 2014		9.0	30.4	-	274	Partly cloudy	32/22	3.6	N	1011
BK2	Greece (mainland)/(Libya)	Mediterranean Sea	19 Aug 2017	88 days	11.9	38.5	-	459*	Cloudy	33/22	2.2	NW	1013
BK3	Crete/Egypt	Mediterranean Sea	30 Aug 2017	92 days	13.6	32.7	-	445	Sunny	27/21	2.2	N	1011
BK4	France (mainland)/Corsica	Mediterranean Sea	11 Sep 2017	82 days	5.9	42.7	-	256	Sunny	28/13	5	NW	1006
	Sardinia/Alergia	Mediterranean Sea	17 Sep 2017	88 days	5.9	39.7	-	238	Sunny	27/14	1.7	NW	1020
BK5	Sardinia/Algeria	Mediterranean Sea	28 Sep 2017	95 days	8.6	28	-	240	Cloudy	27/15	1.1	W	1023
BK6	Morocco/Spain	Gulf of Cádiz	28 Apr 2019	ND	7.3	34.6	-	252	Cloudy	27/13	4.2	SE/ E	1012
BK7	Greece/Libya	Mediterranean Sea	23 Sep 2019	94 days	-	-	-	(750)	-	-	-	-	-
BK8	Croatia/Italy (mainland)	Adriatic Sea	17 Sep 2019	87 days	4.9	34	-	165	Partly cloudy	26/20	1.3	SW	1018
	Italy (mainland)/Sicily	Tyrhennian Sea	20 Sep 2019	90 days	6.8	40.6	-	276	Partly cloudy	28/24	2.8	N/W	1016
	Sicily/Tunisia	Strait of Sicily	17 Oct 2019	117 days	6.7	27.7	-	187	Partly cloudy	22/17	2.3	N/NW	1018
BK9	Crimea/Turkey	Black Sea	7 Sep 2019	92 days	8.6	33.5	-	288	Partly cloudy	26/15	1.6	N/W	1018
BK10	Greece (mainland)/Libya	Mediterranean Sea	17 Sep 2019	ND	4.1	97	-	395	Partly cloudy	27/22	10.8	N	1015
BK11	Croatia/Italy	Adriatic Sea	8 Sep 2020	66 days	6	40.5	436	243	Sunny	27/16	2.6	N/NE	1021
	Italy/Sicily	Tyrhenian Sea	10 Sep 2020	68 days	14.0	38.7	158	542	Sunny	30/20	2.5	N/SE	1013
	Sicily/Tunisia	Strait of Sicily	13 Sep 2020	71 days	7.4	36.6	190	271	Scattered clouds	27/21	4.8	NE	1018

*Black kite BK2 died whilst crossing the Mediterranean Sea 66 km from the Libyan coast; - not known; BK1 (black kite ringed by a ring CT1589 from the Bird Ringing Centre, National Museum Prague, Czech Republic), BK2 (CT1922), BK3 (CT1925), BK4 (CT155855), BK5 (CT155856), BK6 (black kite ringed by a ring EA215043 from Vogelwarte Hiddensee, Germany), BK7 (G000791 from Klivv.at Wien, Austria), BK8 (G000792 from Klivv.at Wien, Austria,), BK9 (black kite tagged with telemetry logger in Ukraine, without a ring), BK10 (BUDAPEST 542386 from the Hungarian Bird Ringing Centre, BirdLife Hungary, Budapest, Hungary). BK11(C110935 Bird Ringing Centre, National Museum Prague, Czech Republic). Wind direction is reported by the direction from which its originated. The age of black kites when crossing the sea was estimated according the lenth of the wing where they were tagged (for a method see Mougeot and Bretagnolle 2006)

ND – not determined

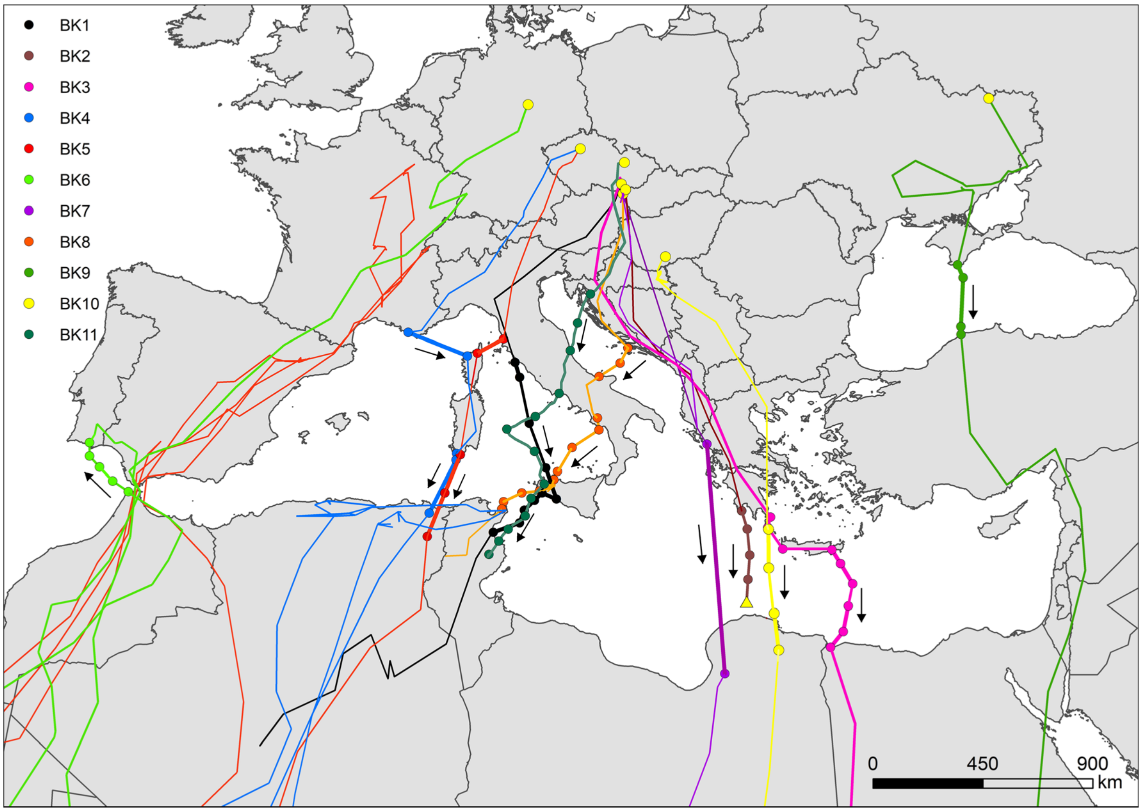


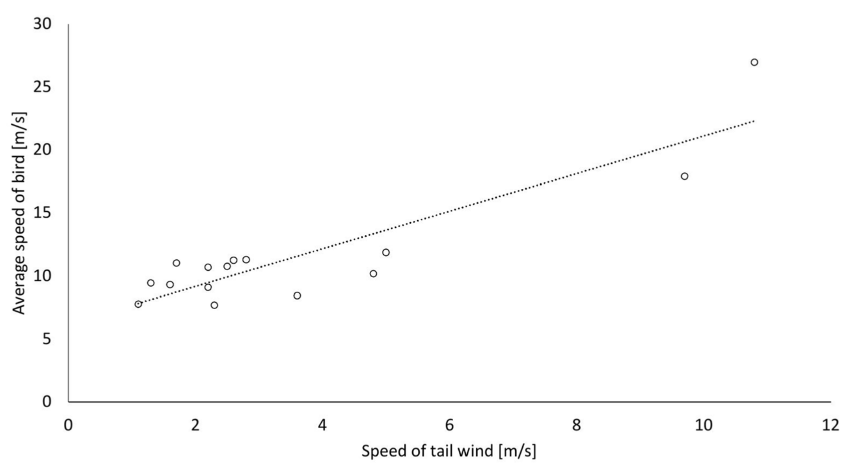
Fig. 1 Routes of black kites (BK) whilst crossing large water bodies of the Mediterranean and Black seas. Green circles, natal nest; the lines connect roosting places chronologically, the lines in bold show crossing over the sea, bold circles on the lines are places where GPS positions were measured; yellow triangle, a place where the bird died

speed fluctuation can be noticed after the change of the flight direction (Fig. 3b).

Discussion

A substantial number of European black kites winter in sub-Saharan Africa (Ortlieb 1998; Ferguson-Lees and Christie 2001; Panuccio et al. 2013; Ovčiariková et al. 2020). Previous studies using telemetry tracking techniques found large areas in sub-Saharan Africa were used by individual black kites during the winter (Meyburg and Meyburg 2009; Tanferna et al. 2012; Sergio et al. 2014; Literák et al. 2020a; Ovčiariková et al. 2020). During migration, tens of thousands of birds are observed migrating across the Straits of Gibraltar, along the eastern side of the Black Sea and the Dardanelles and the Bosporus (Panuccio et al. 2013; Onrubia 2016; Tellería et al. 2019; Santos et al. 2020; Vansteelant et al. 2020). Fewer birds cross the central Mediterranean (Italy including Sicily, Tunisia) and a small number cross the

Fig. 2 Correlation between the speed of black kites crossing the sea and the speed of tailwind



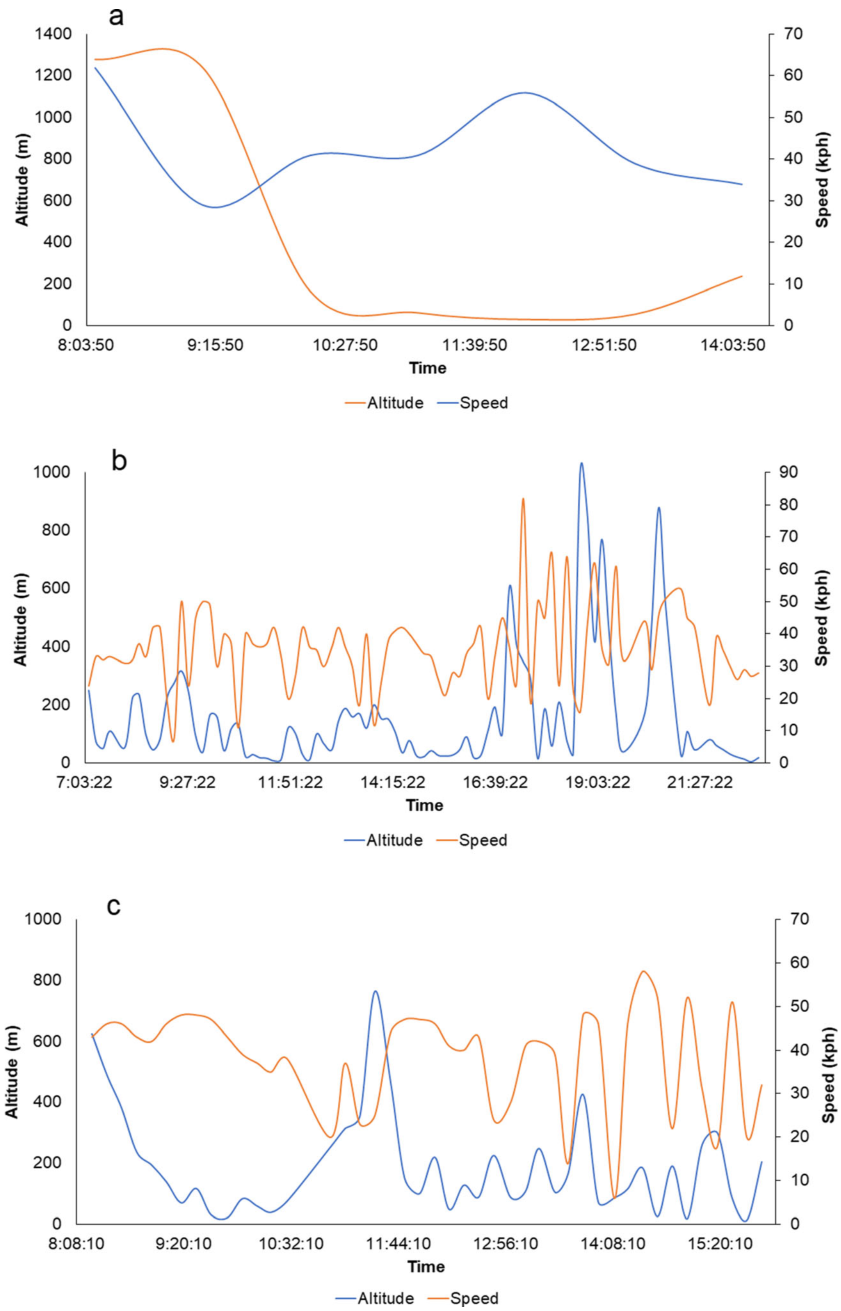


Fig. 3 Fluctuations of an altitude and speed of black kite BK11 whilst sea crossing, starting and ending with the first and last GPS position over the sea. **a** Crossing of Adriatic Sea from Croatia to Italy (one fix every hour); **b** crossing of Tyrhennian Sea from Italy to Sicily (one fix every 10 minutes); **c** crossing of Strait of Sicily from Sicily to Tunis (one fix every 10 minutes)

Mediterranean Sea between the Greek Peloponnese, Crete and Libya (Agostini et al. 2004; Panuccio et al. 2013).

In autumn, black kites mainly cross the Strait of Gibraltar, the Dardanelle Strait and the Bosporus Strait from August to October with the majority of birds migrating in September (Panuccio et al. 2013; Onrubia 2016; Ovčiariková et al. 2020). The Strait of Sicily is used by black kites in August and September (Agostini and Duchi 1994; Agostini et al. 2004; Panuccio et al. 2004; Panuccio and Agostini 2010). Cases of crossing over large water bodies from our study fit well with this time period with most birds migrating in September. In spring, the main migratory passage of black kites over the Strait of Gibraltar peaks in the first half of March (Panuccio and Agostini 2010; Panuccio et al. 2013). We found only one black kite crossing large water bodies during the spring migration, located west of the Strait of Gibraltar in April.

Raptors perform a soaring-gliding flight behaviour exploiting rising thermals and ridge lifts over land to reduce energetic expense. However, during migration when crossing large water bodies, thermal updrafts are weak, and birds mainly use flapping (powered) flight increasing both energy consumption and mortality risk (Agostini et al. 2015). We considered that our tagged black kites used also a flapping flight technique when crossing the water bodies of the Mediterranean Sea out of the Strait of Gibraltar, the Dardanelle Strait and the Bosporus Strait. Black kites crossing the Strait of Gibraltar engaged in heavy wing flapping during Levanter winds or they exhibited less flapping amplitude when crossing during weak crosswinds (Santos et al. 2020). Black kites are typically reluctant to cross large water bodies (Pannuccio and Agostini 2010). They often stop migrating when facing open water and fly back inland. Moreover, non-breeders are more reluctant to cross water barriers and tend to remain at stopovers sites longer than breeding adults. In two cases, Black kites have been documented crossing the water following a marsh harrier *Circus aeruginosus* (Linnaeus, 1758) which crossed the Mediterranean Sea on a wide front; as this species is one of the more broad-winged raptors (black kites are intermediate-winged raptors and are between broad-winged eagles and long-winged harriers) and uses powered flight over large water bodies (Pannuccio and Agostini 2010).

Migrating red kites *Milvus milvus* (Linnaeus, 1758) (a close relative of black kite) also cross the Mediterranean Sea in exceptional circumstances. It has been recently found that a red kite departed north Italy and arrived in Algeria on 26 September crossing the sea in 12 hours with an average flight speed of 58.6 km/h and at an average altitude of 429 metres above sea level (Literák et al. 2020b). During its water crossing the weather conditions were as follows: sunny, almost cloudless, average temperature of 24 °C, pressure of 1092 hPa, tailwind in a south-westerly direction from the early morning with the speed fluctuating during the day from 2 to 5.7 m/s. Hence, we can assume a similar strategy for black kites to cross large water bodies of the Mediterranean Sea because weather plays a significant role in the course and pace of bird migration (Miller et al. 2016). Favourable weather conditions improve the orientation of birds, decrease energy usage and increase the speed of flight. Based on our findings we can predict that favourable conditions for black kites to cross the large water bodies of Mediterranean and Black seas are sunny to partly cloudy weather with temperatures over 20 °C, the speed of the tailwind of 1.7–10.8 m/s and the air pressure over the standard value of 1013 hPa. This is consistent with the fact that migrating raptors including black kites crossing the Strait of Messina prefer sunny weather and avoid flying through fog and low clouds (Panuccio et al. 2019). An average cross-country speed of 37 km/h was calculated in the autumn transcontinental migration of European honey buzzards *Pernis apivorus* (Linnaeus, 1758) (Hake et al. 2003). We found a range of speeds from 27.7 to 97 km/h depending strongly on the tailwind speed. Supportive wind is usually associated with long sea-crossings by soaring raptors (Mellone et al. 2011; Nourani et al. 2018). Recently, it has been also shown that an upward current of air with an increasing temperature gradient can help soaring raptors to cross the sea (Duriez et al. 2018; Nourani et al. 2020). We were able to obtain data of the altitude fluctuation while sea crossing only for one bird. This crossing was found exceptional because of the sudden change of the flight direction only few kilometres before it reached Sardinia coast. We assume that this bird changed the direction along with the wind, rather than risk high energy cost of the flapping flight against the crosswind even though it had doubled the final crossing length and duration. Visible difference in altitude and speed fluctuation are noticeable after the change of a flight direction, therefore the bird might have changed the direction to use upward currents to eliminate the energy cost of the powered flight rather than fly shorter distance against the crosswind.

We considered all routes over large water bodies as sub-optimal for black kites and they are supposedly used only by a minority of black kites originating from Europe since for some of them, as we proved, this route could be fatally unsuccessful. From this perspective, unusual observations of black kites on islands in the Atlantic Ocean, far from breeding territories, as well as far from usual migration routes are questionable. One Black Kite was observed on the Saint Peter and Saint Paul Archipelago, Brazil (a distance of 1970 km from African mainland) in April/May 2014 (Nunes et al. 2015). Further observations of Black Kites were reported from two islands of the Azores Archipelago, Portugal (Barcelos et al. 2015) and three black kites were observed in Iceland (Pétursson and Kolbeinsso 2018). One case of a long journey over the Red Sea was facilitated by the transport of the bird on board of a cargo ship (Literák et al. 2020a).

High mortality rates of black kites were revealed during the first migration and wintering period (Sergio et al. 2011). It seems that some cases of black kite deaths could be attributed to following sub-optimal migratory routes as demonstrated in other raptors and long distance migrants wintering in Africa (Strandberg et al. 2010; Oppel et al. 2015). No fatalities were recorded in black kites crossing the Strait of Gibraltar even if extended sea crossing in this place challenged black kites to prolonged powered flight at very low altitude that could have increased the chance of fatality due to exhaustion (Santos et al. 2020). The ability to cross the Mediterranean Sea (and lately Sahara Desert) in black kites as well as other raptor species is likely the result of evolutionary permanent selection pressure.

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Conflict of interests The author declare that they have no conflict of interest.

References

Agostini N, Duchi A (1994) Water-crossing behaviour of Black Kites (*Milvus migrans*) during migration. Bird Behav 10:45–48

Agostini N, Ptremuda G, Mellone U, Panuccio M, Logozzo D, Bassi E, Cocchi L (2004) Crossing the sea en route to Africa: autumn migration of some *Accipitriformes* over two central Mediterranean islands. Ring 26:71–77. https://doi.org/10.2478/v10050-008-0062-6

Agostini N, Panuccio M, Pasquaretta C (2015) Morphology, flight performance, and water crossing tendencies of Afro-Palearctic raptors during migration. Curr Zool 61:951–958

Barcelos LMD, Rodrigues P, Bried J, Mendonça EP, Gabriel R, Borges PAV (2015) Birds from the Azores: An updated list with some comments on species distribution. Biodivers Data J 3:e6604. https://doi.org/10.3897/BDJ.3.e6604

BirdLife International (2015) *Milvus migrans*. The IUCN red list of threatened species 2015: e.T22734972A60310651. Accessed 18 May 2019

Duriez O, Peron G, Gremillet D, Sforzi A, Monti F (2018) Migrating ospreys use thermal uplift over the open sea. Biol Lett 14: 20180687. https://doi.org/10.1098/rsbl.2018.0687

Ferguson-Lees J, Christie DA (2001) Raptors of the world. Helm identification guides. Christopher Helm, London

Hake M, Kjellén N, Alerstam T (2003) Age-dependent migration strategy in Honey Buzzard *Pernis apivorus* tracked by satellite. Oikos 103: 385–396

Literák I, Horal D, Alivizatos H, Matušík H (2017) Common wintering of Black Kites (*Milvus migrans migrans*) in Greece, and new data on their wintering elsewhere in Europe. Slovak Raptor J 11:91–102

Literák I, Balla M, Vyhnal S, Škrábal J, Peške L, Chrašč P, Systad G (2020a) Natal dispersal of black kites from Slovakia. Biologia 75: 591–598. https://doi.org/10.2478/s11756-019-00323-x

Literák I, Raab R, Petretto M, Škrábal J, Spakovszky P, Steindl J (2020b) Diverse natal dispersal in four sibling red kites originating from Austria, including wintering in Tunisia. Biologia 75:1399–1407. https://doi.org/10.2478/s11756-019-00390-0

Mellone U, Pópez-López P, Limiñana R, Urios V (2011) Weather conditions promote route flexibility during open ocean crossing in a long-distance migratory raptor. Int J Biometeorol 55:463–468. https://doi.org/10.1007/s00484-010-0368-3

Meyburg BU, Meyburg C (2009) GPS-Satelliten-Telemetrie bei einem adulten Schwarzmilan (*Milvus migrans*): Aufenthaltsraum während der Brutzeit, Zug und Überwinterung. Populationsökologie Greifvogel- Eulensarten 6:243–248

Miller RA, Onrubia A, Martín B, Kaltenecker GS, Carlisle JD, Bechard MJ, Ferrer M (2016) Local and regional weather patterns influencing post-breeding migration counts of soaring birds at the Strait of Gibraltar, Spain. Ibis 158:106–115

Mougeot F, Bretagnolle V (2006) Breeding biology of the Red Kite *Milvus milvus* in Corsica. Ibis 148:436–448

Nourani E, Safi K, Yamaguchi NM, Higuchi H (2018) Raptor migration in an oceanic flyway: wind and geography shape the migratory route of grey-faced buzzards in East Asia. R Soc Open Sci 5:171555. https://doi.org/10.1098/rsos.171555

Nourani E, Vansteelant WMG, Byholm P, Safi K (2020) Dynamics of the energy seascape can explain intra-specific variations in sea-crossing behaviour of soaring birds. Biol Lett 16:20190797. https://doi.org/10.1098/rsbl.2019.0797

Nunes G, Hoffmann LS, Macena BCL, Bencke GA, Bugoni L (2015) A Black Kite *Milvus migrans* on the Saint Peter and Saint Paul Archipelago, Brazil. Rev Bras Ornitol 23:31–35

Onrubia A (2016) Spatial and temporal patterns of soaring birds migration through the Straits of Gibraltar. Doctoral Thesis, University of Leon

Oppel S, Dobrev V, Arkumarev V, Saravia V, Bounas A, Kret E, Velevski M, Stoychev S, Nikolov SC (2015) High juvenile mortality during migration in a declining population of a long-distance migratory raptor. Ibis 157:545–557

Ortlieb R (1998) Der Schwarzmilan. Die Neue Brehm-Bücherei Bd. 100. Westarp Wissenschaften, Hohenswarsleben

Ovčiariková S, Škrábal J, Matušík H, Makoň K, Mráz J, Arkumarev V, Dobrev V, Raab R, Literák I (2020) Natal dispersal in Black Kites *Milvus migrans migrans* in Europe. J Ornithol 161:935–951. https://doi.org/10.1007/s10336-020-0178-x

Panuccio M, Agostini N (2010) Timing, age classes and water-crossing behaviour of Black Kites (*Milvus migrans*) during spring migration across the central Mediterranean. Ring 32:55–61. https://doi.org/10.2478/v10050-010-04-y

Panuccio M, Agostini N, Massa B (2004) Spring raptor migration over Ustica, southern Italy. Br Birds 97:400–403

Panuccio M, Agostini N, Mellone U, Bogliani G (2013) Circannual variation in movement patterns of the Black Kite (*Milvus migrans migrans*): a review. Ethol Ecol Evol 26:1–18

Panuccio M, Dell´Omo G, Bogliani G, Catoni C, Sapir N (2019) Migrating birds avoid flying through fog and low clouds. Int J Biometeorol 63: 231–239. https://doi.org/10.1007/s00484-018-01656-z

Pétursson G, Kolbeinsso Y (2018) Black Kites in Iceland. The Icelandic birding pages. https://notendur.hi.is/yannk/status_milmig.html. Accessed 28 Dec 2018

Santos CD, Silva JP, Muñoz AR, Onrubia A, Wikelski M (2020) The gateway to Africa: What determines sea crossing performance of a migratory soaring birds at the Strait of Gibraltar. J Anim Ecol 89: 1317–1328. https://doi.org/10.1111/1365-2656.13201

Sergio F, Tavecchia G, Blas J, López L, Tanferna A, Hiraldo F (2011) Variation in age-structured vital rates of a long-lived raptor: implications for population growth. Basic Appl Ecol 12:107–115

Sergio F, Tanferna A, De Stephanis R, López Jiménez L, Blas J, Taveschia G, Preatoni D, Hiraldo F (2014) Individual improvements and selective mortality shape lifelong migratory performance. Nature 515:410–413. https://doi.org/10.1038/nature13696

Strandberg R, Klaassen RHG, 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. https://doi.org/10.1098/rsbl.2009.0785

Tanferna A, López-Jiménez L, Blas J, Hiraldo F, Sergio F (2012) Different location sampling frequencies by satellite tags yield different estimates of migration performance: pooling data require a common protocol. PLoS One 7(11):e49659

Tellería JL, Fandos G, Tena E, Carbonell R, Onrubia A, Qninba A, Ramírez Á (2019) Constraints on raptor distribution at the southwestern boundary of the Palearctic: implications for conservation. Biodivers Conserv 28:603–619. https://doi.org/10.1007/s10531-018-1677-9

Vansteelant WMG, Wehrmann J, Engelen D, Jansen J, Verhelst B, Benjumea R, Cavaillè S, Kaasiku T, Hoekstra B, de Boer F (2020) Accounting for differential migration strategies between age groups to monitor raptor population dynamics in the eastern Black Sea flyway. Ibis 162:356–372. https://doi.org/10.1111/ibi.12773