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SHORT REPORT

Autumn migration of soaring birds at Bosporus: validating a new survey station design

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Capsule Using a new survey station network we report the highest number of migrating raptors and Black Storks ever recorded on Bosporus during the autumn migration period. Also, we show that migration occurs with similar intensities over the full length of the strait, but individual migration patterns differ for some species at a local scale.

Migration is an annual seasonal movement between regular breeding and wintering grounds, covering large geographical distances over continents, caused primarily by seasonal changes in food abundance (Newton 2008, 2010). Migration in birds is recognized as an energetically demanding process due to the long distances covered in flight, thus the flight strategy adopted can influence survival directly (Videler 2005). Migrating raptors and other large birds (e.g. storks, pelicans and cranes) minimize their energy expenditure and maximize their performance by employing a soaring–gliding flight style using thermals (Alerstam 1975, Pennycuick *et al.* 1979, Kerlinger 1989, Leshem & Yom-Tov 1996, Spaar & Bruderer 1996, 1997a, 1997b, Bildstein 2006). Thermals are columns of rising warm air that form mainly over the land, but not exclusively (Elkins 2004). Soaring birds exploit the uplifting force of the ascending warmer air mass, gaining height by circling up to high altitudes from where they can glide in their favoured migration direction (Leshem & Yom-Tov 1996).

Over the course of their migration, soaring birds follow established air routes (flyways) where (1) the topography of the continent surface favours the development of thermals and (2) natural barriers (e.g. seas, deserts, ice fields or mountains) can be avoided or passed with minimum risk (Elkins 2004, Newton 2008). Typically, natural barriers are traversed using geographical bottlenecks such as narrow land bridges or sea crossings, where large concentrations of migrating soaring birds can be observed (Kerlinger 1989, Bildstein 2006, Newton 2008).

The Eurasian–East African flyway is one of the most important migration corridors globally, connecting northeastern Europe and western Siberia with southern Africa, by way of the Middle East (Zalles & Bildstein 2000, Newton 2008). In the Middle East, soaring birds concentrate at three major geographical bottlenecks en route towards Africa: the Bosporus, Suez and Bab-el-Mandeb (Ferguson-Lees & Christie 2001). The Bosporus Strait is the major bottleneck connecting Europe to Asia, hence several studies have been done to investigate the autumn migration of raptors and other soaring birds in this region (Table 1).

Traditionally, the Çamlıca Hills (Büyük and Küçük Çamlıca) have been considered the most suitable survey stations for autumn migration counts (Steinfatt 1932, Nisbet & Smout 1957, Ballance & Lee 1961, Porter & Willis 1968). The Büyük and Küçük Çamlıca, situated on the Asian side of the strait, are the highest points of Bosporus (268 and 227 m,

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Table 1. A review of the studies published about autumn migration of soaring birds over the Bosporus.

Year	Period	Locations	Number of days	Raptors	Black Storks	References
1931	13 September–4 November	Büyük Çamlıca	53	13199	516	Steinfatt (1932) (cited from Nisbet & Smout 1957)
1956	14–22 September and 27 September–1 October	Büyük Çamlıca, Küçük Çamlıca	16	8448	1376	Nisbet & Smout (1957)
	15–16 and 20–22 September	Kadiköy				
	15 and 21 September	Çekmece				
	18 and 27–30 September	Büyükdere, Rumehilisari				
	11–13 September	various parts of Istambul				
	20 September	Princess Islands				
1959	20 August–7 September	Büyük Çamlıca, Küçük Çamlıca	17	5396	110	Ballance & Lee (1961)
1966	14 July–8 November	Küçük Çamlıca	114	37139	6194	Porter & Willis (1968)
1969	25 August–13 October	Büyük Çamlıca	51	61640	5700	OST (cited from Arslangündoğdu (2011))
1971	13 August–4 October	Büyük Çamlıca	53	75176	7208	OST (cited from Arslangündoğdu (2011))
1972	5 August–6 October	Büyük Çamlıca, Küçük Çamlıca	63	-	4300	Bijlsma (1987) (cited from van den Bossche & Lens (1994))
1973	8 September–3 October	Büyük Çamlıca	26	-	7400	OST (Cramp & Simmons 1980)
1975	9 August–2 October	Büyük Çamlıca	50	26376	5246	OST (cited from Arslangündoğdu (2011))
1980	31 August–4 October	Büyük Çamlıca, Küçük Çamlıca	35	-	5898	Bijlsma (1987) (cited from van den Bossche & Lens (1994))
1986	21–28 September	Büyük Çamlıca, Küçük Çamlıca	8	-	5049	Franckx and Verschueren (1989) (cited from van den Bossche & Lens (1994))
1988	8 September–1 October	Büyük Çamlıca, Küçük Çamlıca Sariyer	24	58154	8781	van den Bossche & Lens (1994)
2007	1–30 September	Büyük Çamlıca	30	24622	1679	Arslangündoğdu (2011)
2008	22 September–10 October	Anadolu Kavağı, Koç Park, Büyük Çamlıca, Kadiköy	19	141844	16088	Present study

respectively). Consequently, the majority of the studies concentrated on these hills, on the Southern part of the strait (Porter & Beaman 1985). Since Bosporus is approximately 31 km long, significant numbers of birds may cross over other parts of it without being noticed. According to our knowledge, only one study has been published where a multi-station survey approach was used and counts were made systematically from three different points. van den Bossche & Lens (1994) recorded the migration of soaring birds from Büyük and Küçük Çamlıca, and also from Sariyer, which is located on the European side of the Bosporus, 15 km north from the Çamlıca Hills. Although the survey lasted approximately three weeks, van den Bossche & Lens (1994) recorded the highest number of migrating Lesser Spotted Eagles *Aquila pomarina* over the Bosporus, with a total of 32 228 individuals. Contrary to the suggestions made in previous studies (Nisbet & Smout 1957, Porter & Willis 1968), the majority of the Lesser Spotted Eagles passed the strait north of Çamlıca Hills, at Sariyer. Although the observed migration pattern can be attributed to temporary weather conditions, it is possible that migration may occur throughout the total length of the Bosporus and not only at particular Southern points of it.

Even though the migration of soaring birds in the area of Çamlıca Hills is relatively well documented, migration in the other areas of the Bosporus remains poorly studied. In the present study we recorded the autumn migration of raptors and Black Storks *Ciconia nigra* over the Bosporus from four different survey stations simultaneously, validating the effectiveness of a new multi-station network. We provide data on the intensity and local pattern of migration of the soaring birds, and finally we suggest some future directions in the migration research over this geographical bottleneck.

The study was made from the Asian side of the Bosporus. Four stations were selected for observations in strategic places, situated mostly on high hills with good visibility, covering the total length of the strait (Fig. 1). The northernmost survey station was situated in the vicinity of Anadolu Kavağı village, on the highest point of the hill, at the ruins of Yoros Castle

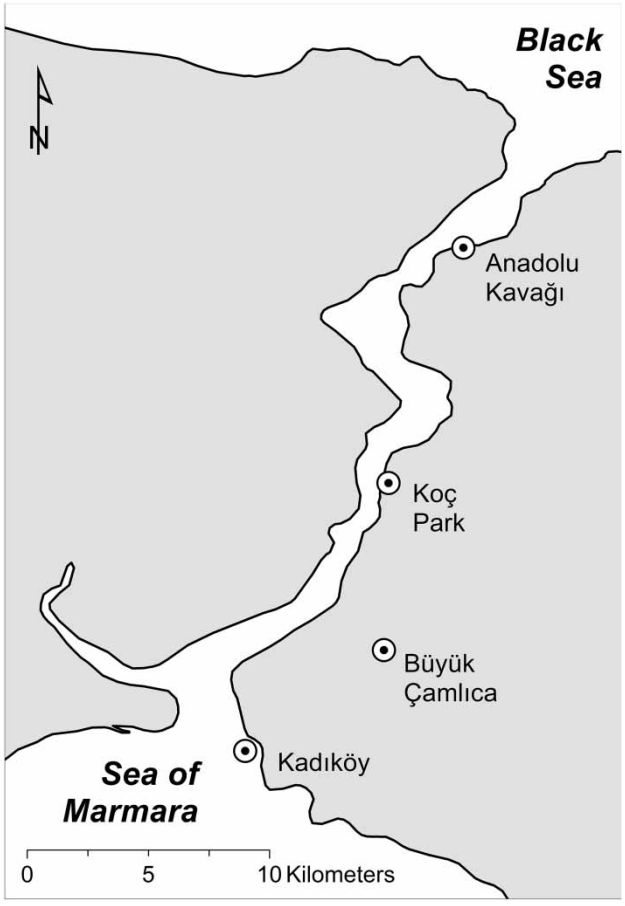

Figure 1. Map showing the exact locations of the survey stations on the Asian bank of the Bosporus.

(hereafter Anadolu Kavağı; N41.178922, E29.095375). Further south from Anadolu Kavağı station, the next survey station was located on the Otagtepe Hill, in the Tema Vehbi Koç Park (hereafter Koç Park; N41.09036, E29.07005) in the district of Beykoz. South from Koç Park, the third survey station was placed on the Büyük Çamlıca Hill (hereafter Büyük Çamlıca; N41.02810, E29.06836) in the district of Üsküdar. Lastly, the southernmost survey station was situated in the district of Kadıköy on the shore of the Sea of Marmara (hereafter Kadıköy; N40.99055, E29.01687). The distance between Anadolu Kavağı and Koç Park survey stations was 10.06 km, between Koç Park and Büyük Çamlıca was 6.92 km and finally between Büyük Çamlıca and Kadıköy was 6.01 km.

The observations were made between 22 September and 10 October 2008. The survey period was chosen to cover primarily the migration peak of the Lesser Spotted Eagle, a species with global conservation concern. More than 95% of the breeding range of these species is in Europe (Bird Life International 2013) and the significant part from the global population migrates over Turkey at Bosporus (Cramp & Simmons 1980).

Counts were performed following the method described by Bird & Bildstein (2007). Two to five observers were present at each survey station daily, between 9 and 18 hours (GMT + 3:00). Counts were carried out simultaneously at all stations and were suspended only in case of harsh weather conditions (e.g. heavy rain or thunderstorm), when migration stopped and also counting became impossible. The observers were equipped with binoculars (magnification 10 ×) and spotting scopes (magnification 20 ×, 30 × and 20–60 ×). All observations were recorded on standard data sheets. Each bird was identified to species level if possible. In case of unidentified raptors, only the number of individuals was noted. When counting individuals one by one became impossible (e.g. rapidly migrating large flocks), individuals were counted in increments of 10. The time of passage, distance to and direction related to the count point of individual birds or flocks were also noted.

Our final dataset presents the total number of migrating individuals counted at each survey station separately (including double counts) as well as the sum total number of migrants through Bosporus as recorded over the full study period (corrected for double counts). Double count correction was performed every day after observations, using the time of migration over the strait, distance and direction related to count points of the migrating birds (Agostini *et al*. 2007).

The total abundance of raptors recorded from our count points, as well as the individual abundances of the five most abundant raptor species and the Black Stork, were compared using Kruskal–Wallis test. In all cases when the categorical variable (count location) proved to be significant, *post hoc* comparisons were performed using Wilcoxon signed-rank test (package 'exactRankTests'; Hothorn & Hornik 2013). Subsequent to the *post hoc* analyses, we have adjusted all P values obtained using a Holm-correction, to exclude the type I error following multiple comparisons. We used a significance level of $P < 0.05$. All statistical analyses were carried out in the *R* statistical environment version 2.15.1 (R Core Team 2012).

We observed a total of 141 844 individuals belonging to 25 raptor species and 16 088 Black Storks. The most abundant raptor species were Common Buzzard *Buteo buteo* (52.2%, 74 055 individuals), Lesser Spotted Eagle (41.1%, 58 327 individuals), Short-toed Eagle *Circaetus*

gallicus (2.9%, 4242 individuals), Levant Sparrowhawk *Accipiter brevipes* (1.7%, 2455 individuals) and Eurasian Sparrowhawk *Accipiter nisus* (1%, 1450 individuals). The rest of the species ($n = 20$) were represented by less than 1% from the total of migrating raptors counted (Table 2).

No significant differences in the total abundance of raptors among the four survey stations were detected ($\chi^2 = 4.1$, df = 3, $P = 0.25$), nor in the abundance of Black Storks ($\chi^2 = 4.6$, df = 3, $P = 0.19$). Regarding the five most abundant raptor species, no significant differences were found among count points in the abundance of Common Buzzards ($\chi^2 = 2.0$, df = 3, $P = 0.57$), Levant Sparrowhawks ($\chi^2 = 1.1$, df = 3, $P = 0.76$) and Eurasian Sparrowhawks ($\chi^2 = 3.4$, df = 3, $P = 0.32$), but significant differences were found for Lesser Spotted Eagles ($\chi^2 = 17.4$, df = 3, $P < 0.01$) and Short-toed Eagles ($\chi^2 = 23.7$, df = 3, $P < 0.01$). *Post hoc* analysis revealed significant differences in the abundance of Lesser Spotted Eagles between Anadolu Kavağı and Büyük Çamlıca ($W = 274.5$, $P < 0.01$), Anadolu Kavağı and Kadıköy ($W = 282$, $P < 0.01$), Koç Park and Büyük Çamlıca ($W = 276$, $P < 0.01$) and lastly Koç Park and Kadıköy ($W = 288.5$, $P < 0.01$) survey stations. The abundance of Short-toed Eagles differed significantly between Anadolu Kavağı and Büyük Çamlıca ($W = 277.5$, $P < 0.01$), Anadolu Kavağı and Kadıköy ($W = 294.5$, $P < 0.01$), Koç Park and Büyük Çamlıca ($W = 297.5$, $P < 0.01$) and Koç Park and Kadıköy ($W = 306.5$, $P < 0.01$). All significant differences between the survey stations obtained during the *post hoc* analysis remained significant after adjusting the *P*-values using the Holm-correction.

In the present study, using a new survey station network, we report the highest number of migrating

Table 2. The complete list of species migrating at Bosporus recorded during the full study period. Individual abundances at the different survey stations present the total number of migrants observed including double counts. The overall abundances, which are corrected for double counts, are presented in the last column of the table.

	Survey station name				
Species name	Anadolu Kavağı	Koç Park	Büyük Çamlıca	Kadıköy	Total (corrected)
Raptors					
European Honey-buzzard *Pernis apivorus*	122	14	27	11	174
Griffon Vulture *Gyps fulvus*	30	28	2	1	55
Egyptian Vulture *Neophron percnopterus*	4	0	0	0	4
Common Buzzard *Buteo buteo*	6795	31765	12639	23133	74055
Long-legged Buzzard *Buteo rufinus*	2	1	19	2	24
Booted Eagle *Aquila pennata*	86	61	31	14	192
Eastern Imperial Eagle *Aquila heliaca*	0	2	1	1	4
Steppe Eagle *Aquila nipalensis*	0	2	0	1	3
Greater Spotted Eagle *Aquila clanga*	2	0	2	2	6
Lesser Spotted Eagle *Aquila pomarina*	17757	23 803	11829	7454	58327
Western Marsh Harrier *Circus aeruginosus*	6	6	32	5	49
Hen Harrier *Circus cyaneus*	1	1	0	0	2
Montagu's Harrier *Circus pygargus*	0	0	1	0	1
Pallid Harrier *Circus macrourus*	2	1	1	0	4
Black Kite *Milvus migrans*	1	8	24	9	42
Northern Goshawk *Accipiter gentilis*	0	0	0	2	2
Eurasian Sparrowhawk *Accipiter nisus*	274	438	371	374	1450
Levant Sparrowhawk *Accipiter brevipes*	35	112	509	1799	2455
Short-toed Eagle *Circaetus gallicus*	1928	1462	646	466	4242
White-tailed Eagle *Haliaeetus albicilla*	1	0	0	0	1
Peregrine Falcon *Falco peregrinus*	3	2	5	2	12
Common Kestrel *Falco tinnunculus*	3	0	3	1	7
Red-footed Falcon *Falco vespertinus*	27	18	42	18	105
Eurasian Hobby *Falco subbuteo*	22	10	13	12	57
Osprey *Pandion haliaetus*	1	0	0	0	1
Unidentified raptor *Rapaces* sp.	104	420	37	14	570
Total	27206	58154	26234	33321	141844
Non-raptors					
Black Stork *Ciconia nigra*	1717	6423	3479	5197	16088

raptors and Black Storks ever recorded on the Bosporus during the autumn season. We show that migration occurs with similar intensities over the full length of the strait, and individual migration patterns differ between species at local scale. According to our knowledge, formerly the highest numbers of raptors were counted by the Ornithological Society of Turkey (OST), at 75 176 individuals (as cited in Arslangündoğdu 2011). The highest number of Black Storks counted was 8 781 individuals (van den Bossche & Lens 1994) (Table 1). Furthermore, we document the highest numbers of Common Buzzards, Lesser Spotted Eagles, Short-toed Eagles and Eurasian Sparrowhawks migrating through the Bosporus to date.

The two most abundant raptor species were the Common Buzzard and the Lesser Spotted Eagle, which constituted together 93.3% of the total of raptors observed. Our results are in accordance with previous studies, which have reported both species as being the most abundant ones migrating over the Bosporus in the similar period (Porter & Willis 1968, van den Bossche & Lens 1994). The high numbers of migrating Common Buzzards and Lesser Spotted Eagles recorded during our study can be attributed to the timing of our observation period, which overlapped with the peak migration of both species (Porter & Willis 1968). The Short-toed Eagle, the Levant Sparrowhawk and the Eurasian Sparrowhawk were also abundant raptors, but much less so (in total 5.6% of the raptors observed) (Table 2), as has been reported in previous studies (Porter & Willis 1968, van den Bossche & Lens 1994). Although we have recorded a high numbers of individuals, compared to previous surveys, this can be attributed to us sampling the migration peak of the species only to a certain extent. Short-toed Eagles are the most abundant in a similar period (Porter & Willis 1968), but Levant Sparrowhawks migrate earlier (van den Bossche & Lens 1994, Arslangündoğdu 2011), and Eurasian Sparrowhawks migrate in low numbers during the whole autumn migration period, showing a peak in late October (Porter & Willis 1968). The rest of the raptor species were represented in low numbers. These species either migrate in other periods, unrecorded in our study (e.g. European Honey-buzzard *Pernis apivorus*), or their migration is not so concentrated over geographical bottlenecks (e.g. *Falco* spp. and *Circus* spp.).

Previously the vast majority of the studies have been focused in the area of Çamlıca Hills, due to the assumption that the majority of the soaring birds would pass the Bosporus by this route (Table 1). Contrary to these studies, but in agreement with van den Bossche & Lens (1994), we have shown that migration occurs over the full length of the Bosporus, with similar intensity at different regions, because we have found no significant differences in the total abundance of raptors and Black Storks when comparing our survey stations. Furthermore, the highest abundance of migrants was recorded over the area of Koç Park and not over the Çamlıca Hills. Among the five most abundant raptor species, we found that Lesser Spotted Eagles and Short-toed Eagles both preferred the Northern part of the strait to cross the Sea of Marmara. These results contradict Nisbet & Smout (1957), but are similar to those described by van den Bossche & Lens (1994), who observed large concentrations of migrating Lesser Spotted Eagles and also Short-toed Eagles at Sariyer, a point situated half way between our two northern survey stations, Anadolu Kavağı and Koç Park. The migration pattern of the species can be influenced by several factors: local weather and thermal conditions (Duerr *et al.* 2012), and species specific traits linked to body morphology: wing aspect ratio (wing span^2/wing area; Kerlinger 1985) and/or body size (Pennycuick 2008, Panuccio *et al.* 2013).

Future efforts should focus on laying the foundations of a long-term monitoring scheme over the Bosporus (as suggested by Leshem 1985). Systematic migration counts over similar geographical bottlenecks have proved to be a useful tool in estimating population trends of several raptor species (Bednarz *et al.* 1990, Agostini *et al.* 2007, Farmer *et al.* 2007). In the present study we provide the first evidence that such a scheme would be of outstanding value at the Bosporus. For example, we recorded 58 327 individual Lesser Spotted Eagles. The estimated number of individuals in Europe, where > 95% of its breeding range lays, is between 42 000 and 57 000 individuals (Bird Life International 2013). Taking into consideration that we did not cover the full migration period of the species, and a small proportion of individuals migrate also at the Eastern coast of the Black Sea, at Batumi (Verhelst *et al.* 2011), we suggest, that the population size of the species may be underestimated. Furthermore, our study has limitations, hence additional surveys are needed to consider the following aspects: (1) the observation period should be extended to cover the full autumn migration season from mid-August to the end of October, (2) the effect of weather conditions on the timing and pattern of soaring bird migration should be

determined precisely and (3) it should be tested whether more than four count points increase the amount and accuracy of the gathered data.

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