Observations of large-scale diurnal raptor migration in the Horn of Africa

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Summary: The Red Sea Flyway is the most important route for soaring birds migrating between Eurasia and Africa. The Bab el-Mandeb strait in Djibouti is the narrowest water crossing of the Red Sea and as such, acts as a critical migratory bottleneck at the entrance point into the Horn of Africa. Despite the global significance of this flyway, very limited observations of migratory birds have been made in the region. The importance of this area has been demonstrated via recent satellite tracking studies, but very little is known about the species composition or number of birds migrating through this region. We conducted road surveys and point counts for raptors across the interior of Ethiopia, Djibouti, and northern Somalia during the autumn migration season over seven years (2013–2019). Of note, large concentrations of Common (Steppe) Buzzards (2250–4325 individuals) were observed at four locations in Ethiopia. Threatened species, including Egyptian Vulture (Endangered), Steppe Eagle (Endangered), Pallid Harrier (Near Threatened), Eastern Imperial Eagle (Vulnerable) and Greater Spotted Eagle (Vulnerable), were observed across the Horn of Africa. Our surveys highlight the Horn of Africa, and particularly the interior of Ethiopia, as an important region for migratory soaring birds using the Red Sea Flyway. Although logistical issues meant that we could not undertake sufficient monitoring at the Bab el-Mandeb strait, we urge further targeted monitoring in this area in order to facilitate conservation of this important migratory pathway. Although these surveys represent preliminary work, our findings could be used as a baseline for further studies to identify important migration corridors and to focus conservations efforts, particularly in light of the rapid development of electrical and wind energy infrastructure, and habitat loss from human and livestock pressures.

INTRODUCTION

Description of bird species' migratory pathways is of fundamental significance in the characterization of their behaviour, population, and conservation status (Berthold 2001, Newton 2008). Many large birds rely on soaring flight, and thus are reliant on wind currents and thermal dynamics for their migrations. Accordingly, migratory birds often concentrate at geographic bottlenecks that funnel avian migration, such as along mountain ridges or along coastlines and straits so that water crossings can occur at the narrowest point. These migratory bottlenecks enable biologists to observe and monitor bird populations that may range across continents during the rest of the year (Bildstein 2006). Migration monitoring can thus allow detection of changes in the population size of species which occur over large geographic areas (Martín *et al* 2016, Sullivan *et al* 2016). Such migration monitoring is especially common for migratory diurnal raptors (Bildstein 2006). There is an extensive network of raptor migration monitoring sites worldwide at important bottlenecks (Zalles & Bildstein 2000), with some preeminent sites, such as Veracruz in Mexico, exhibiting migration of many millions of individual raptors each season (Bildstein 2006).

While providing a unique opportunity to study bird populations, migration bottlenecks are also sites where birds are at significant risk. When species concentrate within small geographic areas during migration, disruption, persecution, and environmental degradation can affect the status of populations breeding and wintering across broad geographic areas (Runge *et al* 2015, Sandor *et al* 2017). Because migratory species depend on a suite of interconnected sites, human impact on individual hotspots can lead to population declines of migrants around the world (Runge *et al* 2015). This is of particular concern in regions such as the Horn of Africa, where migrating birds are highly concentrated but migration routes and raptor populations are relatively little studied (Kirby *et al* 2008, Rayaleh *et al* 2013, Polakowski *et al* 2014). Thus, for the successful conservation of migratory

bird species, it is very important that migratory bottlenecks be identified and properly protected (Buechley *et al* 2018b).

The Red Sea Flyway is regarded as the second most important migratory flyway for soaring birds in the world and the most important route for Palearctic soaring birds migrating between Eurasia and Africa (UNDP 2006). However, it is likely also the least studied major flyway in the world (UNDP 2006). The Bab el-Mandeb strait, which forms the narrowest water crossing of the Red Sea, acts as a critical bottleneck for birds migrating between Africa and Eurasia. It is estimated that some 1.5 million soaring birds of at least 37 species, including ten globally threatened species, regularly cross the Bab el-Mandeb strait each year (Welch & Welch 1988, Rayaleh *et al* 2013). As a result, the Horn of Africa is the entrance point to Africa for many migratory soaring birds, and is thought to host one of the largest concentrations of migrating birds in the world (Bildstein 2006). The region's global significance as an important migratory flyway has been established through relatively sparse count data at the Bab-el-Mandeb strait (Welch & Welch 1989, 1988, Rayaleh *et al* 2013) and with a few very limited observations in Ethiopia (Vittery 1983) and Eritrea (Smith 1960), as well as more recent satellite tracking studies (*eg* Meyburg *et al* 2003, Javed *et al* 2011, Tøttrup *et al* 2012, Rayaleh *et al* 2013, Horns *et al* 2016, Buechley *et al* 2018a). However, very little is yet known about the specific routes, timing, and species composition of soaring bird migration through the Horn of Africa.

Here, we summarize observations of Palearctic migrant raptors during the autumn migration season over seven years (2013–2019) of ornithological research and exploration of the Horn of Africa. Our specific aims are to: (1) summarize the location and species composition of observed large-scale concentrations of soaring raptors in the Horn of Africa; (2) contextualize these findings relative to what else is known about raptor migration in the region, and (3) provide recommendations for future research.

METHODS

Between 2013 and 2019 we conducted road surveys and point counts for raptors across the interior of Ethiopia, Djibouti, and northern Somalia (*ie* Somaliland) during the autumn migration months (August–December). The aim of these surveys was to document the distribution and abundance of all raptor species in the Horn of Africa, and not solely to identify migration bottlenecks. Road surveys took place over seven seasons in Ethiopia (2013–2019), two seasons in Somalia (2015–2016), and one season in Djibouti (2017). During road surveys, two experienced individuals surveyed for raptors while driving in a Toyota Landcruiser at speeds of <60 km per hour during daylight hours. Surveyors aimed to identify all perched and flying raptors within 1 km of the road. When a large group of raptors was observed, the road survey was paused and a point survey was initiated at that location. During point surveys, we logged the species, count, and, when possible, age and sex of raptors following standard methodologies (Bird & Bildstein 2007).

We also attempted to establish a long-term raptor migration count station at the narrowest crossing from the Arabian Peninsula to the Horn of Africa; the Bab-el-Mandeb strait in Djibouti (Ras Siyan Peninsula; 12.4813 N, 43.3158 E) in autumn of 2017, but because of rapidly evolving security concerns along the Djibouti-Eritrea border, we were only permitted one visit to the site on 7 September 2017. Additionally, we spent two days (25–26 September 2017) doing targeted point-surveys for migrant raptors near the town of Abomsa, Ethiopia (8.5845 N, 39.850 E), a site which was pre-determined to be geographically favorable for the facilitation of raptor migration (ie where the Great African Rift valley escarpment funnels to a narrow point in central Ethiopia). Lastly, we also recorded incidental observations of raptors seen by the authors that occurred during fieldwork outside of structured point or road-surveys.

For our aims here, we defined migratory raptor concentrations from our extensive road, point, and incidental observations of raptors throughout the region as locations with 20 or more individuals of any Palearctic migrant raptor species (Table 1). We excluded raptor species that reside within Africa (*ie* non-migratory or inter-African migrants) from this analysis. We then summed the count of each species observed within a 10-km radius on the same date and any counts on the same date with over-lapping 10-km radius buffers. We tabulated the species composition and abundance at the significant migratory raptor concentrations and mapped the large migratory raptor congregations using the packages 'raster' (Hijmans 2019), 'rgeos' (Bivand & Rundel 2019) and 'mapplots' (Gerritsen 2018) in R (R Core Team 2016).

Table 1. Total number of migratory raptors observed per country. Conservation status (Cons. status) abbreviations: LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered.

Species	Scientific name	Cons. status	Ethiopia	Djibouti	Somalia	Total
Common Buzzard	*Buteo buteo vulpinus*	LC	14 451			14 451
Black Kite	*Milvus migrans*	LC	3038	7		3045
Egyptian Vulture	*Neophron percnopterus*	**EN**	392	61	57	510
Lesser Kestrel	*Falco naumanni*	LC	77		2	79
Steppe Eagle	*Aquila nipalensis*	**EN**	37	2	13	52
Pallid Harrier	*Circus macrourus*	**NT**	29			29
European Honey-buzzard	*Pernis apivorus*	LC	24	4		28
Montagu's Harrier	*Circus pygargus*	LC	20	2	1	23
Peregrine Falcon	*Falco peregrinus*	LC	19	2		21
Booted Eagle	*Hieraaetus pennatus*	LC	19			19
Short-toed Snake-eagle	*Circaetus gallicus*	LC	15	2		17
Eurasian Hobby	*Falco subbuteo*	LC	12			12
Long-legged Buzzard	*Buteo rufinus*	LC	7			7
Osprey	*Pandion haliaetus*	LC	4	2		6
Amur Falcon	*Falco amurensis*	LC	3			3
Eurasian Sparrowhawk	*Accipiter nisus*	LC	3			3
Levant/Eurasian Sparrowhawk	*Accipiter brevipes/ nisus*	LC	2			2
Eastern Imperial Eagle	*Aquila heliaca*	**VU**	1			1
Greater Spotted Eagle	*Clanga clanga*	**VU**	1			1
Levant Sparrowhawk	*Accipiter brevipes*	LC	1			1
Lesser/Greater Spotted Eagle	*Clanga pomarina/ clanga*	LC/VU	1			1
			18 156	**82**	**73**	**18 311**

RESULTS

In total, 18 482 km of road surveys were completed throughout the Horn of Africa (Ethiopia 16 302 km; Djibouti 177 km; Somalia 2003 km). From all surveys, a total of 18 311 migratory raptors were recorded (Table 1), of which 15 528 were in congregations of 20 or more individuals of the same species (Figure 1, Table 2).

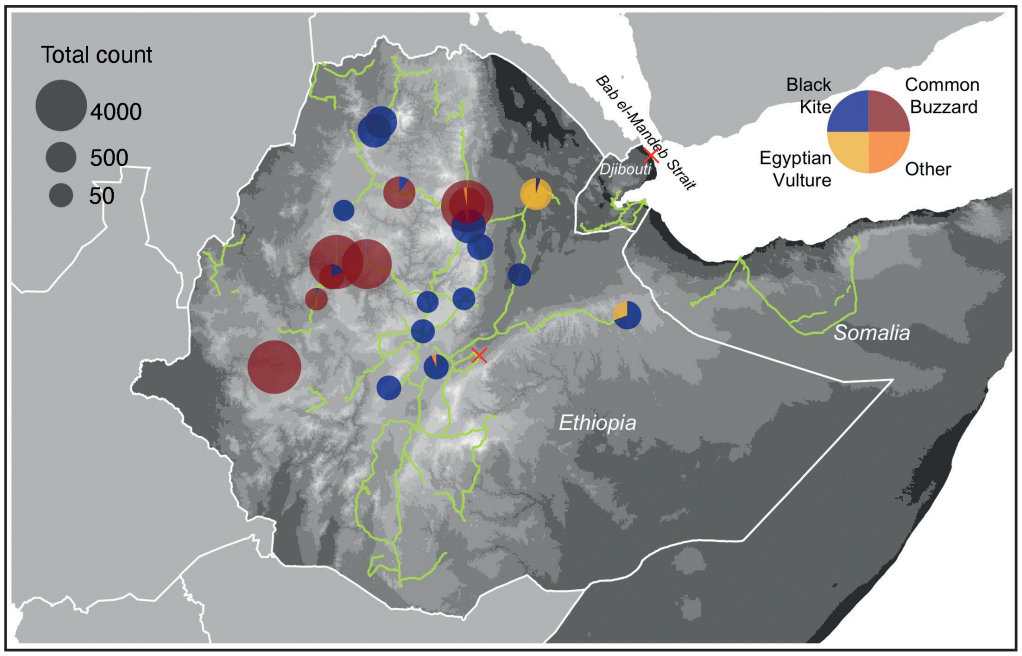

Figure 1. Raptor surveys in the Horn of Africa during autumn (southwards) migration, 2013–2019. Topography (grey-scale; paler indicates higher altitudes) is shown for Ethiopia, Djibouti and Somalia. Road survey routes are shown in green. The location of the Ras Siyan Peninsula, Djibouti and Abomsa, Ethiopia, which were sites that were pre-determined to be geographically favorable for migration are shown by red crosses. Large-scale counts including more than 20 individuals of any Palearctic migrant raptor species are shown as pie charts, centered on the survey location. Pie sizes are scaled by the logarithm of total counts at each location.

We recorded 22 large-scale concentrations of migratory raptors (Figure 1). Of note, four hotspots with particularly large congregations were recorded which mainly consisted of Common (Steppe) Buzzards *Buteo buteo vulpinus* (2250–4325 individuals, Table 2). In addition, nine other migratory raptor species were observed at these sites, including at least one Greater Spotted Eagle *Clanga clanga*, which is listed as globally Vulnerable. Large concentrations of Black Kites *Milvus migrans* (Plate 1) were observed throughout the surveyed region (Figure 1), with group sizes generally smaller than that of buzzards (up to 194 individuals). Concentrations of 25–135 Egyptian Vultures *Neophron pernopterus* (Endangered; Plate 2) were seen at three locations in north-eastern Ethiopia. The largest two of these congregations (39 and 135 individuals) were observed in 2013 and 2015, respectively, at similar locations in the Afar Region of north-east Ethiopia, which is known to be an important overwintering site for this species (Arkumarev *et al* 2014, Buechley *et al* 2018a).

Table 2. High counts of Palearctic migrant raptors in the Horn of Africa during autumn (southwards) migration, 2015–2019. Only counts with 20 or more individuals of any one species are shown. `Other` includes small numbers (up to six individuals of at any time) of Peregrine Falcon, Booted Eagle, Eurasian Hobby, European Honey-buzzard, Greater Spotted Eagle, Lesser Spotted Eagle, Lesser Kestrel, Long-legged Buzzard, Osprey, Levant Sparrowhawk and Eurasian Sparrowhawk.

Date	Latitude	Longitude	Common Buzzard	Black Kite	Egyptian Vulture	Other	Total
2017/10/12	10.410	37.021	4325	9	0	2	4336
2019/10/15	8.343	35.816	4000	0	0	0	4000
2017/09/29	11.507	39.617	3311	11	0	5	3327
2017/10/07	10.372	37.627	2250	12	0	2	2264
2017/09/30	11.524	39.612	253	1	0	8	262
2017/09/28	11.116	39.645	8	194	0	0	202
2017/10/08	12.986	37.766	7	175	0	3	185
2017/10/12	11.774	38.267	132	15	0	0	147
2015/08/31	11.740	40.989	0	6	135	0	141
2017/10/08	13.153	37.899	0	141	0	0	141
2015/08/26	9.352	42.772	0	56	25	0	81
2017/09/27	10.710	39.875	0	57	0	0	57
2017/10/04	8.359	39.000	0	45	0	4	49
2017/10/12	10.118	36.930	40	9	0	0	49
2015/09/25	7.948	38.069	0	46	0	0	46
2017/09/22	9.059	38.738	0	41	0	0	41
2013/11/25	11.714	40.969	0	1	39	0	40
2017/09/25	9.695	39.549	0	35	0	0	35
2013/11/24	10.162	40.653	0	35	0	0	35
2017/10/13	9.679	36.632	32	1	0	0	33
2017/10/05	9.633	38.831	0	30	0	0	30
2014/10/31	11.421	37.163	0	27	0	0	27
			14 358	**947**	**199**	**24**	**15 528**

Plate 1. Black Kite *Milvus migrans* of the subspecies *lineatus*, Ethiopia. © *Evan Buechley*

Plate 2. Immature Egyptian Vulture *Neophron percnopterus*, Ethiopia. © *Evan Buechley*

Unfortunately, the amount of time that we spent at the two point-count locations that were either known to be or predetermined to likely be bottlenecks for migrant Palearctic raptors, Ras Siyan Peninsula in Djibouti and Abomsa in Ethiopia, was very limited. We could only visit the Ras Siyan Peninsula once on 2 September 2017, from 09:09 to 11:39 hours, during which time period we logged only four raptors (two Peregrine Falcons *Falco peregrinus*, one Montagu's Harrier *Circus pygarus*, and one Osprey *Pandion haliaetus*). Meanwhile, over two partial days (25–26 September 2017) of observation at Abomsa, no Palearctic migrant raptors were recorded.

DISCUSSION

The Horn of Africa is a critical region for the migration of soaring raptors between Eurasia and Africa, but the specifics of migration in the area have been little studied. Our survey results indicate that large concentrations of migratory soaring raptors occur over much of Ethiopia. However, our findings represent preliminary work and our lack of observed congregations is not evidence of a lack of an important bottleneck or flyway in any particular location. Rather, we urge further targeted monitoring of raptor migration in the region, in order to map hotspots and migratory pathways in this ecologically important region. Gaining a better understanding of the factors influencing these migration corridors could prove crucial in facilitating their conservation.

Common Buzzard was, by far, the most frequently recorded migrant raptor in our surveys. The steppe subspecies *Buteo buteo vulpinus*, which is what we exclusively recorded in our observations, breeds in Eurasia and spends the winter south of the Sahara in Africa (del Hoyo *et al* 2018). The species has previously been recorded migrating in very large numbers in autumn via the Bab-el-Mandeb strait, Djibouti (Welch & Welch 1988), where, over a 17-day period in 1985 (15 October–1 November) and a 34-day period in 1987 (3 October–9 November), 17 875 and 98 339 individuals were observed migrating, respectively. Our observations of 14 451 migrating Common Buzzards provides some interesting additional information on the species' migration through the region, given

that most observations occurred in northern or western Ethiopia, at sites far from the Bab-el-Mandeb strait. It is unclear whether these groups crossed into Africa via the Bab-el-Mandeb strait, whether they migrated south through Egypt and Sudan after crossing the Sinai Peninsula, or perhaps are a mixture of both. Records of congregations of migratory raptors further north in Eritrea (Smith 1960) suggest that at least some may be originating from a Sinai passage. However, satellite tracking of Steppe Eagles has shown that at least some individual raptors may migrate via Bab-el-Mandeb and then travel north into Eritrea, before dispersing elsewhere into Africa (Meyburg *et al* 2012, 2003).

Common Buzzards rely heavily on soaring flight during migration (Spaar & Bruderer 1997), and it was therefore expected that they would congregate along the predominantly north-south mountain ridges along the Rift valley, where orographic uplift could facilitate their migration. This was consistent with one large concentration of migrating Common Buzzards in northern Ethiopia, near the town of Wichale (11.507 N, 39.617 E), where buzzards were migrating along a north-south escarpment. However, the other large concentrations of Common Buzzards that we observed occurred in locations lacking such features. The species is also able to use thermal uplift for soaring migration when conditions are right, which is likely to facilitate a broad-front migration through the region.

Egyptian Vulture and Black Kite were the two other Palearctic migrant raptor species most commonly recorded in large congregations in our surveys. However, it is important to note that both of these species have conspecific resident populations in Africa, and we could not be certain of the origin of individuals surveyed. Further, most observed congregations of these two species were not exhibiting migratory behavior, and were seen around towns and potential feeding sites, with the exception of two large directional migratory movements of Black Kites in the Simien mountains in northern Ethiopia, near the towns of Debark (13.153 N, 37.899 E) and Dabat (12.986 N, 37.766 E) (Table 2). Our observations of large congregations of Egyptian Vultures, an Endangered species, in north-eastern Ethiopia augment other findings showing the importance of this region for the species (Arkumarev *et al* 2014, Buechley *et al* 2018a), and thus we encourage further work to promote the conservation of the species there (Bakari *et al* 2020).

We did not observe large congregations of migratory raptors in locations which we predicted would act as bottlenecks along migration corridors based on geography, including the Rift Valley. The Rift Valley is thought to act as an important corridor for raptors along the Eurasian-East African Flyway in their southerly autumn migration (Newton 2008), and the natural funnel created by the narrowing of the Rift Valley would be expected to concentrate soaring migratory birds following their passage of the Bab el-Mandeb strait. However, the maximum count in this predicted bottleneck region was only 49 individuals, including 45 Black Kites (4 October 2017; Table 2). Our targeted observations at a site pre-selected to be at a position that had key features of a migratory bottleneck near the town of Abomsa, Ethiopia, yielded no observations of Palearctic migrant raptors, although observations only took place over two days in September. Nonetheless, previous limited monitoring of raptor migration that occurred in the Ethiopian Rift valley in the 1970s documented fairly large movements of Palearctic migrant raptors, particularly Common Buzzards and Black Kites (Vittery 1983), with that author estimating that in excess of 10 000 Palearctic raptors pass through the Rift valley in autumn, with smaller concentrations in spring. We thus encourage further targeted observations of migration in the Rift valley to better identify potential concentration sites, as well as species composition, abundance, and phenology of migration.

Although large-scale raptor migration concentrations were not recorded at the sites closest to the Bab-el-Mandeb strait, relatively few surveys were performed in Djibouti (three points counts and 177 km of road surveys), during a limited time (31 August–17

September 2017). Nevertheless, eight species were observed in this region, including a significant number of Egyptian Vultures, which was both the most frequently recorded species in the region and also the most threatened (Table 1). Unfortunately, we were only allowed a partial day visit to the Ras Siyan Peninsula at the Bab-el-Mandeb strait on 2 September 2017, during which time period we logged only four raptors. But this in no way detracts from the fact that the Bab-el-Mandeb strait is one of the largest migratory bottlenecks for soaring birds in the world, as evidenced by previous survey work (Welch & Welch 1989, 1988, Rayaleh *et al* 2013).

Although these surveys do not provide robust information on raptor migratory routes in the Horn of Africa, they represent a large body of exploratory work investigating the distribution and abundance of raptors throughout the Horn of Africa. Due to the nature of these surveys, they only occasionally covered the same stretches of road in different years. However, there was some indication that raptor congregations were consistent between years. For example, two of the large-scale congregations of Egyptian Vultures occurred in approximately the same location in different years (2015, 2017). We encourage further studies to identify important migration corridors and focus conservation efforts, particularly as human development is increasing rapidly, introducing new threats including the installation of electrical infrastructure, development of wind energy, and habitat loss. Long-term population monitoring at important migration locations will also be relevant to monitor and detect changes in population trends, as is done at other globally significant raptor migration sites.

In particular, we recommend that full-season migration counts (in both autumn and spring) be completed at the Bab-el-Mandeb strait, which is expected to be one of the largest bottlenecks for migratory soaring birds in the world (UNDP 2006). Such counts would fill out the picture of migration at this bottleneck that was outlined with groundbreaking partial season counts during survey work in the 1980s (Welch & Welch 1988, 1989). Second, we encourage a collaborative study pooling satellite tracking data from migratory soaring birds using the Red Sea Flyway, in order to identify migratory bottlenecks, as was recently done for the Egyptian Vulture (Buechley *et al* 2018b). We also encourage additional targeted observations of raptor migration at potential migratory bottleneck sites in Ethiopia, including in the Rift Valley, where significant congregations were observed in the past (Vittery 1983), and along the northern escarpment, perhaps particularly near the town of Wichale (11.507 N, 39.617 E), an important site identified here. Besides bottlenecks, it is clear that mountainous areas such as the Ethiopian highlands are used heavily by migratory raptors. Such areas are also likely to be targeted for wind energy development and further quantification of this potential conflict would be useful. Finally, we urge that environmental impact assessments related to all energy infrastructure development carefully consider raptor migration and conduct pre-construction monitoring for migratory soaring birds in peak migration seasons.

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Editor's note: The Horn of Africa falls outside the OSME region, but this article is being published in *Sandgrouse* because the observations it describes clearly relate to a migratory flyway that has its origins in the OSME region. This decision has been agreed with the Editor of the *Bulletin of the African Bird Club*, to whom other papers on the birds of this region should be submitted.