Globally important proportions of six raptor populations migrate past Galala Bird Observatory, Egypt, in spring

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Summary: Monitoring raptors along migration corridors can be used to assess changes in population size, migration phenology and reproductive output. Along the East African-Eurasian flyway, several migratory bottlenecks exist where a large number of migratory soaring birds congregate during migration. Based on extensive monitoring experience in the region and using evidence from satellite-tracked Egyptian Vultures *Neophron percnopterus*, we established a new observatory at the well-known spring migration bottleneck along the northern Red Sea coast near Galala, Egypt. In March 2022, we explored nine localities around the newly built city of Galala to evaluate for which species long-term migration monitoring would be valuable in this area. We found that locations on top of the Galala plateau offered consistently better observation conditions over a broad range of meteorological conditions than a previous location along the coast. Within six weeks we observed >1200 Egyptian Vultures, >300 000 Steppe Buzzards *Buteo buteo vulpinus*, and >10 000 Steppe Eagles *Aquila nipalensis* and Lesser Spotted Eagles *Clanga pomarina*. Long-term raptor monitoring at three points to the east, north, and west of the city of Galala would require 2–4 observers at each point from mid-February until late April. Together, these observation points would allow the monitoring of globally significant proportions of the eastern Europe and western and central Asia populations of Lesser Spotted Eagle (25–37%), Steppe Eagle (23–32%), White Stork *Ciconia ciconia* (10%), Steppe Buzzard (6–11%), Egyptian Vulture (3–10%), Short-toed Snake Eagle *Circaetus gallicus* (3–6%), Black Stork *Ciconia nigra* (3–5%) and Black Kite *Milvus migrans* (2–4%).

INTRODUCTION

Many raptor species around the world are declining (McClure *et al* 2018, Cruz *et al* 2021), but monitoring population changes of raptors can be logistically difficult because most species have large home ranges and breed at low densities in sometimes remote localities. For migratory species, counts at migratory bottlenecks can provide useful indices of population size for a given region, and require much lower effort than breeding season surveys covering large areas (Farmer *et al* 2007, Jobson *et al* 2021, Panuccio *et al* 2021).

For birds from western Palaearctic breeding grounds that winter in Africa, the northern Red Sea coast of Egypt is a well-known bottleneck during spring migration (Porter & Beaman 1985, Hilgerloh 2009, Megalli & Hilgerloh 2013). Birds that winter across a large area of sub-Saharan Africa migrate north-east until they meet the Red Sea, and then follow the western Red Sea coastline to the northern tip of the Red Sea at Suez (Buechley *et al* 2018, Phipps *et al* 2019, Panuccio *et al* 2021). Previous counts of migratory birds in this area indicate that the region is likely to be of global importance (>1% of flyway population) for Lesser Spotted Eagle *Clanga pomarina*, Steppe Eagle *Aquila nipalensis*, Short-toed Snake Eagle *Circaetus gallicus*, and Egyptian Vulture *Neophron percnopterus* (Jobson *et al* 2021). Monitoring raptors along this flyway can therefore provide useful indices of the size of eastern European and western Asian populations for several species of conservation priority.

Recent research using bird tracking devices has shown that the migratory tracks of many individual Egyptian Vultures converge just south of Suez over the North Galala plateau (Buechley *et al* 2018, Phipps *et al* 2019, Oppel *et al* 2022). In this particular area, an exhaustive count of migratory soaring birds over two months in the spring of 2012 at Ayn Sokhna recorded 183 275 migratory soaring birds of 28 species during 310 hours of observation (Megalli & Hilgerloh 2013). However, the observation site used in 2012 was based at sea level at the base of the mountains of the Northern Galala plateau, and observers noted that from 11:00 hrs onwards many birds migrated too high or were obscured by cliffs and peaks of the plateau (Megalli & Hilgerloh 2013). Since 2015, a new urban city (Galala city) has been constructed by the Egyptian government in the Eastern Desert on the Northern Galala plateau, including major access roads from Cairo, Ayn Sokhna, and the south (Abdelazeem *et al* 2019, Mahgoub 2022, Ogila *et al* 2022). This new infrastructure now facilitates easy access to montane vantage points that had not been accessible in 2012 but could considerably improve the proportion of visible migration.

In March 2022, we conducted exploratory work around the new city of Galala to identify monitoring locations that could capture the majority of migratory soaring birds passing through this region. We first explored a range of potential observation sites and then counted migratory soaring birds from three observation stations that could comprise the new Galala Bird Observatory network. This work provides guidance on where and how long-term raptor monitoring could be implemented at Galala, and for which migratory species globally important proportions of their respective populations could be monitored to estimate population trends.

METHODS

Study region

The Northern Galala plateau extends for about 80 km from east to west and reaches an elevation of 750 m above sea level only *c*3 km from the coast of the Red Sea (Figure 1). The towering cliffs of the eastern margin of the plateau provide orographic and thermal uplift to migratory soaring birds, thus facilitating very efficient travel during northbound migration (Porter & Beaman 1985, Hilgerloh *et al* 2011, Megalli & Hilgerloh 2013).

Selection of potential raptor migration monitoring sites

We began observations on a rocky desert ridge that has been designated by the Egyptian government as a birdwatching area, and had proved to be a suitable vantage point in previous explorations by the authors ('Galala Bird Observatory' in Figure 1, hereafter referred to as 'the observatory'). This ridge is located high above the new highway from the Red Sea coast to Galala City, at an elevation of 690 m above sea level but only 2.8 km from the coast of the Red Sea. The ridge offered excellent views in all directions and facilitated the observation of birds migrating northwards on either the eastern (coastal) or western (inland) side of the ridge, both above and below the level of the vantage point.

After several days of watching migration from the observatory, we began to explore alternative and complementary vantage points based on where migration streams of raptors had been observed, local topography and ease of access (Table 1, Figure 1).

We first explored two points on either side of the observatory ridge but at a lower elevation (400–500 m asl) to avoid missing migratory birds passing below the observatory, as these birds can be difficult to detect against the background of rocky desert and built-up areas. We then explored four further points at the southern escarpment of the Galala plateau, ranging in elevation from 650 to 1250 m asl, where we expected migrating raptors to gain altitude when arriving from the lowland desert areas to the south. Finally, we explored points to the north and north-west of Galala City to capture streams of migrating birds that followed the western slope of an interior mountain range and were therefore too far west to be counted from the observatory.

During all exploratory observation days, we retained at least one observer at the observatory as a reference count, and we maintained phone contact to evaluate whether birds counted from one observation point were visible or counted from any other simultaneously active observation point.

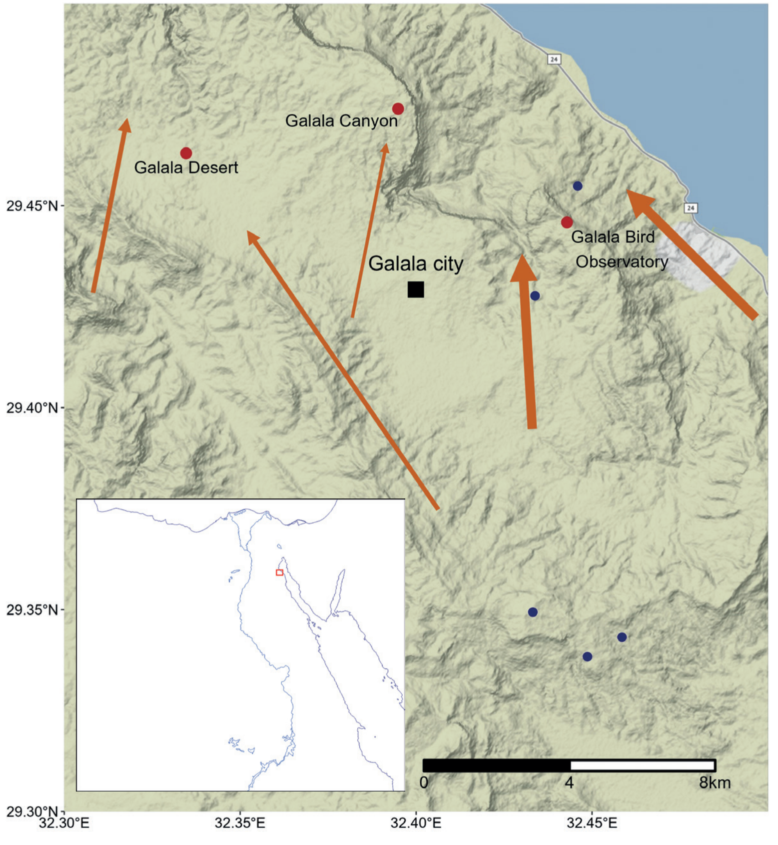

Figure 1. Detailed map of the North Galala plateau (Egypt) surrounding the newly built Galala City where we explored bird migration observation sites during spring migration in 2022. Blue points indicate observation points that were explored but eventually discarded, red points indicate the locations eventually retained to form the network of the Galala Bird Observatory (Table 1). Orange arrows indicate major flight-lines of soaring migratory birds.

Table 1. Coordinates (decimal degrees, WGS84 datum), elevation (m above sea level), observation effort (duration of observations) and total number of soaring migratory birds at nine observation points explored within the vicinity of Galala. These observation points were selected based on preliminary information from satellite-tracked individuals, local topography, accessibility, and observations of typical migration corridors. The three main points are indexed with their four-digit ID number on www.trektellen.org, where all data are available.

Location	Longitude	Latitude	Elevation (m)	Effort (hrs)	Number of soaring birds
Galala Bird Observatory (3335)	29.45	32.44	700	356.1	353 649
Galala Desert (3356)	29.46	32.33	520	81.4	24 398
Galala Canyon (3355)	29.47	32.39	800	54.8	6174
Galala test6	29.34	32.46	650	5.3	224
Galala test4	29.43	32.43	500	0.9	287
Galala test2	29.35	32.43	850	2.0	125
Galala test5	29.34	32.45	700	1.1	52
Galala test8	29.34	32.39	1250	1.2	25
Galala test3	29.45	32.45	350	0.5	1

Field data collection

We used standard raptor migration monitoring guidelines (Bildstein *et al* 2007, Vansteelant *et al* 2020) to record soaring migratory birds passing our observation locations. We collected data on migrating birds between 1 March and 20 April 2022, with daily observations occurring between 08.00 and 18.00 h local time, except on days when migration intensity was low or logistical difficulties prevented monitoring activities for certain parts of the day (see Table 1 for details on temporal effort). We continuously scanned the sky both above and below the vantage points with the naked eye and 8× or 10× binoculars. All migrating raptors and other large soaring migratory birds (storks, pelicans, cormorants) were recorded when they passed the observation point with the Trektellen app on mobile phones (Troost & Boele 2019) using the 'storks and raptors' protocol. Birds that could not be identified with binoculars were either photographed with telephoto lens cameras for identification, or identified using 30–60× spotting scopes. Birds that could not be identified on images or with a spotting scope were recorded as 'unidentified raptors' or to the highest taxonomic unit possible (*eg* 'unidentified eagle'). For Egyptian Vultures, we recorded the age class of all clearly visible individuals based on the extent of white in their plumage as either adults, immatures or juveniles.

We recorded the number of observers and the actual observation effort for every hourly monitoring interval. Due to the temporally varying number of available observers (2–8 throughout the six weeks) and the temporally varying intensity of migration, we were unable to consistently record data from all eventually chosen observation points simultaneously (Figure 1). On days when multiple locations were monitored simultaneously, care was taken to avoid double-counting of any birds by matching time and location of flight paths from detailed observer records or by direct communication between adjacent observation points.

RESULTS

We recorded >350 000 migratory birds of 29 species within six weeks. The most abundant species were Steppe Buzzard *Buteo buteo vulpinus*, White Stork *Ciconia ciconia*, Black Kite *Milvus migrans*, and three eagle species (Table 2). We also observed >1200 Egyptian Vultures, and of the 1149 individuals whose age was recorded, 1057 (93.2%) were in adult plumage.

The intensity of migration and species composition varied over the course of the six-week observation period. In early March, the migration volume was dominated by Steppe Eagles, followed by the peak of Lesser Spotted Eagle, Short-toed Snake Eagle and Egyptian Vulture between 19–24 March (Figure 2). The peak migration period for Black Kites was in late March, and for Steppe Buzzards in early April, even though this species was also the most common species throughout March (Figure 2). Similarly, temporal variation in migration intensity was high even within days, with some days experiencing consistent migration throughout the entire day, while on other days with similar conditions migration either started late or ended in the middle of the day (Figure 3).

Migrating birds generally followed the coast of the Red Sea in a north-westerly direction, and soaring birds used the coastal-facing cliffs for orographic uplift to gain altitude. However, despite our observation points being >500 m above sea level, many birds migrated very high above observers and an unknown number of birds will have been missed because they migrated too high or were too far west (inland) from the respective observation points.

At the main observatory, several distinct flight lines were evident, with one corridor along the coast (beneath the observatory) and another to the west leading into the canyon between the observatory and Galala city (Figure 1). During simultaneous observations

Table 2. Number of migratory soaring birds observed around Galala between 1 March and 20 April 2022 (summed across all points). The comparison number from 2012 is based on observations at Ayn Sokhna (sea level) obtained by Megalli *et al* (2012) between 1 March and 2 May 2012.

Species		**2022 (6 weeks)**	**2012 (8 weeks)**
Northern Steppe Buzzard	*Buteo buteo vulpinus*	224 566	116 560
White Stork	*Ciconia ciconia*	70 264	27 030
Black Kite	*Milvus migrans*	41 324	10 024
Steppe Eagle	*Aquila nipalensis*	15 851	8837
Lesser Spotted Eagle	*Clanga pomarina*	14 773	6536
Short-toed Snake Eagle	*Circaetus gallicus*	5839	5301
European Honey Buzzard	*Pernis apivorus*	4573	595
Egyptian Vulture	*Neophron percnopterus*	1258	1128
Black Stork	*Ciconia nigra*	1168	1438
Unidentified eagle species		1087	2301
Booted Eagle	*Hieraaetus pennatus*	962	1177
Eurasian Sparrowhawk	*Accipiter nisus*	625	512
Great Cormorant	*Phalacrocorax carbo*	483	
Long-legged Buzzard	*Buteo rufinus*	372	322
Levant Sparrowhawk	*Accipiter brevipes*	138	67
Western Marsh Harrier	*Circus aeruginosus*	101	24
Greater Spotted Eagle	*Clanga clanga*	83	57
Eastern Imperial Eagle	*Aquila heliaca*	66	43
Western Osprey	*Pandion haliaetus*	48	34
Common Kestrel	*Falco tinnunculus*	45	106
Common Buzzard	*Buteo buteo buteo*	27	
Pallid Harrier	*Circus macrourus*	24	
Great White Pelican	*Pelecanus onocrotalus*	23	500
Montagu's Harrier	*Circus pygargus*	16	15
Sooty Falcon	*Falco concolor*	5	
Eurasian Griffon Vulture	*Gyps fulvus*	3	5
Lesser Kestrel	*Falco naumanni*	3	9
Peregrine	*Falco peregrinus*	3	
Eurasian Hobby	*Falco subbuteo*	1	2
Crested Honey Buzzard	*Pernis ptilorhynchus*	1	

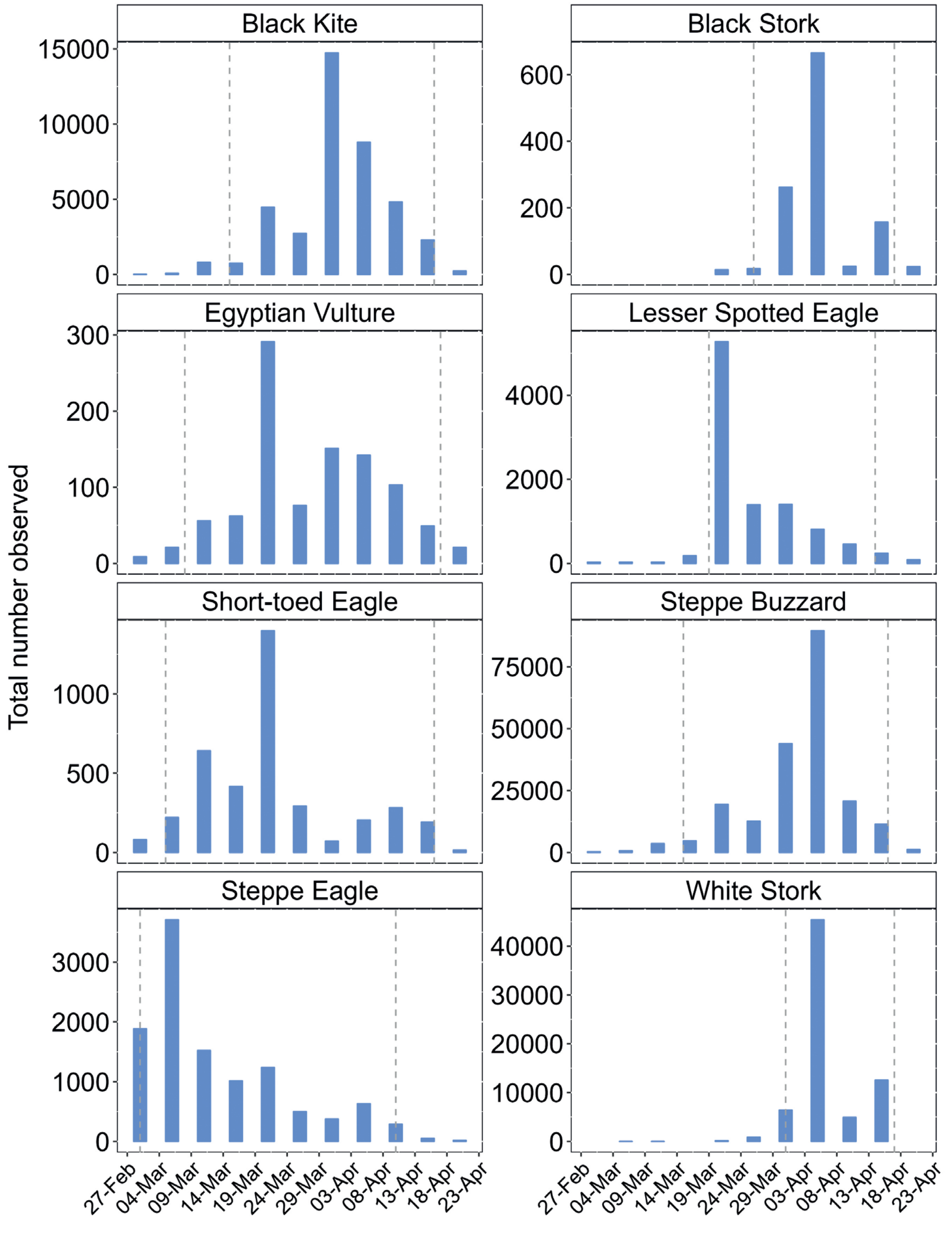

Figure 2. Migration phenology at Galala Bird Observatory in spring 2022 for the eight species for which the total number observed exceeded 2% of the estimated global population. Total numbers of observed birds per species are summed over 5-day periods, using only observations from the Galala Bird Observatory point to avoid the confounding effects of observer coverage. Dashed vertical lines demarcate the time window during which 95% of the total migration was recorded.

from the main observatory and at Galala Canyon on 12, 13, 17 and 19 March, no evidence was found that birds that were counted at Galala Bird Observatory were also counted at Galala Canyon. These two points can therefore complement each other without significant overlap, as long as observers count only birds that are visible without the aid of a spotting scope. Simultaneous observations from Galala Canyon and Galala Desert on 17 March revealed no double-counting of birds observed at either station.

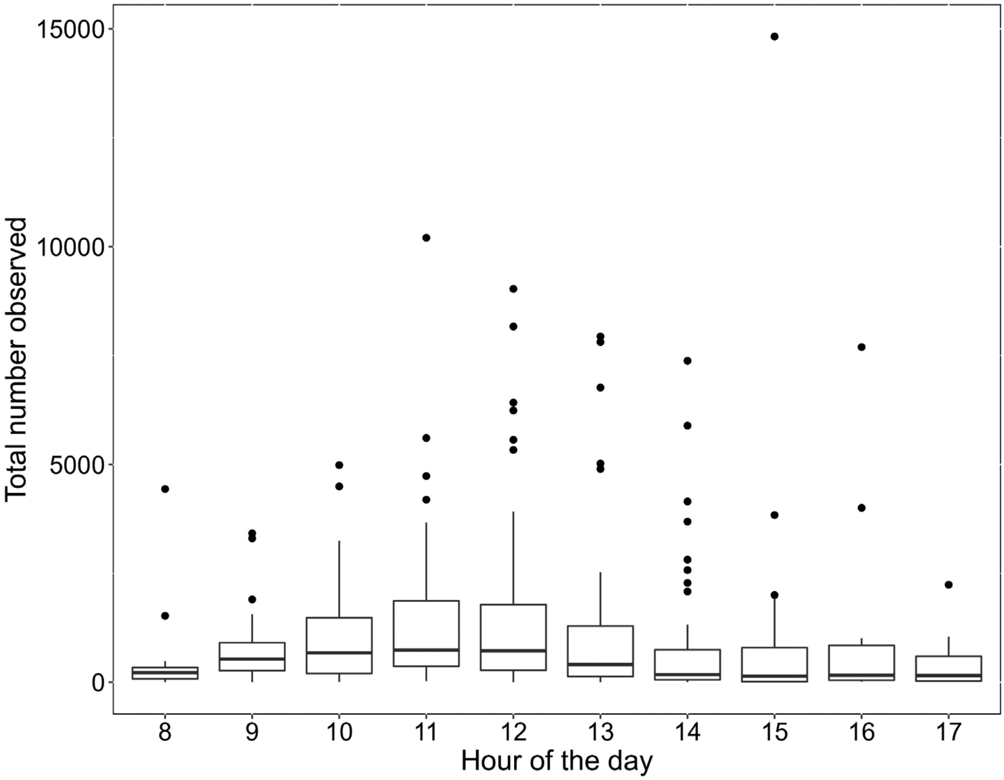

Figure 3. Daily migration phenology at Galala Bird Observatory in spring 2022. Total number of observed birds of the eight species for which the total number observed exceeded 2% of the global population (Figure 2), using only observations from the Galala Bird Observatory point. Box plots represent median (thick line), interquartile range (box), 95% confidence intervals (vertical bars) and outliers (points).

DISCUSSION

We recorded >350 000 migratory soaring birds at the new Galala Bird Observatory and complementary observation points to the north and north-west of Galala city during spring 2022, almost twice as many birds as a previous study observed in 2012 (Table 1; Megalli & Hilgerloh 2013). The higher number of observed birds was due to observation points being situated at higher elevation, thus facilitating observations of birds migrating above the Galala plateau, which was not possible from the coastal observation point in 2012. We therefore believe that the points identified in 2022 offer a significant improvement over the coastal observation points used during previous counts, and hold great potential for long-term monitoring.

The Galala Bird Observatory is ideally placed to record a significant proportion of the global populations of Lesser Spotted Eagle (25–37%), Steppe Eagle (23–32%), Steppe

Buzzard (6–11%), White Stork (10%), Egyptian Vulture (3–10%), Short-toed Snake Eagle (3–6%), Black Stork (2–4%) and Black Kite (2–4%) (Jobson *et al* 2021). Because two of those species are globally threatened (Egyptian Vulture and Steppe Eagle), long-term monitoring at Galala will facilitate both the understanding of population trends of these species, as well as allow an evaluation of the potential benefit of any conservation actions for these species along the flyway (Oppel *et al* 2021, McGrady *et al* 2022). Among various raptor migration observatories along the East African-Eurasian flyway, our results indicate that Galala may record the highest number of Egyptian Vultures and the second highest of Steppe Buzzard and Black Kite after Batumi in Georgia (Verhelst *et al* 2011, Jobson *et al* 2021).

We therefore recommend that future monitoring at Galala occurs over a time period that captures the phenology of six raptor species (Figure 2). Specifically, a 10-week period beginning around 15 February and lasting until early May would probably capture the majority of the passage of the six raptor species for which >2% of the global population can be observed (Hilgerloh *et al* 2009). Steppe Eagles in particular can migrate very early and a start in February would be required to comprehensively count that species (Hilgerloh *et al* 2009, McGrady *et al* 2022). Many Steppe Eagles winter on the Arabian peninsula (Keijmel *et al* 2020, Shobrak *et al* 2021), but perform a loop migration that results in many individuals migrating north along the west coast of the Red Sea in spring (Meyburg *et al* 2003, Meyburg *et al* 2012, McGrady *et al* 2022). Egyptian Vultures also winter on the Arabian peninsula (Shobrak *et al* 2020), but major congregations occur in Ethiopia (Arkumarev *et al* 2014, Arkumarev *et al* 2019, Buechley *et al* 2021) from where birds migrate along the Red Sea coast in spring (Buechley *et al* 2018, Phipps *et al* 2019, Oppel *et al* 2022).

Although migration routes of large soaring birds converge on a continental scale along the western coast of the Red Sea during spring migration, the migration paths over the Galala Plateau can vary within and between days over a distance of 10-20 km from the coast (Figure 1). Several terrain features allow birds to use both thermal and orographic uplift to gain altitude and soar efficiently for long distances, and it is therefore unlikely that all birds passing the region can be observed from a single point. We therefore recommend that besides the main point of the Galala Bird Observatory along the prominent ridge overlooking the Red Sea, two additional points north of the Galala Canyon and farther west at the base of the interior mountain range (Galala Desert) are included in any long-term monitoring programme to avoid annually fluctuating numbers as a result of weather and flight path variation (Hilgerloh *et al* 2011, Verhelst *et al* 2011, Vansteelant *et al* 2014).

On days with very clear visibility, the coastline of the Sinai peninsula was clearly visible over a <20 km wide stretch of the Red Sea. We repeatedly observed soaring birds (Buzzards, White Storks and Black Kites) attempting and often succeeding to cross the Red Sea on such days, as they do at other narrow water bodies (Becciu *et al* 2020). Especially storks, pelicans and Ospreys *Pandion haliaetus* may therefore divert from the coastal route northwards along the Red Sea and migrate northwards via the Sinai Peninsula, which would explain why observations at Zait Bay (200 km south-east of Galala) recorded much higher numbers of storks during spring migration (Hilgerloh *et al* 2009). By contrast, on a day with very hazy conditions and poor visibility across the sea, we recorded 61 962 birds from Galala Bird Observatory – mainly White Storks and Steppe Buzzards. Although we recorded >2% of the global populations of both Black and White Storks, we speculate that the annually recorded number of storks is highly wind- and weather-dependent as an annually varying proportion of birds could migrate via Sinai (Hilgerloh *et al* 2011). We therefore consider Galala Bird Observatory to be an internationally important migration monitoring station where globally important populations of six raptor species can be recorded during spring migration, but its importance for storks would require re-evaluation after several years of data have been collected.

In summary, Galala Bird Observatory offers an ideal location to monitor large numbers of raptors on migration similar to other observatories where autumn migration has been routinely monitored (Verhelst *et al* 2011, Oppel *et al* 2014, Heiss *et al* 2020). A coordinated approach to monitoring across the flyway has been called for since 1989 (Welch & Welch 1989, Jobson *et al* 2021), and Galala Bird Observatory has great potential to contribute towards the coordinated long-term monitoring of migratory raptor populations due to the site's international relevance for migratory soaring birds, ease of access, proximity to a new university, and support by the local government to develop the site for birdwatching. Besides the scientific value of Galala Bird Observatory, the site allows observation of raptors from above, from the side and from below, and thus offers an opportunity to scrutinize species that few other migration monitoring sites provide. We therefore consider Galala Bird Observatory as a very promising venue for ecotourism and to promote the spectacle of bird migration in general.

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