Monitoring of migratory soaring birds in the East African-Eurasian flyway: a review and recommendations for future steps

BEN JOBSON, TRIS ALLINSON, ROB SHELDON, WOUTER VANSTEELANT, EVAN BUECHLEY, STEFFEN OPPEL & VICTORIA R JONES

Summary: Monitoring of migratory soaring birds at flyway bottlenecks is vital for informing population estimates and detecting population-level changes, since monitoring these species on their breeding grounds is notoriously difficult. Since the last review of bottleneck monitoring in the Red Sea/Rift Valley flyway over 15 years ago, there has been progress to coordinate and standardise monitoring along flyways around the world for various avian groups, from waterbirds to raptors. The same period also saw dramatic improvements in our understanding of migratory routes through the development of remote tracking technologies. This article reviews current monitoring of major bottlenecks for migratory soaring birds in the East African-Eurasian flyway. We summarise developments in migratory soaring bird monitoring and research and identify priority locations for implementing standardised and coordinated monitoring initiatives. Our review identified 10 sites that have recorded one of the three highest counts for the 12 main migratory soaring bird species in the flyway, and can be considered priorities for targeting future monitoring. Additionally, we provide recommendations to progress coordination and standardisation of monitoring across this globally important flyway.

INTRODUCTION

The East African-Eurasian flyway represents one of the most important routes for migratory soaring birds in the world. Each spring and autumn, 37 species of migratory soaring birds (MSBs) navigate this flyway, with over a million birds passing through the larger bottlenecks (BirdLife International 2021). These include the entire global population of Lesser Spotted Eagle *Clanga pomarina*, the Palearctic populations of Levant Sparrowhawk *Accipiter brevipes* and Great White Pelican *Pelecanus onocrotalus*, and globally important populations of White Stork *Ciconia ciconia* and European Honey-buzzard *Pernis apivorus* among other species. However, the true scale of migration along the flyway is presumably much larger than the historically recorded figures, and only through advances in monitoring can we progress our understanding of this phenomenon. Improved monitoring would also allow for the detection of population trends, distributional shifts and phenological responses to climate change.

Due to the nature of their soaring flight, MSB species, such as pelicans, vultures, storks and eagles, are obligate diurnal migrants (Leshem & Yom-Tov 1996). They also follow predictable paths across land as they seek thermals and orographic uplift and avoid large bodies of water. The complicated geography and topography of the Levant, the Caucasus and the Middle East funnel Eurasian MSBs through a number of bottleneck locations where they congregate in the largest numbers and where they are therefore most easily counted on their way to and from East Africa. Some of these bottlenecks, such as the Bosphorus bottleneck for storks in Turkey, have been recognised as locations for major migratory spectacles since the early nineteenth century. As migration research progressed over the following years, numerous site counts were conducted along the flyway, with many of the pioneering studies occurring around the 1980s (Shirihai *et al* 2000). More recently, remote tracking of birds has permitted a far greater understanding of migration routes and has enabled the identification of optimal locations for MSB monitoring (*eg* Oppel *et al* 2014, Buechley *et al* 2018).

The process of bottleneck monitoring is a necessary undertaking as many of the focus species contribute positively to human well-being and can alert researchers to conservation issues more widely, since predatory and scavenging raptors act as effective indicators of environmental change (Bildstein 2001, O'Bryan *et al* 2018). Migration studies have underpinned the identification of many Important Bird and Biodiversity Areas (IBAs), as well as contributing towards our overall understanding of raptor population trends (Bednarz *et al* 1990, Agostini *et al* 2007, Farmer *et al* 2007, Dumandan *et al* 2021) and flyway population sizes (Hilgerloh 2009). There are cases where counts at bottleneck sites have recorded larger numbers of individuals than were suggested by the existing global population estimates. In some instances, this may occur due to migration counts not distinguishing between juvenile and adult birds. However, when counts account for the age composition, they can provide important information for updating global population estimates (Fülöp *et al* 2014, Vansteelant *et al* 2020).

Since the pioneering era of raptor research in the 1970s, major bottlenecks between Eurasia and East Africa were identified around Suez and Bab-el-Mandeb. The need for improved understanding of migration at the flyway scale quickly led to calls for standardised and coordinated monitoring that have still not been met (Welch & Welch 1989). In 2005, Richard Porter conducted a comprehensive review of soaring bird migration bottleneck sites in the Middle East and North East Africa (Porter 2005). Porter's review recommended that efforts should be focussed at the Bab-el-Mandab strait in Yemen/Djibouti, South Sinai/Ras Mohammed/El Qa/Gebel El Zeit in Egypt and Suez Ain Sukna/Suez in Egypt. Today, these locations are still understudied, even though satellite-tracking data have confirmed their importance as bottlenecks for recording certain MSBs (*eg* Lesser Spotted Eagle, Meyburg *et al* 2017, Egyptian Vulture *Neophron percnopterus*, Buechley *et al* 2018, Oppel *et al* 2014). However, telemetry studies have also indicated that other locations may be equally suitable to monitor migratory soaring birds at previously lesser-known bottleneck sites (*eg* Oppel *et al* 2014). Moreover, some MSBs exhibit surprisingly flexible route choice (Vansteelant *et al* 2017), which suggests that a network of observatories may be needed to adequately monitor their populations. These observations urge us to rethink the potential for migration monitoring of Palearctic soaring bird populations throughout this region.

Migratory bird monitoring can serve multiple purposes in addition to understanding population and demographic changes amongst birds. The spectacle of bird migration in the Middle East has resonated with local people since biblical times (Jeremiah 8:7, Job 39:26) and continues to inspire awe, with the Great Rift Valley migration flyway being proposed as a UNESCO World Heritage Site in 2006. Bird migration across the globe attracts large numbers of enthusiasts and experts to well-known bottlenecks like the Hawk Mountain Sanctuary in Pennsylvania (USA), Tarifa in Spain, or Batumi in Georgia. This provides an opportunity to educate people about the science of bird migration and the threats facing migratory birds. Avitourism to migratory bottlenecks to witness the passage of a large number and diversity of birds is increasing. The Society for the Protection of Nature in Israel (SPNI) has worked to advance Israel's avitourism sector with government ministries and developed a network of 14 birdwatching stations across the country for visiting birders and researchers. SPNI estimate 1.5 million domestic and foreign birding tourists visit each year (Y Perlman pers comm). This can support new local jobs and provide capacity to enhance monitoring efforts. Furthermore, the 'Bird Camp' initiative, which originated at Besh Barmag (Azerbaijan) and expanded to Lebanon in 2018 is one example of a migration count that aims to inclusively engage local people and provide positive social impact (T Haraldsson pers comm). Initiatives like Batumi Raptor Count (Georgia) and the Bird Camp count sites maintain a dual focus of firstly monitoring soaring birds but also training, educating, inspiring and collaborating with local volunteers interested in nature, such as students, ornithological association members and responsible hunting groups (Hoekstra *et al* 2020).

Despite committed efforts by a number of dedicated observers over the past decades, many locations across the flyway have never been regularly monitored and at best receive only ad hoc site counts. A number of persistent barriers to monitoring across the flyway have prevented a coordinated approach being established to date. These include political instability, scarcity of funding, low capacity for organisation of migration counts, lack of a flyway-wide monitoring initiative and limited numbers of experienced bird watchers. In contrast, in North America, where there are less limiting geopolitical, linguistic, funding and capacity conditions, raptor monitoring has progressed to the stage of having almost two hundred monitoring locations affiliated with the Hawk Migration Association of North America, who alongside several other organisations have generated a raptor migration database that can be used to inform continental trends in raptor populations (Raptor Population Index, RPI http://rpi-project.org/; Farmer & Hussell 2008).

To make sense of migratory bird populations at the flyway scale, it is necessary to coordinate research. The data needed to inform robust estimates of population trends should cover a long enough time window to accommodate weather-related shifts in phenology. Additionally, whilst population trends can still be detected through infrequent migration counts, annual counting would allow higher confidence in estimates of percentage change in migrants per year (Wauchope *et al* 2019). There are multiple factors to take into account, which can lead to reduced migration intensity at a site, and may or may not result from changes in overall population numbers of migrants. Lott (2002) noted that migration counts are notoriously variable and that apparently reduced numbers can be the result of effects of weather and observation effort. Furthermore, migratory behaviour can also be influenced by climate change, with many birds wintering further north than previously (Paprocki *et al* 2017). Nevertheless, migration bottleneck counting can be an efficient and cost-effective process, particularly as many populations of raptors cannot be effectively censused on their breeding grounds due to inaccessible terrain, the low density of territories and the cryptic nesting habits of many species.

Following the study of Porter (2005), there has been a number of major developments in raptor research, particularly the improvement and reduction in price of GPS tracking technology, which has enabled the routes of MSBs to be understood more precisely. Additionally, there has been an increased usage of web-based platforms like Trektellen and similar apps to facilitate monitoring (Troost & Boele 2019). However, the significant skew of count sites and data from Western Europe indicates that there are still limiting factors to MSB monitoring along the East African-Eurasian flyway.

This review aims to assess the status of monitoring across the flyway, update information on the priority locations to monitor, and present recommendations for future coordination across the flyway.

METHODS

Our review of the East African-Eurasian flyway encompasses the Red Sea/Rift Valley flyway but also extends northwards and eastwards to consider additional bottlenecks for the same populations of MSBs. In autumn, the Via Pontica flyway (Western Black Sea Corridor) converges with the Trans-Caucasian flyway and feeds into bottlenecks in the Middle East before emerging into the wintering grounds of Africa. Monitoring at these more northerly bottlenecks is therefore also necessary to contribute towards a better understanding of population trends. Additionally, as a proportion of the birds migrating from the far north may winter in the Arabian Peninsula, the northerly migration counts may record individuals that do not pass through larger bottlenecks in Africa. Consequently, the overall flyway includes Bourgas (Bulgaria), the Caucasus, the Turkish Bosphorus, the Gulf of Iskenderun and the Jordan valley down through Syria, Lebanon, Israel, Jordan and Palestine. The flyway then splits into three, with two routes crossing the Gulf of Suez - one passing down the Nile valley and the other down the west coast of the Red Sea (Egypt, Sudan, Eritrea, Ethiopia and Djibouti). The third route follows the east coast of the Red Sea (Saudi Arabia and Yemen), crossing the Red Sea towards the southern end at the Bab-el-Mandeb strait before continuing south to the East African Rift valley (Figure 1).

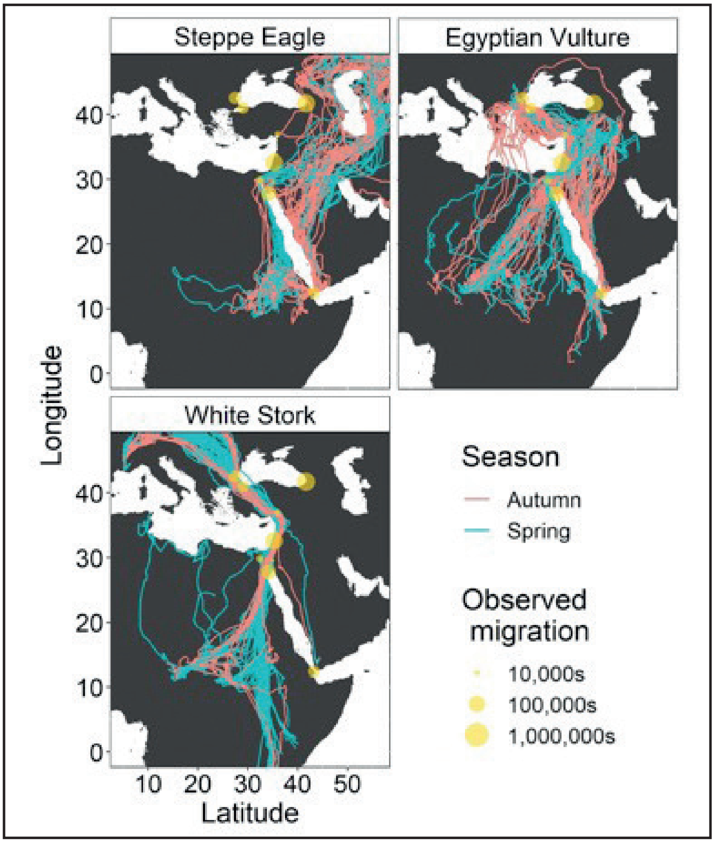

Figure 1. Overview of the flyway and the 10 sites from Table 1 (yellow points) that have recorded the largest numbers of MSBs across the 12 main species in autumn. Tracking data for Steppe Eagle (Efrat *et al* in prep), Egyptian Vulture (Phipps *et al* 2019) and White Stork (Rotics *et al* 2018, Cheng *et al* 2019, Flack *et al* 2020) have been added to exemplify different migration routes and demonstrate how the locations of the key bottleneck sites within the flyway are appropriate for recording the majority of observable MSB migration.

The majority of observable movements of large soaring birds along this flyway comprises 12 species; in descending order of recorded abundance these are European Honey-buzzard, Eurasian (Steppe) Buzzard *Buteo buteo vulpinus*, White Stork, Black Kite *Milvus migrans*, Lesser Spotted Eagle, Levant Sparrowhawk, Steppe Eagle *Aquila nipalensis*, Great White Pelican, Black Stork *Ciconia nigra*, Short-toed Snake-eagle *Circaetus gallicus*, Booted Eagle *Hieraaetus pennatus* and Egyptian Vulture. Therefore, migration count data to inform species population trends and, in some cases, demographic trends, are likely to be primarily associated with these species.

Although other raptors and large migratory birds follow the East African-Eurasian flyway, this review focusses on those soaring migrants that are most likely to show fidelity to traditional bottlenecks. Whilst Batumi (Georgia) records globally significant populations of Western Marsh-harrier *Circus aeruginosus*, Montagu's Harrier *C. pygargus* and Pallid Harrier *C. macrourus*, these species were not included in this review as few other sites record them regularly or in large enough numbers to represent significant proportions of the global population (Wehrmann *et al* 2019).

To review the current state of migratory bird monitoring across the flyway, a literature review was conducted to draw upon research that had been published (in English) since Porter's review (2005). Web of Science and Google Scholar were searched for publications of MSB counts in the East African-Eurasian flyway since 2005. Keywords included 'migratory' OR 'soaring' OR 'bird monitoring' AND name of particular country in flyway. Additionally, an expert consultation process was conducted using a semi-structured interview technique to identify additional research and data relevant to each country in the flyway. The process of selecting experts and evaluating responses was facilitated by the BirdLife International partnership, which represents many national organisations involved in species monitoring along the flyway. Experts from these organisations, as well as authors on historical papers about migration counts in the region and other points of contact recommended during these conversations were consulted about MSB monitoring. Additionally, information was requested from researchers involved in any of the ongoing migration counts. Lastly, guidance and input was provided by the Ornithological Society of the Middle East (OSME).

Based on the largest migration count records from the literature review, the expert consultation process, as well as the literature included in Porter (2005), this review identified the most important autumn bottlenecks in the flyway for focussing future MSB monitoring. In this review, we consider monitoring to refer to MSB recording at a station or series of stations that follow a standardised and repeatable protocol with sufficient coverage across the migratory season and over multiple seasons and years. The top three bottleneck monitoring sites for each of the 12 main MSB species were chosen as the locations where the largest number of each species had been recorded in the last 40 years.

RESULTS

Ten bottleneck sites in the East African-Eurasian flyway recorded the three highest autumn counts of each of the 12 main MSB species (Table 1). These 10 sites were: Bab-el-Mandeb (Djibouti), Batumi (Georgia), Bosphorus (Turkey), Bourgas (Bulgaria), Eilat (Israel), Northern Valleys (Israel), Ras El Matn (Lebanon), Ras Mohammed (Egypt), Sarimazi (Turkey) and Suez (Egypt) (Figure 1, Table 1). Of these sites, eight recorded the maximum site counts for more than one species in the flyway. Specific country-by-country details of additional count sites are provided in Appendix 1.

Maximum bottleneck counts for European Honey-buzzard, Lesser Spotted Eagle, Levant Sparrowhawk and Steppe Eagle exceed the known global population estimates for these species (BirdLife International 2021). These data suggest that the estimates could be revised, especially as these species are listed as Least Concern on the IUCN Red List (except for Steppe Eagle, which is listed as Endangered), indicating that their populations are stable and have not decreased significantly since the maximum recorded counts.

Since Porter's (2005) review, there has been no flyway-wide coordination of MSB monitoring and Porter's recommendation of monitoring at Bab-el-Mandab strait, South Sinai/Ras Mohammed/El Qa/Gebel El Zeit and Ain Sukna/Suez have not led to renewed and coordinated monitoring in these areas (aside from at wind farm complexes). However, counts have been initiated at several additional sites with the intention of leading to long-term monitoring and education programmes. Most notably, Batumi Raptor Count quickly gained recognition after scoping surveys in 2008 led to robust protocols being developed, which quickly uncovered the true scale of the migration spectacle in Georgia (Verhelst *et al*

2011). This attracted international attention and expert volunteers that allowed the project to develop further over subsequent years (Hoekstra *et al* 2020). In 2014, Sarimazi Raptor Count was initiated through Egyptian Vulture LIFE projects with the specific purpose of monitoring Egyptian Vultures. This count also aims to attract international volunteers to bolster local capacity and provide training in the initial years. In 2019, Bird Camp Lebanon initiated Raptor Watch Lebanon, which, although not recording the same volume of MSBs as other sites, is a developing project. The count follows a successful initiative for monitoring migratory land birds at Besh Barmag, Azerbaijan (Heiss 2013, Heiss *et al* 2020) and aims to engage and educate local communities regarding the threats facing migratory birds. The Batumi model of migration counting relies on dozens of volunteering citizen scientists and income from sources such as avitourism (Hoekstra *et al* 2020). However, sites that are not supported by local capacity are susceptible to unforeseen issues, such as the Covid-19 pandemic restrictions, and not all sites worth monitoring will be able to replicate such a comprehensive protocol, especially in areas that present more logistical challenges.

Across the 10 major bottleneck sites, Batumi Raptor Count represents by far the best practice for standardised, transparent and systematic monitoring (tailored to collect the best possible data, including demographic parameters, for selected species), as well as data management and open science (Wehrmann *et al* 2019). It is also the only site with an ongoing, consistent and coordinated monitoring scheme. Batumi's methods are now being emulated by Sarimazi Raptor Count and Raptor Count Lebanon. The remaining sites are either recent start-ups, locations with historical ad hoc site counts, or locations with historical monitoring that is now discontinued. There are additional sites that represent significant bottlenecks and also conduct standardised monitoring for other purposes, including wind farm complexes at Gebel El Zeit and Suez Bay. It would be valuable for MSB research if scoping studies assessing the potential impact of wind farms at these locations would engage in open data sharing and contribute to a coordinated flyway-scale monitoring initiative. Currently, there is much goodwill and exchange of researchers and citizen scientists among these sites, but there is limited formal coordination between count sites, except for researchers that have been involved in multiple sites and shared methodologies. As such, researchers still have limited ability to analyse population trends of MSBs at a flyway-scale, and there is still a lack of tracking data to quantify connectivity of each bottleneck with breeding and non-breeding areas.

Threats to MSBs were not reported to be especially high at any of the bottleneck count stations themselves compared with the rest of the flyway. However, it is clear that the main threats to MSBs vary by region (Oppel *et al* submitted). The types of threats reported were mostly those that are pervasive across the countries or regions in the flyway. In much of the Middle East, illegal shooting and dangerous power infrastructure are the major threats and require further engagement (Brochet *et al* 2019, Shobrak *et al* 2020). Power line surveys and anecdotal evidence from local residents at Sarimazi revealed a seasonal spike in electrocutions during the passage of White Storks. As these electrocutions cause power outages, local power distribution and transmission companies should be receptive to assistance in the form of recommendations for cost-effective mitigation measures. Additionally, the areas around Batumi and Raptor Count Lebanon experience illegal shooting and would benefit from further efforts to engage with hunting groups in order to manage any unsustainable and illegal activity (W Vansteelant pers obs). Engaging local volunteers in a similar manner to the Bird Camp initiative will benefit monitoring schemes by increasing capacity. However, additional benefits were suggested to be the ability to educate local groups about the threats to migratory birds and encourage positive behaviour change around threats to MSBs like illegal shooting.

DISCUSSION

Identifying the three main bottleneck sites for the 12 main MSB species in the flyway was an effective way of prioritising sites from the numerous other bottlenecks within the East African-Eurasian flyway. As major bottlenecks, these sites are also likely to be important for the less common migrants following the same flyway. With eight of the 10 bottlenecks having recorded a maximum count for two or more species, these sites also showed a high level of complementarity across species. However, this prioritisation method is likely to effectively recognise those sites with long histories of monitoring and less likely to be representative of sites that have not been conducive to MSB monitoring in the past. If possible, it would be more accurate to use the maximum estimated number of birds passing rather than recorded counts (which underestimate the sites with limited data like Bab-el-Mandeb); however, sites would first need to use comparable methodologies to enable this estimation. Future replications of this review would benefit from additionally identifying hotspots from the density of tracking data (*eg* Buechley *et al* 2018) if sufficient data can be obtained for all the major species.

By focussing on major bottlenecks, we aim to coordinate and standardise MSB monitoring across the flyway and achieve more useful research outputs as a result. Notwithstanding, there are other valuable methods of recording MSBs in the region, such as counting winter aggregations at waste disposal sites (Keijmel *et al* 2020), road censuses and surveys of stop-over lakes (for pelicans).

Progress in migration research since Porter (2005)

Our overall understanding of the fine-scale movements and seasonality of soaring bird migration has greatly improved in the last decade through remote tracking. This has clarified much of the speculation about the routes of raptor passage between bottlenecks, so that resources for monitoring can now be focussed with confidence on the main sites for concentrated MSB passage (Buechley *et al* 2018). Tracking data have also demonstrated the influence of weather on MSB migration, which until recently had been recorded only anecdotally. It has been demonstrated that age and environmental factors like wind influence migration routes and can lead to significant shifts in the migratory paths of soaring birds (Vansteelant *et al* 2014, 2017a, 2017b, Becciu *et al* 2020, Santos *et al* 2020). In certain locations where MSBs can facultatively cross bodies of water, such as the Gulf of Iskenderun or Gulf of Suez, consideration of how factors like wind can influence the observable passage of birds will be important to gain comparable estimates of the numbers of passing migrants. When weather data are paired with the migratory phenology of different species, more realistic estimates of actual migration can be reliably extrapolated from the observed number of MSBs for the more common species.

Several persistent limitations can complicate human observations of soaring bird migration. Experience and expertise are required to differentiate between certain soaring birds, and the limits of human vision inevitably result in many MSBs passing undetected if they fly too high or far from the monitoring station. This is even more significant on clear days as birds usually fly higher and are harder to detect without the contrast against cloud cover. Both these complications are of particular relevance in the desert regions of the Red Sea / Rift Valley flyway. However, technology has improved to such an extent that it can begin to compensate for human error. For example, radar technology can identify migrating birds (including nocturnal passerine migrants) and has been trialled successfully at wind farms in Gebel El Zeit, Egypt (O El-Gebaly pers comm). Using radar to quantify migration passage can reveal the number of birds missed by human observers, for example in clear conditions or when birds are crossing water (Panuccio *et al* 2018a). As radar cannot identify birds at the species level, its use is limited. Nevertheless, using radar in conjunction with human observations may allow for a more accurate extrapolation of count data. Furthermore, as advanced radar systems are already in place at many airports, collaboration with national air forces is one way to simultaneously learn about migration intensity and reduce bird strike (van Gasteren *et al* 2019). In addition, progress in automated camera image processing and real-time camera tracking may provide opportunities for cost-effective monitoring by reducing the relatively high cost of human observers being present at monitoring stations for several weeks or months (McClure *et al* 2018, Niemi & Tanttu 2020).

Current status of MSB monitoring in the East African-Eurasian flyway

Despite the development of promising new monitoring programmes in recent years, most key sites along the flyway still lack coordination. In the countries along the main East African-Eurasian flyway, there are currently 53 Important Bird and Biodiversity Areas (IBAs) identified under criterion A4iv, relating to bottlenecks where migratory species pass regularly in numbers ≥1% of the global population (BirdLife International 2021). However, IBA monitoring is not currently standardised at the flyway-scale to answer specific questions on population sizes and trends of the MSBs. Whilst it may not be possible or necessary to monitor all sites effectively every year, consistency affords much greater power to detect population trends and is key to building capacity to continue long-term counts (Lewis & Gould 2000, Wauchope *et al* 2019). When counts are not possible every year, at least three standardised migration counts every decade could provide useful data towards informing population level trends (Y Perlman pers comm). This is valuable as raptors are, on average, more likely to be threatened than other bird species (McClure *et al* 2018) and monitoring can help to identify populations in need of conservation action. However, 10 of the 12 main species in this study are listed as Least Concern on the IUCN Red List (BirdLife International 2021), with only Egyptian Vulture and Steppe Eagle listed as Endangered. This relatively low proportion of threatened species may be due to the inherent difficulties with monitoring raptors on breeding grounds and failure to detect population changes; however, several of the highest migration counts could provide information to support increased estimates of global population sizes for certain species (Table 1).

Funding for long-term monitoring programmes is difficult to acquire, and the lack of funding is one of the key reasons for insufficient migration monitoring along the main East African-Eurasian flyway. To date, external funding has often come from organisations with an interest in understanding bird migration. For example, the Israel Air Force funded long-term studies of bird migration to understand the risk of bird strike with aircraft (van Gasteren *et al* 2019). Similarly, Red Eléctrica de España, a power transmission company in Spain, helped fund the Centro Internacional de Migración de Aves in Tarifa. Batumi Raptor Count has been successful in attracting funding from different sources, including private sponsors such as Swarovski and ecotourism operators, and conservation grants from the Champions of the Flyway, OSME and The Rufford Foundation (Hoekstra *et al* 2020). The diversity of funding sources shows that local partnerships may be an opportunity, especially in resource-rich countries in the region. In high-income countries, government funding supports over half of all species monitoring schemes (Moussy *et al* 2021). This has not been the case for many monitoring programmes in the East African-Eurasian flyway but could be increasingly sought as a source of funding in future. However, few if any funding bodies have thus far supported migration counts purely for the importance of monitoring migrant raptors as key indicator species. Some funding may be contingent on monitoring schemes that additionally offer beneficial activities like education and

Table 1. The top three autumn bottleneck sites for the 12 most abundant migratory soaring bird species in the East African-Eurasian flyway and the percentage of the global population that the site records for each species. (*Recorded populations are larger than the estimated global population; BirdLife International 2021)

Species	Global population (BirdLife Datazone 2021)	Highest count location	Year	Max count (percentage of world population)	Source
European Honey-Buzzard	280 000-420 000	Batumi (Georgia)	2014	656 171 (156-234 %*)	Wehrmann *et al* 2019
		Northern Valleys (Israel)	1997	544 215 (130-194%*)	Krumenacker 2013
		Sarimazi (Turkey)	2018	26 863 (6-10%)	Arslan *et al* 2019
Eurasian (Steppe) Buzzard	2 100 000-3 700 000	Batumi (Georgia)	2014	486 467 (13-23%)	Wehrmann *et al* 2019
		Bab-el-Mandeb (Djibouti)	1987	98 339 (3-5%)	Welch & Welch 1989
		Bosphorus (Turkey)	1969	32 895 (1-2%)	Magnin & Yarar 1997
White Stork	700 000-704 000	Bosphorus (Turkey)	1972	338 353 (48%)	Arslangündoğdu *et al* 2017
		Northern Valleys (Israel)	2005	326 081 (46-47%)	Krumenacker 2013
		Ras Mohammed (Egypt)	1998	275 743 (39%)	Ibrahim 2009
Black Kite	1 000 000-2 499 999	Batumi (Georgia)	2019	221 647 (9-22%)	Wehrmann *et al* 2019
		Northern Valleys (Israel)	1998	2695 (<1%)	Alon *et al* 2004
		Bosphorus (Turkey)	1971	2617 (<1%)	Shirihai *et al* 2000
Lesser Spotted Eagle	40 000-60 000	Northern Valleys (Israel)	1983	141 868 (236-355%*)	Krumenacker 2013
		Sarimazi (Turkey)	2019	45 562 (76-114%*)	Arslan *et al* 2019
		Suez (Egypt)	1981	45 000 (75-113%*)	Bijlsma 1983
Levant Sparrowhawk	10 000-19 999	Northern Valleys (Israel)	2003	78 934 (395-789%*)	Krumenacker 2013
		Sarimazi (Turkey)	2019	30 157 (151-302%*)	Arslan *et al* 2019
		Ras El Matn (Lebanon)	2019	11 562 (58-116%*)	Käch 2019
Steppe Eagle	50 000-75 000	Bab-el-Mandeb (Djibouti)	1987	76 586 (102-153%*)	Welch & Welch 1988
		Suez (Egypt)	1981	64 880 (87-130%*)	Bijlsma 1983
		Eilat (Israel)	1980	24 243 (32-48%)	Shirihai & Christie 1992
Great White Pelican	260 000-300 000	Northern Valleys (Israel)	1988	76 909 (26-30%)	Yeshem & Yom-Tov 1996
		Bourgas (Bulgaria)	1996	37 703 (13-15%)	Mitchev *et al* 2011
		Ras El Matn (Lebanon)	2019	7116 (2-3%)	Käch 2019
Black Stork	24 000-44 000	Bosphorus (Turkey)	2008	16 088 (37-67%)	Fülöp *et al* 2014
		Bourgas (Bulgaria)	1981	5154 (12-21%)	Mitchev *et al* 2011
		Batumi (Georgia)	2018	1750 (4-7%)	Wehrmann *et al* 2019
Short-toed Snake-eagle	100 000-200 000	Sarimazi (Turkey)	2019	13 121 (7-13%)	Arslan *et al* 2019
		Suez (Egypt)	1981	12 136 (6-12%)	Bijlsma 1983
		Northern Valleys (Israel)	1986	8045 (4-8%)	Yeshem & Yom-Tov 1996
Booted Eagle	149 000-188 000	Batumi (Georgia)	2016	7370 (4-5%)	Wehrmann *et al* 2019
		Sarimazi (Turkey)	2019	2315 (1-2%)	Arslan *et al* 2019
		Northern Valleys (Israel)	1986	1973 (1%)	Yeshem & Yom-Tov 1996
Egyptian Vulture	12 000-38 000	Suez (Egypt)	1984	1002 (3-8%)	Yosef & Alon 1997
		Sarimazi (Turkey)	2019	903 (2-8%)	Arslan *et al* 2019
		Bab-el-Mandeb (Djibouti)	1987	554 (1-5%)	Welch & Welch 1988

engagement with local people. Nevertheless, the linking up of monitoring programmes and a flyway-scale initiative for joint fundraising provides a major opportunity to seek new and ambitious funding, looking to support wider scale understanding of species populations and conservation across the flyway. However, counter-intuitively, funding is often relatively more attainable for new initiatives and those that can demonstrate near-term results rather than the long-standing migration monitoring programmes that are needed.

The future of MSB monitoring in the East African-Eurasian flyway

Several barriers to establishing monitoring sites result from the complex geopolitical environment that the flyway traverses and are unlikely to be fully resolved in the foreseeable future. However, there is still opportunity for great progress in MSB monitoring in the region. Several key recommendations for better monitoring are likely to apply to any site in the flyway. These include considering the appropriate time period and minimum effort that is required to obtain valuable data for a migratory season, and systematically recording data, for example by using resources such as Trektellen. Additionally, data from both monitoring stations and commercial sites like wind farms should contribute to the wider state of knowledge through being added to open data platforms like the Global Biodiversity Information Facility (GBIF) or eBird. Publication of results will advance the understanding of raptor research in the region through insights into crucial species and site-specific information.

The East African-Eurasian flyway is a complex flyway in terms of its biogeography and politics. Many of the MSB species have differing migration strategies but the majority converge at one or more of the 10 major bottleneck sites (Figure 1). If collaborative funding opportunities for a flyway monitoring scheme can be created, we recommend prioritising strategic locations to focus professional count effort. It will be important to maintain newly initiated counts, such as Sarimazi Raptor Count and Raptor Count Lebanon, and also to establish standardised monitoring in other key locations including the Bosphorus, Suez and the Bab-el-Mandeb strait. Monitoring of these sites will significantly improve the state of knowledge regarding population trends for the majority of MSBs. Additionally, if multi-station monitoring could be re-established across a broad front in Israel, this would contribute valuable data on population trends for a range of species. Furthermore, monitoring at Bab-el-Mandeb with additional programmes at Galugah (Iran) has huge potential to contribute new information from species migrating between Eurasia and Africa.

To advance MSB monitoring in the flyway, the locations to prioritise should be chosen on the basis of their potential to complement the existing knowledge base (particularly the bottlenecks identified in this review where no monitoring stations currently operate). However, it will also be important to prioritise those with the greatest ease of access, potential for funding and likelihood of long-term capacity. Post-breeding autumn counts (as opposed to spring counts) are particularly valuable to monitor reproductive success in raptors that use overland flyways and bottlenecks from a young age (Hubálek 2003, Vansteelant *et al* 2020). The counts at these sites should complement each other and ideally share similar methodologies, so that species' trends can be compared between sites. The sites should cover the main autumn routes of each species in order to obtain comprehensive flyway-scale population estimates. However, an important consideration when prioritising sites is the redundancy of different monitoring stations along the flyway, and the extent of overlap of migratory populations being counted. For example, autumn counts of White Storks in Bourgas (Bulgaria), Turkey, Israel and Egypt are likely to detect and count the same individuals, making each of these counts potentially redundant in terms of recording MSBs. In contrast, counts of European Honey-buzzard in western Turkey and at Batumi will be complementary and can be summed to derive a flyway total.

Thus, the ideal combination of monitoring sites will not necessarily be the combination of sites that currently record the greatest number of a particular species, but those that most likely cover different sub-populations most comprehensively.

Recommendations

The coordination of bottleneck monitoring along the East African-Eurasian flyway could be enhanced through workshops and training, taking inspiration from existing initiatives such as the International Bird Observatory Conference, which seeks to facilitate knowledge exchange between bird observatories globally. This could provide the momentum needed for a joint fundraising effort and establishment of a platform for sharing expertise between researchers from across the flyway. A further unifying and motivating initiative would be the launch of a website and social media outlet for migration monitoring across the flyway (similar to migrantlandbirds.org or migration.net), where reports, resources, events and records could be shared and newer initiatives could benefit from additional support and motivation.

Stronger links between those organising bottleneck monitoring counts would facilitate exchange of experience, methodology and training, while there would also be opportunities for seeking input and experience from other regions where migration bottleneck monitoring has been in place for many years. Workshops run by a coalition of interested organisations and experts at key bottleneck sites could lead to a more sustainable monitoring programme in the East African-Eurasian flyway, and consequently to better knowledge of migratory soaring birds.

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LITERATURE CITED

Agostini, N, M Panuccio, U Mellone, G Lucia, S Wilson & J Ashton-Booth. 2007. Do migration counts reflect population trends? A case study of the Honey Buzzard *Pernis apivorus*. *Ardeola* 54: 339–344.

Alon, D, B Granit, J Shamoun-Baranes, Y Leshem, GM Kirwan & H Shirihai. 2004. Soaring-bird migration over northern Israel in autumn. *British Birds* 97: 160–182.

Alon, D, Y Leshem, E Dovrat & A Tsovel. 1992. Autumn migration of soaring birds: cross-Samaria and Northern Valleys (1982-1991). *Torgos* 10: 3–73.

Andrews, IJ. 1996. Preliminary data on raptor passage in Jordan. *Sandgrouse* 18: 36–45.

Arkumarev, V, D Dobrev & A Stamenov. 2019. First record of Eurasian Griffon Vulture *Gyps fulvus* from the Balkans migrating to South Sudan revealed by GPS tracking. *Scopus* 39: 27–35.

Arslan, Ş, IT Erkol, N Kan, S Özuslu, K Kolçak & C Yeniyurt. 2019. *Sarimazi Raptor Migration Count 2019 in Turkey*. Technical report under action D1 of the "Egyptian Vulture New LIFE" (LIFE16 NAT/BG/000874) project. Doğa Derneği (BirdLife Turkey), İzmir, Turkey.

Arslangündoğdu, Z, E Bacak, V Beşkardeş, C Dalyan, L Smith, MR Payne & Ü Yardım. 2017. Autumn migration of the White Stork, *Ciconia ciconia*, and the Black Stork, *C. nigra*, over the Bosphorus. *Zoology in the Middle East* 63: 103–108.

Becciu, P, S Rotics, N Horvitz, M Kaatz, W Fiedler, D Zurell, A Flack, F Jeltsch, M Wikelski, R Nathan & N Sapir. 2020. Causes and consequences of facultative sea crossing in a soaring migrant. *Functional Ecology* 34: 840-852.

Bednarz, JC, D Klem, LJ Goodrich & SE Senner. 1990. Migration counts of raptors at Hawk Mountain Pennsylvania, as indicators of population trends, 1934-1986. *The Auk* 107: 96–109.

Bijlsma, RG. 1983. The migration of raptors near Suez, Egypt, autumn 1981. *Sandgrouse* 5: 19–44.

Bijlsma, RG. 1987. *Bottleneck areas for migratory birds in the Mediterranean region: an assessment of the problems and recommendations for action*. International Council for Bird Preservation, Cambridge, UK.

Bildstein, KL. 2001. Why migratory birds of prey make great biological indicators. *In:* KL Bildstein & D Klem Jr (eds). *Hawkwatching in the Americas*. Hawk Migration Association of North America. North Wales, PA USA, pp 169–178.

BirdLife International. 2021. BirdLife Data Zone. http://datazone.birdlife.org/birdlife-is-working-to-mainstream-soaring-bird-conservation-along-the-rift-valley/red-sea-flyway. [Accessed 20 January 2021].

Boyla, KA. 2011. *Turkey - Private Sector Renewable Energy and Energy Efficiency Project: environmental assessment (Vol. 35) : Ornithological report: Kapidag Windfarm Project 34MW, Balikesir, Turkey* (English). World Bank Group, Washington DC, USA.

van den Bossche, W & L Lens. 1994. Soaring bird migration at the Bosphorus (Turkey): the need for a multi-station survey. *Le Gerfaut* 84: 51–62.

Brochet, A-L, S Jbour, RD Sheldon, R Porter, VR Jones, W Al Fazari, O Al Saghier, S Alkhuzai, LA Al-Obeidi, R Angwin, K Ararat, M Pope, MY Shobrak, MS Willson, SS Zadegan & SHM Butchart. 2019. A preliminary assessment of the scope and scale of illegal killing and taking of wild birds in the Arabian peninsula, Iran and Iraq. *Sandgrouse* 41: 154-175.

Buechley, ER, S Oppel, WS Beatty, SC Nikolov, V Dobrev, V Arkumarev, V Saravia, C Bougain, A Bounas, E Kret, T Skartsi, K Aghababyan, E Frehner & CH Şekercioğlu. 2018. Identifying critical migratory bottlenecks and high-use areas for an endangered migratory soaring bird across three continents. *Journal of Avian Biology* 49: e01629.

Cheng, Y, W Fiedler, M Wikelski & A Flack. 2019. "Closer-to-home" strategy benefits juvenile survival in a long-distance migratory bird. *Ecology and Evolution* 9: 8945–8952.

Dumandan, PKT, KL Bildstein, LJ Goodrich, A Zaiats, TT Caughlin & TE Katzner. 2021. Shared functional traits explain synchronous changes in longterm count trends of migratory raptors. *Global Ecology and Biogeography* 30: 640-650.

Farmer, CJ, DJT Hussell & D Mizrahi. 2007. Detecting population trends in migratory birds of prey. *The Auk* 124: 1047–1062.

Farmer, CJ & DJT Hussell. 2008. The raptor population index in practice. State of North America's birds of prey. *Series in Ornithology* 3: 165-178.

Flack, A, PJ Schaeffer, JRE Taylor, I Müller, M Wikelski & W Fiedler. 2020. Daily energy expenditure in white storks is lower after fledging than in the nest. *Journal of Experimental Biology* 223: jeb219337.

Frumkin, R, B Pinshow & S Kleinhaus. 1995. A review of bird migration over Israel. *Journal of Ornithology* 136: 127–147.

Fülöp, A, I Kovács, E Baltag, SJ Daróczi, AS Dehelean, LA Dehelean, RB Kis, IS Komáromi, H Latková, T Miholcsa & A Nagy. 2014. Autumn migration of soaring birds at Bosporus: validating a new survey station design. *Bird Study* 61: 264-269.

van Gasteren, H, KL Krijgsveld, N Klauke, Y Leshem, IC Metz, M Skakuj, S Sorbi, I Schekler & J Shamoun-Baranes. 2019. Aeroecology meets aviation safety: early warning systems in Europe and the Middle East prevent collisions between birds and aircraft. *Ecography* 42: 899–911.

Heiss, M. 2013. The importance of Besh Barmag bottleneck (Azerbaijan) for Eurasian migrant birds. *Acta Ornithologica* 48: 151–164.

Heiss, M, K Gauger, C Himmel, P Fetting, TA Haraldsson, G Caucal, Z Ferecli & E Sultanov. 2020. The development of the Besh Barmag Bird Migration Count in Azerbaijan and its importance for the monitoring of Eurasian migrant birds. *Sandgrouse* 42: 29–45.

Hilgerloh, G. 2009. The desert at Zait Bay, Egypt: a bird migration bottleneck of global importance. *Bird Conservation International* 19: 338–352.

Hilgerloh, G, A Michalik & B Raddatz. 2011. Autumn migration of soaring birds through the Gebel El Zeit Important Bird Area (IBA), Egypt, threatened by wind farm projects. *Bird Conservation International* 21: 365–375.

Hoekstra, B, J Jansen, D Engelen, F de Boer, R Benjumea, J Wehrmann, S Cavailles, T Kaasiku, D Jansen, P Fetting, A Aintilla & WMG Vansteelant. 2020. Batumi Raptor Count: from migration counts to conservation in a raptor flyway under threat. *British Birds* 113: 439-460.

Hubálek, Z. 2003. Spring migration of birds in relation to North Atlantic Oscillation. Folia Zoologica 52: 287–298.

Ibrahim, WAL. 2009. *Status and Trends of Selected Important Bird Areas in Egypt.* Egyptian Environmental Affairs Agency, Cairo.

Käch, M. 2019. *Raptor Count Lebanon* 2019. BirdLife Switzerland, Zürich, Switzerland.

Keijmel, M, J Babbington, P Roberts, M McGrady & B-U Meyburg. 2020. The world's largest gathering of Steppe Eagles *Aquila nipalensis* discovered in central Saudi Arabia. *Sandgrouse* 42: 59-68.

Khoury, F. 2017. Spring migration of soaring birds over the highlands of southwest Jordan: flight patterns and possible implications for wind farm developments. *Sandgrouse* 39: 61–67.

Leshem, Y & Y Yom-Tov. 1996. The use of thermals by soaring migrants. *Ibis* 138: 667–674.

Leshem, Y & Y Yom-Tov. 2008. Routes of migrating soaring birds. *Ibis* 140: 41–52.

Lewis, SA & WR Gould. 2000. Survey effort effects on power to detect trends in raptor migration counts. *Wildlife Society Bulletin* 28: 317-329.

Lott, CA. 2002. Raptor migration in Israel and the Middle East: A summary of 30 years of field research. *The Auk* 119: 284-288.

Magnin, G & M Yarar. 1997. *Important Bird Areas in Turkey*. Doğal Hayatı Koruma Derneği, Istanbul, Turkey.

McClure, CJ, JR Westrip, JA Johnson, SE Schulwitz, MZ Virani, R Davies, A Symes, H Wheatley, R Thorstrom, A Amar & R Buij. 2018. State of the world's raptors: Distributions, threats, and conservation recommendations. *Biological Conservation* 227: 390-402.

McClure, CJ, L Martinson & TD Allison. 2018. Automated monitoring for birds in flight: Proof of concept with eagles at a wind power facility. *Biological Conservation* 224: 26-33.

Meyburg, UB, U Bergmanis, T Langgemach, K Graszynski, A Hinz, I Börner, C Meyburg & WMG Vansteelant. 2017. Orientation of native versus translocated juvenile Lesser Spotted Eagles (*Clanga pomarina*) on the first autumn migration. *Journal of Experimental Biology* 220: 2765–2776.

Michev, T, L Profirov, K Nyagolov & M Dimitrov. 2011. The autumn migration of soaring birds at Bourgas Bay, Bulgaria *British Birds* 104: 16-37.

Moussy, C, IJ Burfield, PJ Stephenson, AFE Newton, SHM Butchart, WJ Sutherland, RD Gregory, L McRae, P Bubb, I Roesler, C Ursino, Y Wu, EF Retief, JS Udin, R Urazaliyev, LM Sánchez-Clavijo, E Lartey & PF Donald. 2021. A quantitative global review of species population monitoring. *Conservation Biology*, doi: 10.1111/cobi.13721.

Niemi, J & JT Tanttu. 2020. Deep learning–based automatic bird identification system for offshore wind farms. *Wind Energy* 23: 1394–1407.

O'Bryan, CJ, AR Braczkowski, HL Beyer, NH Carter, JEM Watson & E McDonald-Madden. 2018. The contribution of predators and scavengers to human well-being. *Nature Ecology and Evolution* 2: 229–236.

Oppel, S, P Iankov, S Mumun, G Gerdzhikov, M Iliev, S Isfendiyaroglu, Ç Yeniyurt & E Tabur. 2014. Identification of the best sites around the gulf of Iskenderun, Turkey, for monitoring the autumn migration of Egyptian Vultures *Neophron percnopterus* and other diurnal raptors. *Sandgrouse* 36: 240–249.

Panuccio, M, N Agostini, G Bogliani & G Dell'Omo. 2018a. Migrating raptor counts: the need for sharing objectives and field protocols, and the benefits of using radar. *Bird Study* 65: S77–S84.

Panuccio, M, B Ghafouri & E Nourani. 2018b. Is the slope between the Alborz Mountains and Caspian Sea in Northern Iran a bottleneck for migrating raptors? *Journal of Raptor Research* 52: 530–533.

Paprocki, N, D Oleyar, D Brandes, L Goodrich, T Crewe & SW Hoffman. 2017. Combining migration and wintering counts to enhance understanding of population change in a generalist raptor species, the North American Red-tailed Hawk. *The Condor* 119: 98–107.

Phipps, WL, P López-López, ER Buechley, S Oppel, E Álvarez, V Arkumarev, R Bekmansurov, O Berger-Tal, A Bermejo, A Bounas & IC Alanís. 2019. Spatial and temporal variability in migration of a soaring raptor across three continents. *Frontiers in Ecology and Evolution* 7: 323.

Porter, RF. (2005) *Soaring bird migration in the Middle East and North East Africa: the bottleneck sites.* BirdLife International, Cambridge, UK.

Rayaleh, H, M McGrady, E Abdillahi & A Darar. 2013. *Spring raptor migration across the Bab el Mandeb Straits and fitting of GPS PTT to Egyptian vulture – Djibouti Side - February 28 to March 14, 2013*. Technical report. Djibouti Nature, Djibouti City, Djibouti.

Rotics, S, M Kaatz, S Turjeman, D Zurell, M Wikelski, N Sapir, U Eggers, W Fiedler, F Jeltsch & R Nathan. 2018. Early arrival at breeding grounds: Causes, costs and a trade-off with overwintering latitude. *Journal of Animal Ecology* 87: 1627–1638.

Santos, CD, JP Silva, A Muñoz, A Onrubia & M Wikelski. 2020. The gateway to Africa: What determines sea crossing performance of a migratory soaring bird at the Strait of Gibraltar? *Journal of Animal Ecology* 89: 1317–1328.

Shirihai, H. 1982. The autumn migration of Steppe Eagles at Eilat, Israel, 1980. *Sandgrouse* 4: 108–110.

Shirihai, H, R Yosef, D Alon, GM Kirwan & R Spaar. 2000. Raptor Migration in Israel and the Middle East: A Summary of 30 Years of Field Research. *Special publication for the Raptors 2000 congress of the Raptor Research Foundation and the World Working Group on Birds of Prey*: 1–191.

Shobrak, M, S Alasmari, A Alqthami, F Alqthami, A Al-Otaibi, M Al Zoubi, EL Moghrabi, S Jbour, V Arkumarev & S Oppel. 2020. Congregations and threats of migratory Egyptian Vultures *Neophron percnopterus* along the southwest coast of Saudi Arabia. *Sandgrouse* 42: 248-258.

The Royal Society for the Conservation of Nature. 2018. *Report on Demographic Baseline Data and Conservation Status Assessment for Sensitive Species*. The Royal Society for the Conservation of Nature, Amman, Jordan.

Troost, G & A Boele. 2019. Trektellen.org - Store, share and compare migration data. *Bird Census News* 32: 17–26.

Vansteelant, WMG, B Verhelst, J Shamoun-Baranes, W Bouten, EE van Loon & KL Bildstein. 2014. Effect of wind, thermal convection, and variation in flight strategies on the daily rhythm and flight paths of migrating raptors at Georgia's Black Sea coast. *Journal of Field Ornithology* 85: 40–55.

Vansteelant, WMG, J Kekkonen & P Byholm. 2017a. Wind conditions and geography shape the first outbound migration of juvenile honey buzzards and their distribution across sub-Saharan Africa. *Proceedings of the Royal Society B: Biological Sciences* 284: 1-9.

Vansteelant, WMG, J Shamoun-Baranes, W van Manen, J van Diermen & W Bouten. 2017b. Seasonal detours by soaring migrants shaped by wind regimes along the East Atlantic flyway. *Journal of Animal Ecology* 86: 179–191.

Vansteelant, WMG, J Wehrmann, D Engelen, J Jansen, B Verhelst, R Benjumea, S Cavaillès, T Kaasiku, B Hoekstra & F Boer. 2020. Accounting for differential migration strategies between age groups to monitor raptor population dynamics in the eastern Black Sea flyway. *Ibis* 162: 356–372.

Verhelst, B, J Jansen & W Vansteelant. 2011. South west Georgia: an important bottleneck for raptor migration during autumn. *Ardea* 99: 137–146.

Wauchope, HS, A Tatsuya, WJ Sutherland & A Johnston. 2019. When can we trust population trends? A method for quantifying the effects of sampling interval and duration. *Methods in Ecology and Evolution* 10: 2067-2078.

Wehrmann, J, F de Boer, R Benjumea, S Cavaillès, D Engelen, J Jansen, B Verhelst & WMG Vansteelant. 2019. Batumi Raptor Count: autumn raptor migration count data from the Batumi bottleneck, Republic of Georgia. *ZooKeys* 836: 135–157.

Weiss, N, E Haviv, D Alon, Y Perlman & J Schäckermann. 2019. How fast does the Steppe Eagle population decline? Survey results from Eilat, Israel. *Raptors Conservation* 38: 59–67.

Welch, GR & HJ Welch. 1988. Autumn migration across the Bab-el-Mandeb Straits. *Sandgrouse* 10: 26–50.

Welch, GR & HJ Welch. 1989. Raptor counting: where should we go from here? *Ornithological Society of the Middle East Bulletin* 22: 7–9.

Welch, GR & HJ Welch. 1991. Spring raptor observations from Djibouti. *Ornithological Society of the Middle East Bulletin* 26: 25–27.

Welch, GR & HJ Welch. 1992. Preliminary observations of raptor migration along the Al Hada escarpment near Taif, Kingdom of Saudi Arabia. *Ornithological Society of the Middle East Bulletin* 28: 5–20.

Welch, GR & HJ Welch. 1998. Raptor Migration Bab al Mandab, Yemen Spring 1998. *The Phoenix* 15: 11–12.

Yosef, R & D Alon. 1997. Do immature Palearctic Egyptian Vultures *Neophron percnopterus* remain in Africa during the northern summer? *Vogelwelt* 118: 285–290.

Yosef, R & L Fornasari. 2004. Simultaneous decline in Steppe Eagle (*Aquila nipalensis*) populations and Levant Sparrowhawk (*Accipiter brevipes*) reproductive success: Coincidence or a Chernobyl legacy? *Ostrich* 75: 20–24.

B Jobson, T Allinson, V Jones, BirdLife International, David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK, ben.jobson@birdlife.org

R Sheldon, RDS Conservation, 78 Riverdene Road, Ilford IG1 2EA, UK

W Vansteelant, BRC Foundation, Hannah Arendtweg 84, 1349CM Almere, The Netherlands and Doñana Biological Station, Cartuja TA-10, Edificio I, Calle Américo Vespucio, s/n, 41092 Sevilla, Spain

E Buechley, HawkWatch International. Salt Lake City, UT 84106, USA / Migratory Bird Center, Smithsonian Conservation Biology Institute, National Zoological Park, Washington, DC 20013-7012, USA

S Oppel, RSPB Centre for Conservation Science, Royal Society for the Protection of Birds, The David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

APPENDIX 1. MIGRATORY SOARING BIRD BOTTLENECKS AND MONITORING

Bulgaria

Site: Bourgas

Current autumn coverage: Ad hoc site counts occur most years between a range of watch points. Mean counts of Great White Pelican: 20 946, Dalmatian Pelican: 208, White Stork: 145 177, Black Stork: 2718, Lesser Spotted Eagle: 10 030, Red-footed Falcon 898 from 1640 days in August, September and October between 1979 and 2003 (Michev *et al* 2011).

Maximum day counts from Trektellen: Black Stork (2395 on 20 September 2019), White Stork (58 126 on 26 August 2003), Great White Pelican (12 384 on 29 September 2019), Dalmatian Pelican (263 on 27 October 1980), Lesser Spotted Eagle (19 418 on 24 September 2014) and Red-footed Falcon (10 517 on 27 September 2017).

Key MSB species: Great White Pelican, White Stork, Black Stork, Lesser Spotted Eagle.

Research and monitoring: Bourgas Bay is one of the most important sites for MSB monitoring in Europe. A coordinated monitoring scheme ran during most autumn seasons 1979–2003, results published by Michev *et al* (2011). However, the site has not benefited from coordinated monitoring in recent years, primarily due to lack of funding. Site counts tend to occur with varied coverage, observer effort, count methodologies and data recording. Since 2011, some data have been recorded by a range of Bulgarian and international groups with Trektellen but other counts conducted for consultancies may not have contributed publicly available data. Counts in 2011, sponsored by wind energy companies, were run through the Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences. Bourgas Bay represents a good candidate site for focussing efforts to coordinate MSB monitoring in future years.

Other bottleneck sites in Bulgaria:

Site	Latitude	Longitude	Bottleneck estimate (BirdLife Datazone 2021)
Bakarlaka IBA	42.44	27.64	127 000
Balchik IBA	43.40	28.10	134 000
Batova IBA	43.36	27.95	226 000
Belite Skali IBA	43.40	28.22	37 000
Emine IBA	42.74	27.73	172 928
Galata IBA	43.12	27.88	32 000
Kaliakra IBA	43.40	28.43	32 000
Kamchia Complex IBA	43.00	27.82	60 000
Kamchiyska Mountain IBA	42.94	27.59	80 000
Mandra-Poda complex IBA	42.42	27.38	98 660
Provadiysko-Royaksko Plateau IBA	43.17	27.27	38 000
Strandzha IBA	42.07	27.65	285 000
Suhu Reka IBA	43.86	27.59	42 000
Varna-Beloslav Lakes Complex IBA	43.19	27.81	50 700

Djibouti

Site: Bab-el-Mandeb

Current autumn coverage: Currently no active site counts. The major historic count for this site recorded 246 478 raptors between 3 October and 9 November 1987 (Welch & Welch 1988).

Key MSB species: Steppe Eagle, Eurasian (Steppe) Buzzard, Egyptian Vulture, Eastern Imperial Eagle, Greater Spotted Eagle, Lesser Spotted Eagle, White Stork, Black Stork, Long-legged Buzzard, European Honey-buzzard.

Research and monitoring: The Bab-el-Mandeb strait between Yemen and Djibouti represents one of the largest bottlenecks for monitoring MSBs in the flyway. Due to its southerly location, this bottleneck is also used by Central Asian MSBs travelling from the Persian Gulf. Relatively limited ornithological research has occurred in Djibouti to date (Rayaleh *et al* 2013, Welch & Welch 1988, 1991) but this bottleneck has long been regarded as a priority for monitoring as the true scale of migration is presumably much larger than the recorded figures suggest. Tracking data have since confirmed the site's importance for autumn migration in particular (Buechley *et al* 2018). Plans for a monitoring station led by Hawkwatch International are underway but would be reliant on Djiboutian government and military approval; a previous attempt in 2017 was denied. Monitoring in Djibouti is expected to be complicated by variable winds that shift the position of birds arriving from Yemen in the autumn, or that cause birds to stage on the Djibouti side of the strait in spring. For example, in autumn, depending on conditions, MSBs may arrive at Ras Siyyan or Doumeira (sites 30 km apart), the latter site being situated along a contested Djibouti-Eritrea border.

Egypt

Sites: Ain Sukhna, Suez, El Qa Plain, Ras Mohammed National Park, Gebel El Zeit

Current autumn coverage: Currently no coordinated systematic monitoring, outside of Gebel El Zeit and Gulf of Suez wind farms.

Other bottleneck sites in Egypt:

Site	Latitude	Longitude	Bottleneck estimate (BirdLife Datazone 2021)
Ain Sukhna IBA	29.58	32.33	100 000 soaring birds (IBA estimate based on 1980-1984)
El Qa Plain IBA	28.16	33.66	200 000 soaring birds (IBA estimate from 1998)
Gebel El Zeit IBA	27.85	33.50	145 432 MSBs, including 134 599 storks and 9376 raptors over a period of 453.6 hours were observed 20 August - 29 October 2006 (Hilgerloh *et al* 2011).
Ras Mohammed National Park IBA	27.73	34.25	275 743 White Stork counted (total estimated at 390 000 - 470 000), as well as 11,653 raptors on 27 days in August and September 1998 (Ibrahim 2009).
Suez IBA	29.96	32.55	134 000 raptors were recorded between 4 September - 5 November 1981. 1002 Egyptian Vultures were recorded in 1984 (Yosef & Alon 1997). 64 880 (although estimated c100 000) Steppe Eagles and 12 136 Short-toed Snake-eagles in 1981 (Bijlsma 1983).

Key MSB species: White Stork, Black Stork, Great White Pelican, Steppe Eagle, Levant Sparrowhawk, Eurasian Buzzard (Steppe)

Research and monitoring: As with many count sites in the region, research and monitoring has varied in intensity and standardisation over the years with systematic counts being conducted in Suez in 1981 and 1984 (Bijlsma 1983, 1987), as well as a systematic survey of Ras Mohammed in 1998 (Shirihai *et al* 2000).

The most advanced monitoring in the region continues today as a result of the Gulf of Zeit wind farm complex and the Gulf of Suez Regional Centre for Renewable Energy and Energy Efficiency (RCREEE), where human observers and radar systems are employed to inform shut down on demand programmes. There are also intentions to create a database to collate monitoring data between wind farms (O Elgebaly pers comm). Migration would be expected to be more intense during spring as MSBs make their way along the coast of the Red Sea.

Egypt is on the shortlist of potential locations for a future Bird Camp, which would aim to engage local volunteers with the spectacle of migration and provide education about the local threats to migratory soaring birds, at the same time as monitoring their passage (T Haraldsson pers comm). This would likely be located in Aswan, which whilst not capturing the main passage of MSBs along the Red Sea coast would be better for engaging volunteers due to improved facilities and the opportunity to additionally record passerine migration.

Georgia

Site: Batumi IBA

Current autumn coverage: Comprehensive multi-station coverage, mid-August to mid-October annually since 2011. Over 1 million raptors are recorded every autumn with 1 138 915 counted over 1462 hours between 12 August and 21 October 2019.

Key MSB species: European Honey-buzzard, Eurasian Buzzard (Steppe), Black Kite, Eurasian Sparrowhawk, Levant Sparrowhawk, Lesser Spotted Eagle, Greater Spotted Eagle, Booted Eagle.

Research and monitoring: Batumi only became known as a globally important bottleneck site relatively recently, despite being an IBA and ad hoc counts having been conducted since the 1970s. Between 2008 and 2010, scoping surveys were held and informed the coordinated monitoring scheme that continues today. Batumi is currently the most comprehensively monitored location in the flyway with over 60 national and international volunteers assisting in autumn 2019. Despite initially experiencing limited funding and low capacity, Batumi has rapidly developed a rigorous monitoring programme that is progressing raptor research across the flyway. The count procedures were developed to include standardised monitoring protocols, count coordination, data registry on Trektellen, data standardisation and data quality control (Wehrmann *et al* 2019, Vansteelant *et al* 2020). In addition, all data are made available through GBIF. Aside from potentially Bab-el-Mandeb, Batumi is the only location on the flyway where monitoring harriers is likely to inform population-level estimates for these species.

Other bottleneck sites in Georgia:

Site	Latitude	Longitude	Bottleneck estimate (BirdLife Datazone 2021)
Alazani Valley IBA	41.63	46.16	200 000 (IBA estimate from between 1999-2002)

Iran

Site: Galugah

Current autumn coverage: Scoping surveys with the intention of establishing longer-term raptor monitoring.

Key MSB species: Steppe Eagle, Eastern Imperial Eagle

Research and monitoring: A new raptor count initiative has been set up in recent years to record MSB migration at the south east corner of the Caspian Sea. Initial surveys 8-12 October 2017 recorded 770 raptors with the most numerous species being Steppe Eagle (284) (Panuccio *et al* 2018b). Subsequent surveys at Galugah in 2020 recorded *c*15 000 large eagles mostly comprised of Steppe Eagle with some Eastern Imperial Eagles (E Talebi pers comm). This site will be a valuable addition to the network of monitoring sites as it can contribute additional data about the migration of birds (Steppe Eagles in particular) from Central Asia into Africa.

Israel

Site: Broad-front monitoring scheme

Current autumn coverage: see below

Key MSB species: Lesser Spotted Eagle, Steppe Eagle, Honey Buzzard, Levant Sparrowhawk, Great White Pelican, White Stork, Black Stork.

Research and monitoring: Israel is optimally placed on the flyway to monitor MSBs, as the majority of species will pass directly through the country. Schekler & Sapir (in prep) estimate about 150 million birds per autumn, and 130 million per spring pass through Israel. However, migration in Israel takes place across a broad front with the path of migration shifting throughout the day and with weather conditions (Leshem & Yom-Tov 2008). Due to the lack of clearly defined bottlenecks, MSB monitoring in the past has occurred over a number of count sites stretching the breadth of the country.

Since the late 1970s, Israel Air Force has funded autumn soaring bird counts coordinated and carried out by SPNI. From the mid-1980s to 2013 across the northern valleys, 5-10 stations operated daily between 20 August and 10 October. Stations were positioned 3-4 km from each other with radio communication between stations, and data reviewing eliminated double counts (Alon *et al* 2004). For two species, Lesser Spotted Eagle and Levant Sparrowhawk, this count covered practically 100% of global population and inferences about population-level declines have been suggested (Yosef & Fornasari 2004). Since 2014, the count moved back to central Israel, it was reduced to one permanent station, and duration reduced to one month, from 15 September to 15 October. As a result, counts of Lesser Spotted Eagle and Levant Sparrowhawk have been only partial, and other species that migrate outside of this period are not counted.

To reduce risk of collision with aircraft, Israel Air Force continues to support autumn monitoring of Great White Pelicans, coordinated by SPNI, between 15 September and 15 December. Data are also used to manage the conflict between pelicans and the fish farming industry and many of the fisherman and rangers contribute information via an instant messaging application. Landing and take-off at Agamon Hula/Hula NR, a major stopover site, are recorded and a migration count over central Israel is carried out by two observers.

Levant Sparrowhawk and Lesser Spotted Eagle should potentially be priorities for monitoring as the majority of their global populations pass through Israel, and are not counted comprehensively elsewhere. Complete counts of both species are possible, but require an estimated team of 67 skilled observers. Full counts should ideally be conducted for three consecutive years every decade. Steppe Eagles are also not counted systematically in any other bottleneck in significant numbers at this time. Though numbers passing through Israel represent only a small proportion of global population, systematic counts, coupled with satellite tracking, permits understanding of complete seasonal movements and their fidelity to migration routes through Israel.

In spring, raptor counts took place in years 2014 to 2018 in the Eilat mountains across 2-3 coordinated stations, operated by IBRCE/SPNI. Radio communication and data review eliminated double counts. During standard weather conditions, these two stations cover almost all migration that is channelled through Eilat Mountains. Counts were run from 1 February to 10 May, except in 2018 when counts ended on 10 April (Weiss *et al* 2019).

Other bottleneck sites in Israel:

Jordan

Site	Latitude	Longitude	Peak estimate / count	Level of monitoring
Carmel coast IBA	32.55	34.91	80 000	IBA monitoring
Cliffs of Zin and the Negev highlands IBA	30.83	34.80	36 000	IBA monitoring
Hefer valley IBA	32.45	34.93	20 000	IBA monitoring
Hula Valley IBA	33.08	35.61	100 000	IBA monitoring
Jezre'el, Harod and Bet She'an valleys IBA	32.58	35.33	596 216	Systematic counts in autumn 1988-1998 (Shirihai *et al* 2000)
Judean desert IBA	31.26	35.26	19 000	IBA monitoring
Judean foothills IBA/ Bet Shemesh	31.75	34.92	96 590 counted	IBA monitoring and counts 1980-1985 by Ezera Hadad
Kafr Qassem	32.10	34.98	604 000 counted	Systematic counts 1977-1987 (Alon *et al* 1992)
Northern Arava Valley IBA	30.88	35.32	36 600	IBA monitoring
Northern Lower Jordan valley IBA	32.41	35.55	232 000	IBA monitoring
Western Negev IBA / Be’er Sheva	31.17	34.67	75 500 counted	IBA monitoring and systematic spring count in 1984 (Frumkin *et al* 1995)
Zevulun valley IBA/ Afek	32.88	35.10	55 000	IBA monitoring and SPNI surveys submitted to Trektelen since 2017

Current autumn coverage: Currently no systematic monitoring, except at wind farms

Key MSB species: European Honey-buzzard, Eurasian (Steppe) Buzzard, Lesser Spotted Eagle, Levant Sparrowhawk

Research and monitoring: The Jordan Rift Valley extends though the country and attracts the majority of soaring bird migration in the country with similar species composition to that seen in Israel (Andrews 1996). Migration is more visible during spring when it is concentrated along the Rift Valley, as opposed to in autumn where broad front migration occurs over the whole country. The majority of MSBs enter the country from the Eilat bottleneck before travelling northwards in spring. As of 2020, there is no comprehensive raptor monitoring scheme, except for in the regions of wind farm expansion, which have recorded relatively low numbers of MSBs compared to Eilat (The Royal Society for the Conservation of Nature 2018). However, although the wind farms are unlikely to encounter the full passage of migration and thus would not be good candidate sites for migration monitoring for informing population level information, they are still a significant risk to MSBs and appropriate mitigation is crucial (Khoury 2017). Outside wind farm complexes, the priority sites for monitoring have been suggested to be Wadi Dana, Wadi Kafrayn, Wadi Shy'ayb and near Umm Qays; however, as the total extent of migration between 1989-1992 was only 17 644 raptors, effort may be better focussed in other areas of the flyway (Andrews 1996).

Bottleneck sites in Jordan:

Site	Latitude	Longitude	Peak estimate	Level of monitoring
Aqaba coast and mountains IBA	29.42	35.07	50 000-99 999 (IBA estimate 1993)	IBA monitoring

Lebanon

Site: Ras El Matn (Beirut River Valley IBA)

Current autumn coverage: Raptor Count Lebanon was established at Ras El Matn in 2019 and ran from 10 September to 12 October 2019 (Käch 2019). Significant counts included 11 562 Levant Sparrowhawks, 6046 Lesser Spotted Eagles and 7116 Great White Pelicans.

Key MSB species: Great White Pelican, Levant Sparrowhawk, Lesser Spotted Eagle

Research and monitoring: Raptor Count Lebanon was based on the Bird Camp initiative that started as a way of monitoring landbirds in Azerbajan. Being closely linked with Besh Barmag and Batumi, these counts follow standard protocols and log their data with Trektellen.

Site	Latitude	Longitude	Peak estimate	Level of monitoring
Beirut River Valley IBA	33.82	35.62	72 410	IBA monitoring
Hima Ebel es-Saqi IBA	33.36	35.63	70 000	IBA monitoring
Jabal Moussa Mountain IBA	34.03	35.75	49 999	IBA monitoring
Lake Qaraoun IBA	33.56	35.69	49 999	IBA monitoring
Rim - Sannine Mountain IBA	33.88	35.86	49 999	IBA monitoring
Tannourine Nature Reserve IBA	34.20	35.93	49 999	IBA monitoring
Upper Mountains of Akkar-Donnieh IBA	34.44	36.20	49 999	IBA monitoring

Palestinan Authoritory Territories

Current autumn coverage: Currently no systematic monitoring.

Key MSB species: Lesser Spotted Eagle, Steppe Eagle, Honey Buzzard, Levant Sparrowhawk, Great White Pelican, White Stork, Black Stork.

Site	Latitude	Longitude	Peak count	Level of monitoring
Jericho IBA	31.85	35.45	34 510	79 656 (spring 2004), 34 510 (autumn 2004) Palestinian Wildlife Society (Porter 2005)

Saudi Arabia

Current autumn coverage: Currently no systematic monitoring.

Key MSB species: Steppe Eagle, Egyptian Vulture, Greater Spotted Eagle, Lesser Spotted Eagle, White Stork, Black Stork.

Research and monitoring: For European MSBs passing down the Arabian peninsula to the Bab-el-Mandeb strait, many follow the coast of Saudi Arabia along the Red Sea. Systematic counts in 1991 confirmed the presence of 25 330 MSBs in 12 days in October (Welch & Welch 1992). The Asir mountains have great potential as an alternative monitoring location to the Bab-el-Mandeb strait, especially in autumn and further exploratory counts would be valuable to determine the suitability of this location.

Site	Latitude	Longitude	Peak Count	Level of monitoring
Taif Escarpment IBA	33.36	35.63	25 300	IBA monitoring

Turkey

Site: Bosphorus IBA and Sarimazi

Current autumn coverage: Ad hoc site counts in Bosphorus with a maximum count of 141 844 raptors and 16 088 Black Storks over 19 days in 2008 (Fülöp *et al* 2014) and 338 353 White Storks recorded over 63 days in 1975 (Arslangündoğdu *et al* 2017). 32 895 Eurasian Buzzards recorded in 1969 (Magnin & Yarar 1997). Sarimazi Raptor Count has monitored three watch sites on the Gulf of Iskenderun throughout September since 2019 with a maximum count of 163 349 MSBs including 118 124 raptors between 30 August – 30 September 2019 (Arslan *et al* 2019).

Key MSB species: Egyptian Vulture, Lesser Spotted Eagle, European Honey-buzzard, Levant Sparrowhawk, White Stork, Black Stork.

Research and monitoring: The spectacle of migration at the Bosphorus led to awareness of one of the first noted bottlenecks in the flyway for raptors and Black Storks in particular. A number of systematic counts have occurred since the 1930s but these never gained accurate results due to the need for a coordinated multi-station survey (van den Bossche & Lens 1994). As a result of a coordinated site count, larger numbers of birds were recorded. In 2008, 141 844 raptors and 16 088 Black Storks were recorded over 19 days, significantly higher than any previous single-station counts (Fülöp *et al* 2014). However, in spring there is also a significant crossing at the Dardenelles and Kapıdağ Peninsula with many birds going unrecorded at the Bosphorus, the same may be true in autumn so a multi-station approach is likely needed (Boyla 2011). In 2013, 13 localities around the gulf of Iskenderum were visited and assessed for their suitability for long-term migration monitoring stations (Oppel *et al* 2014). Satellite tracking data had confirmed that the most concentrated bottleneck was around the village of Sarimazi, as opposed to in the Amanos mountain range at the Belen pass as previously thought. In 2019, the first full migration count was held at 3 coordinated observation points across the Sarimazi bottleneck. This inaugural count was held 30 August – 30 September to encompass the peak Egyptian Vulture passage. The Sarimazi bottleneck is also relevant for other soaring birds, including, notably, Levant Sparrowhawk. Additional species could be monitored at Sarimazi if the count duration was extended, such as storks and pelicans that mainly pass in August, as well as juvenile and immature Griffon Vultures, which pass in mid-October and may not be reliably counted until they reach Suez in Israel (Arkumarev *et al* 2019). Sarimazi's 2019 count gained interest from international volunteers, who increased the capacity beyond the partners of the Egyptian Vulture New LIFE Project. All data are recorded on Trektellen and future counts aim to replicate the protocols established in 2019. Once the project funding and support concludes, it is hoped that national capacity is sufficient to organise the monitoring station at Sarimazi and attract enough volunteers. Additional counts of significance occurred in the Northeast Pontic mountains. However, today the Batumi Raptor Count in Georgia is likely to record most birds that could pass through this region of Turkey.

Other bottleneck sites in Turkey:

Site	Latitude	Longitude	Peak estimate	Level of monitoring
Amanos Mountains IBA	36.81	36.28	82 887	IBA monitoring and *ad hoc* counts in the Belen pass
Göksu Delta IBA	36.30	33.98	22 000	IBA monitoring
İstanbul Islands IBA	40.89	29.07	20 000	IBA monitoring
Sarıyar Reservoir IBA	40.033	31.62	20 000	IBA monitoring

Yemen

Current autumn coverage: Currently no systematic monitoring.

Key MSB species: Steppe Eagle, Egyptian Vulture, Greater Spotted Eagle, Lesser Spotted Eagle, White Stork, Black Stork.

Research and monitoring: Very limited research and monitoring has taken place on the Yeman side of the Bab-el-Mandeb strait due to it being a highly sensitive and militarised area. Nevertheless, tracking confirms that birds passing into Djibouti would also be countable in Yemen, although, like many sites, prevailing winds alter the point of crossing/arrival for MSBs and should to be taken into account if any monitoring initiatives become feasible in the future (Welch & Welch 1998).

Site	Latitude	Longitude	Peak estimate	Level of monitoring
Bab al-Mandab - Mawza IBA	12.68	43.46	246 000	IBA monitoring