

The desert at Zait Bay, Egypt: a bird migration bottleneck of global importance

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Summary

The study area at Zait Bay, Egypt (c. 700 km²) is situated in the middle of the West Asian-East African migration flyway used by very large numbers of soaring migrants. At this site the corridor narrows into a bottleneck. There exist only very few bottlenecks of this magnitude in the world. Observations were performed at all hours between sunrise and sunset at 26 observation sites, situated 5 km apart. The northern part of the area under investigation (19 observation sites) was situated within the Gebel El Zeit IBA (criteria A1 and A4iv), while the southernmost part (8 observation sites) was outside. The overall evaluation has shown that 179,681 soaring birds including 122,454 storks and 36,976 raptors were observed in total. Within a radius of 2.5 km from each observation site 97,143 soaring birds including 59,308 storks and 30,489 raptors were observed during the 604 hours of observation. Eleven species were recorded in numbers that exceed 1% of their flyway populations. Of special concern regarding bird conservation are those birds resting or flying in the first 200 m of elevation. In total 6,624 soaring birds were seen resting (2,252 within a radius of 2.5 km). Thirty-three percent of the storks and 47% of the raptors were observed resting or flying at heights within the lowest 200 m. The median height of flying birds varied between 5 m (harrisers) and 500 m (Common Crane *Grus grus*). According to the raw data, criteria for nomination of the area as an IBA (20,000 raptors and storks in one migration season, globally threatened species) were fully met outside the existing IBA. Also, to the south of the study area, very high numbers of migrants were confirmed by spontaneous, non-systematic observations. Accordingly, a change of the boundaries is suggested. The regional analysis, based on extrapolations, has to be regarded as a preliminary study. The analysis failed to show a geographical trend for any single species. The data from this study establish a high concentration of gliding and soaring birds in the study area, within and adjacent to the already designated IBA.

Introduction

Soaring birds are almost entirely dependent on updrafts to sustain their migration flight. This dictates and vastly reduces their choice of migration routes and funnels them along very narrow migration 'corridors'. The lack of updrafts over large bodies of water prevents them from crossing seas except at the narrowest of straits. Among the best-known of these are the Straits of Gibraltar, the Bosphorus and Bab-el-Mandeb (Newton 2008). Many of the birds migrating to and from East Africa even avoid crossing the Gulf of Suez and detour via Suez instead. However, others migrating to Sinai in spring concentrate at Zait Bay as it is the narrowest crossing point in the southern part of the Gulf of Suez.

Globally threatened species such as Egyptian Vulture *Neophron percnopterus* ('Endangered'), Lesser Kestrel *Falco naumanni* ('Vulnerable'), Greater Spotted Eagle *Aquila clanga* ('Vulnerable'), and Eastern Imperial Eagle *Aquila heliaca* ('Vulnerable'), and the 'Near threatened' Pallid

Harrier *Circus macrourus* are known to migrate through this area. The most numerous species is reported to be Levant Sparrowhawk *Accipiter brevipes* and White Stork *Ciconia ciconia* (Baha El Din 1999). In the space of a very few days the entire world population of Levant Sparrowhawks migrate through this area, usually in huge flocks (Baha El Din 1999). The main route of White Storks migrating along the eastern flyway passes through the area of Zait Bay (Schulz 1988, Berthold *et al.* 2001). Ornithologists have not been slow to recognise the area's importance (Grieve 1996, Baha El Din 1999, Christensen and Jensen 2002, Tammens 2008). BirdLife International has acknowledged the great relevance of the Zait Bay area for soaring and gliding migrants and has designated an Important Bird Area (IBA), Gebel El Zeit, (criterion A1 – globally threatened species, and a bottleneck of global importance (criterion A4iv – more than 20,000 raptors and storks or cranes in one of the two migration seasons).

In the current study, initial systematic observations have been carried out in the desert next to Zait Bay in order to present a quantitatively supported general evaluation of the global significance of the site. Special attention needs to be paid to resting and low-flying birds as these are more endangered by constructions such as wind turbines standing in their path.

The fact that the northern part of the study area is situated within the Gebel El Zeit IBA and the southernmost part outside, presents an occasion to re-examine the present boundaries of the IBA and to make suggestions for changes if necessary.

Methods

Study area

This study was made to assess the risks to migratory soaring birds from wind farms. The study area is situated in the coastal desert west of Zait Bay and west of the main Suez-Hurghada road in Egypt (Figure 1). It is bordered on the west by the foothills of the Red Sea Mountains and on the east by plains stretching to the foothills of the mountain chain of Gebel El Zeit, with hills up to 460 m high rising directly out of the Red Sea. Except for a salt depression (sabkha) in the north, the study area consists entirely of dry desert. The northernmost 18 observation sites are situated within the Gebel El Zeit IBA, the southernmost eight sites outside it.

Bird species

The area supports only a few permanent or seasonal resident bird species, the chief of which are sandgrouse (mainly Spotted Sandgrouse *Pterocles senegallus*), along with Brown-necked Raven *Corvus ruficollis*, a few Bar-tailed Desert Larks *Ammomanes cincturus*, Hoopoe Larks *Alaemon alaudipes* and Pale Crag Martins *Ptyonoprogne fuligula*. On the other hand, it is visited twice a year by staggering numbers of birds on migration. The majority of these belong to soaring and gliding species such as storks and raptors that migrate during the day. Other day-migrating species recorded during the project were cormorants, waders and small birds, mainly passerines.

Standardised daytime field observations

A row of thirteen observation sites 5 km apart from each other was established in the central part of the western desert. Five kilometres further east, a second row of 13 observation points – also 5 km apart – was set up along the road running through the eastern part of the study area (Figure 1, See Supplementary materials 1).

Given an observation radius from each observation point of 2.5 km, this created a double row of 13 observation circles of 19.6 km² succeeding one another from south to north. The observations were made from February 20 to May 6 2007. Site 1 of the road row was re-sited to coincide with the nearby radar site of the project. The observations were performed by ornithologists with more than five years experience in bird identification.

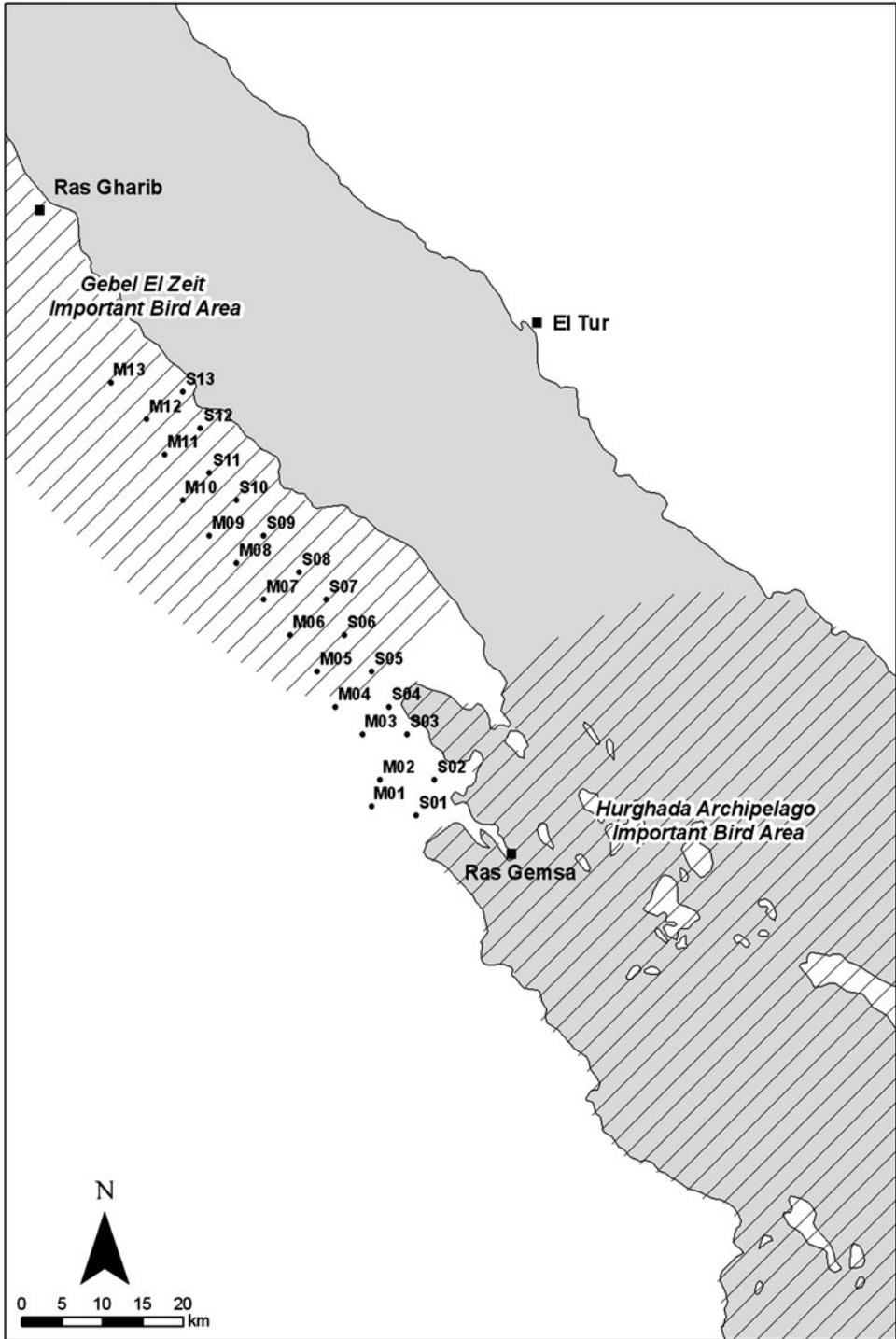


Figure 1. Position of the observation sites M1–13 and S1–13 and of the IBAs ‘Gebel El Zeit’ and ‘Hurghada Archipelago’ (produced by BirdLife International based on IBA information in the World Bird Database and information supplied by the author).

Two observation teams, each consisting of two persons, were formed and a rotation schedule was set up according to which all the sites were visited at all hours between sunrise (05h07 to 06h30) and sunset (17h45 to 18h35), each site being visited every third day. One team worked from sunrise to noon, the other from noon to sunset. Observation periods were principally of 60 minutes per site and 11 hours per day. Deviations from the work plan were caused by sand storms and by the occasional illness or unreliability of locally hired drivers. The study area was under observation for a total of 604.4 hours. Each of the sites received on average 23 visits by alternate teams.

The first team started observations at the south of the central corridor (M1) and continued at the subsequent sites northwards (M2, M3 and so on). The second team started observations at the road-sites in the north (S13) and continued visiting the sites southwards (S12, S11 and so on). Each team searched the sky for birds using binoculars of 10 x 40 magnification. For detailed identification, telescopes with magnifications from 20x to 60x were used. The following parameters were determined and documented: start of observation at a site, end of observation, exact time of observation, species, number of birds, flight direction, flight height of the birds, distance from observer, direction from observer, fibrillation border (m), visibility (km), cloud cover (%), type of cloud, wind direction, wind strength (Beaufort scale).

Estimations of the flight height and distances of the birds were calibrated with the help of laser binoculars (Geovid 10 x 40 and 7 x 40 magnification) and by comparisons with radar readings. Distances over 1 km from the observer were calibrated by reference to distances to topographical features measured by means of GPS. With large aggregations of birds the height of the lower margin of the flock was recorded. During the first weeks, the composition of teams was changed regularly in order to achieve standardised procedures and minimise differences among individual observers and between teams. The data contain a margin of error, as parameters such as migration height, distance, number of birds in large flocks and population sizes are not measured but estimated.

Radar observations

Radar observations were performed using a 25KW Furuno ship radar. It was situated close to the southern border of the concessionary area (27.69° N, 033.49° E). The radar was fixed on a stand permitting manual adjustment of the rotation plane. The radar beam rotated vertically in order to evaluate the height of birds.

Evaluation of daytime observations

Evaluation of the raw data was performed at three levels. The first evaluation ignored the distance at which birds were recorded. Then, in order to assign the birds to a specific area and in order to standardise the conditions of species recognition, subsequent evaluations took account only of birds recorded within 2.5 km of the observer. At greater distances, some of the species can no longer be identified safely.

Centred on each observation site was a circular reference area of 2.5 km radius. All birds crossing this area were recorded once. In a further evaluation, the height of migrating birds was taken into consideration. Birds present in the first 200 m were considered separately. The height distribution of the birds was evaluated within a radius of 2.5 km from the observer.

The estimate of the number of birds migrating through the different parts of the study area throughout the migration season was achieved by means of extrapolations. These are very rough approximations, subject to several uncertainties, but they do compensate to some extent for the lack of manpower for more hours of observation.

In order to assess the regional distribution of migrants for each species and site, the percentage of the flyway population was calculated and 1% taken as a general measure of global importance.

Three parameters were required: the number of birds per hour, the number of birds per season and the size of the flyway population.

The dates of the first and last daytime sightings of a species in each migration season are taken as indicators of the daily presence and the limits of the migration period of the species in this area. The number (median, range) of birds per hour during the migration period of the species and during its daily hours of presence was calculated (See Supplementary materials 2). In a few cases where the observation lasted less than 60 minutes, the number per hour was extrapolated. The estimation of the number of birds per observation season was extrapolated from the mean migration frequency (total number of birds per total number of hours within the hours and days of presence of a species at a site) (See Supplementary materials 3).

The number of days with the central 90% of the passage of a species was used in the extrapolation of the birds per season in order to keep the estimates conservative (See Supplementary materials 4).

Except in the cases of storks and cranes, the number of hours of active migration in general was similar to that during which resting birds of a species were seen. In order to keep the extrapolations conservative, for most species a presence of nine hours was taken, for Black Kite *Milvus migrans* 10 and for harriers 11 (See Supplementary materials 2). In contrast, whereas storks were seen migrating throughout 10.5 hours, they were observed resting during seven hours only. Consequently, for the daily hours of presence, a general value of eight hours was taken. On the same principle, the same value was taken for the Common Crane *Grus grus* (with 8.5 hours seen resting and 10 hours seen in flight).

Estimating flyway populations

For soaring species migrating on a narrow front it is possible to make counts of the flyway population. The birds migrating through the study area also pass through Israel, where numerous such counts have been performed. The maximum numbers emerging from these counts were used as a basis for the population estimates in this study (Leshem and Yom-Tov 1996, Shirihai 1996, Shirihai *et al.* 2000). However, where the breeding population of birds migrating north along the east African flyway exceeded the flyway population counts from Israel, the former - higher - figures were taken as the flyway population size. However, there was one exception: the flyway population of Common Cranes was estimated at 5,000–10,000 individuals in Israel (Shirihai 1996), whereas we saw more than 30,000 at Zait Bay. In view of this a flyway population of 50,000 birds is certainly more accurate (Appendix 1). Flyway population sizes for species migrating on a broad front on this flyway are not available.

Results

Magnitude of migration

Soaring and gliding birds were present in the form of pelicans, herons, egrets, storks, cranes, bee-eaters and raptors (Table 1).

In total, 179,681 soaring birds, including 122,454 storks and 36,976 raptors were observed during systematic observations between February 20 and May 6 2007 (Table 1). White Stork was the most numerous species, followed by Steppe Buzzard *Buteo buteo vulpinus*, Common Crane and Levant Sparrowhawk (Table 1).

Within a radius of 2.5 km of the observers, 97,143 soaring birds including 59,308 storks and 30,489 raptors were identified (Table 1). 44,835 storks and 23,052 raptors were observed within and 14,473 storks and 7,437 raptors outside of the existing IBA (Figure 1). In the first 200 m 19,355 storks and 14,297 raptors were observed during systematic counts (Table 2). In total, 14,937 storks and 11,099 raptors were observed inside the existing IBA and 6,073 storks and 3,492 raptors outside. Thus, inside and outside the IBA, 47–48% of the raptors were identified in the first 200m. Thirty-three percent of the storks were flying inside the IBA and 42% outside.

Table 1. Number of resting and flying birds of soaring and gliding species at all distances and at distances up to 2.5 km in the desert of Zait Bay from February 20 to May 6 2007.

Species	All distances Total	Radius 2.5 km Total
Great White Pelican <i>Pelecanus onocrotalus</i>	1,801	882
Cattle Egret <i>Bubulcus ibis</i>	1	1
Squacco Heron <i>Ardeola ralloides</i>	6	6
Western Reef Heron <i>Egretta gularis</i>	82	82
Purple Heron <i>Ardea purpurea</i>	9	9
Egret species <i>Egretta</i> sp.	3	3
White Stork <i>Ciconia ciconia</i>	120,745	58,063
Black Stork <i>Ciconia nigra</i>	1,709	1,245
Stork species <i>Ciconia</i> sp.	273	
Greater Flamingo <i>Phoenicopterus ruber</i>	25	25
Black Kite <i>Milvus migrans</i>	1,660	1,366
Egyptian Vulture <i>Neophron percnopterus</i>	64	60
Montagu's Harrier <i>Circus pygargus</i>	12	12
Pallid Harrier <i>Circus macrourus</i>	13	13
Pallid Harrier/Montagu's Harrier <i>C. macrourus/</i> <i>C. pygargus</i>	12	11
Western Marsh Harrier <i>Circus aeruginosus</i>	62	60
Harrier species <i>Circus</i> sp.	2	1
Eurasian Sparrowhawk <i>Accipiter nisus</i>	76	73
Levant Sparrowhawk <i>Accipiter brevipes</i>	7,600	6,700
Levant Sparrowhawk/Sparrowhawk <i>A. nisus/A. brevipes</i>	6	6
Hawk species <i>Accipiter</i> sp.	18	18
European Honey Buzzard <i>Pernis apivorus</i>	1,381	1,227
Steppe Buzzard or Honey Buzzard <i>Pernis apivorus/</i> <i>Buteo b. vulpinus</i>	855	559
Steppe Buzzard <i>Buteo buteo vulpinus</i>	23,539	17,792
Long-legged Buzzard <i>Buteo rufinus</i>	98	68
Buzzard species <i>Buteo</i> sp.	82	46
Eastern Imperial Eagle <i>Aquila heliaca</i>	1	1
Steppe Eagle <i>Aquila nipalensis</i>	1,747	1,553
Steppe Eagle/Tawny eagle <i>A. nipalensis/rapax</i>	1	1
Greater Spotted Eagle <i>Aquila clanga</i>	9	9
Lesser Spotted Eagle <i>Aquila pomarina</i>	195	177
<i>Aquila</i> sp.	669	364
Booted Eagle <i>Hieraetus pennatus</i>	118	115
Short-toed Snake-eagle <i>Circaetus gallicus</i>	95	87
Osprey <i>Pandion haliaetus</i>	7	7
Common Kestrel <i>Falco tinnunculus</i>	53	53
Eurasian Hobby <i>Falco subbuteo</i>	3	3
Lesser Kestrel <i>Falco naumanni</i>	20	20
Lesser Kestrel/Kestrel <i>F. naumanni/F. tinnunculus</i>	19	19
Peregrine Falcon <i>Falco peregrinus</i>	3	3
Barbary Falcon <i>Falco pelegrinoides</i>	2	2
Barbary Falcon/Peregrine <i>F. pelegrinoides/</i> <i>F. peregrinus</i>	2	2
Lanner Falcon <i>Falco biarmicus</i>	2	2
Falcon species <i>Falco</i> sp.	2	2
Raptor spec. <i>Accipitriformes</i>	583	57
Common Crane <i>Grus grus</i>	15,906	6,228
European Bee-eater <i>Merops apiaster</i>	60	60
Blue-cheeked Bee-eater <i>Merops persicus</i>	10	10
Bee-eater species <i>Merops</i> sp.	40	40
Total	179,681	97,143

Table 2. Number of resting birds, number of birds present in the first 100 m of height (including resting birds), in the second 100 m and above 200 m. The observations were performed in the desert of Zait Bay in the time period between February 20 and May 6 2007 within a radius of 2.5 km from each site.

Species	Resting	< 101	101–200	> 200	Total
Great White Pelican	53	724	76	29	882
Cattle Egret		1			1
Squacco Heron	6				6
Western Reef heron	82				82
Purple Heron		9			9
Egret sp.	3				3
White Stork	1,656	8,981	9,817	37,609	58,063
Black Stork	31	218	327	669	1,245
Greater Flamingo	25				25
Black Kite	16	778	203	369	1,366
Egyptian Vulture		12	3	45	60
Montagu's Harrier		11	1		12
Pallid Harrier		13			13
Pallid Harrier/Montagu's Harrier	1	8		2	11
Western Marsh Harrier	4	50	2	4	60
Harrier sp.		1			1
Eurasian Sparrowhawk		54	5	14	73
Levant Sparrowhawk		25	2,574	4,101	6,700
Levant Sparrowhawk/Sparrowhawk		5		1	6
Hawk undetermined		11	1	6	18
European Honey Buzzard		401	244	582	1,227
Steppe Buzzard or Honey Buzzard		227	84	248	559
Steppe Buzzard	143	5,850	3,213	8,586	17,792
Long-legged Buzzard		21	9	38	68
Buzzard sp.	1	12	5	28	46
Eastern Imperial Eagle				1	1
Steppe Eagle	3	63	189	1,298	1,553
Steppe Eagle/Tawny Eagle				1	1
Greater Spotted Eagle		1		8	9
Lesser Spotted Eagle		18	24	135	177
Aquila sp.	6	53	34	271	364
Booted Eagle		20	15	80	115
Short-toed Snake-Eagle	1	18	10	58	87
Osprey	1	3	1	2	7
Common Kestrel	9	42	1	1	53
Eurasian Hobby		2	1		3
Lesser Kestrel		16	3	1	20
Lesser Kestrel/Kestrel		19			19
Peregrine Falcon		2		1	3
Barbary Falcon			2		2
Barbary Falcon/Peregrine		2			2
Lanner Falcon		2			2
Falcon sp.		1		1	2
Raptor sp.		9	32	16	57
Common Crane	204	1,109	310	4,605	6,228
European Bee-eater	7	53			60
Blue-cheeked Bee-eater				10	10
Bee-eater sp.		40			40
Total	2,252	18,885	17,186	58,820	97,143

Percentage of the flyway population

One percent of the flyway population is taken as a general measure of global importance. Regardless of the kind of counts recorded – those ignoring the distance at which birds were recorded or those considering only birds observed within the range of 2.5 km – there were 11 species whose recorded numbers were in excess of 1% of their flyway population. For seven of these, this still applies if one considers only the birds flying at or below 200 m, and for as many as five of these again when counting only those at or below 100 m (Table 3). White Stork, Common Crane and Levant Sparrowhawk were present with the highest percentage of the flyway population. Storks can be recognized at up to 12 km distance, which explains the high percentage of storks seen during the systematic observations irrespective of distance.

Resting birds

Whether birds use an area for resting is essential to the evaluation of the risks to birds at this site. Disregarding the distance of the birds from the observer, 6,624 soaring birds were observed resting, of which 2,252 were within 2.5 km (Table 2). In total, 0.6% of the raptors and 2.8% of the storks observed within the range of 2.5 km were resting (Table 2). Among the resting birds White Stork, Common Crane and Steppe Buzzard were the most frequent species (Supplementary material 5). A high proportion of the storks and cranes were resting outside the IBA – 49% and 66% respectively. Pelicans, herons and flamingos were only seen in the vicinity of S13 with its salt lake situated in the salt flats.

Altitude of migrating birds

Twelve of the 21 soaring and gliding species studied migrated at median heights between 200 and 500 m, and nine species at median heights below 100 m (Table 4). The low-flying species were Great White Pelican *Pelecanus onocrotalus*, Black Kite, Pallid Harrier, Montagu's Harrier *Circus pygargus*, Western Marsh Harrier *Circus aeruginosus*, Eurasian Sparrowhawk *Accipiter nisus*, Common Kestrel *Falco tinnunculus*, Lesser Kestrel and European Bee-eater *Merops apiaster*.

Table 3. Percentage of the flyway population: all birds observed at any distance and height, birds observed within a radius of 2.5 km and birds in the first 200 m or in the first 100 m within a radius of 2.5 km. Observations were performed in the desert at Zait Bay during the period between February 20 and May 6 2007. Only species present in numbers exceeding 1% of the flyway population are included. Population estimates see Appendix.

Species	All distances	Radius 2.5 km	Radius 2.5 km, < 201m	Radius 2.5 km, < 101 m
Great White Pelican	2.3	1.1	1.1	1
White Stork	16.1	7.7	2.7	1.4
Black Stork	4.3	3.1	1.4	0.6
Black Kite	4.6	3.7	2.8	2.2
Egyptian Vulture	1.3	1.2	0.3	0.2
Levant Sparrowhawk	12.7	11.2	4.3	0
Steppe Buzzard	5.1	3.8	2.0	1.3
Long-legged Buzzard	1.6	1.1	0.5	0.4
Steppe Eagle	2.3	2.1	0.3	0
Booted Eagle	2.4	2.3	0.7	0.4
Common Crane	31.8	12.5	3.3	2.6

Table 4. Median height, lower and upper quartile of height, range and height up to which 90% of the birds were observed. The observations were performed in the desert of Zait Bay in the time period between February 20 and May 6 2007.

Species	Median height (m)	Lower quartile (m)	Upper quartile (m)	90% (m)	Range (m)
Great White Pelican	50	30	50	150	290
White Stork	300	200	300	300	799
Black Stork	300	150	400	400	890
Black Kite	50	15	300	500	999
Egyptian Vulture	300	225	500	650	770
Montagu's Harrier	5	4	10	20	149
Pallid Harrier	5	1	10	30	99
Western Marsh Harrier	5	4.5	10	150	399
Eurasian Sparrowhawk	30	10	150	400	599
Levant Sparrowhawk	300	200	400	600	599
Honey Buzzard	200	100	400	500	599
Steppe Buzzard	200	100	400	500	1,349
Long-legged Buzzard	300	90	650	800	799
Steppe Eagle	400	300	500	650	999
Lesser Spotted Eagle	350	250	600	800	997
Booted Eagle	300	200	400	600	680
Short-toed Snake-Eagle	300	150	400	500	795
Common Kestrel	20	10	50	50	599
Lesser Kestrel	30	10	75	200	399
Common Crane	500	300	500	600	690
European Bee-eater	30	1	100	100	99

Species with the greatest median heights were the Common Crane, Steppe Eagle *Aquila nipalensis* and Lesser Spotted Eagle *Aquila pomarina* (500 m, 400 m and 350 m respectively).

Particular attention was paid to the extent to which soaring birds made use of the lower air layers, as the risks to low flying birds by construction of wind farms is highest. Forty percent of the soaring birds (= 38,000 birds), 33% of the storks and 47% of the raptors were observed at or below 200 m (Table 2). Over 50% of the pelicans, harriers, kites and kestrels were observed in the first 200 m, while large species such as Steppe Eagle, Lesser Spotted Eagle, White Stork, Black Stork *Ciconia nigra* and Common Crane were present with less than 30%. This may in part be due to the sheer size of these species, which makes them more readily visible at greater heights, thus increasing the percentage of birds counted outside the 200 m layer.

Regional differences of migration magnitude

Of the 16 species considered, only for Great White Pelican was there a significant difference in migration frequency between sites (Kruskal-Wallis test $\chi^2 = 42.796$, $P = 0.015$). See Supplementary materials 6 and 7 for full results including a graph on the distribution of the Great White Pelican.

Eastern Imperial Eagle, Greater Spotted Eagle, Pallid Harrier and Lesser Kestrel are broad-front migrants and accordingly not expected in high numbers. These four globally threatened or near threatened species were not concentrated in any one particular area, but distributed unevenly throughout the entire study area (Table 5). Narrow front migrants tend to be spatially more concentrated on migration, and their flyway populations are better known. Table 6 and Supplementary materials 8 and 9 demonstrate that at all sites at least one species was present in

Table 5. The number of migrants extrapolated for the central 90% of migration at different sites in the course of the observation period of each of these globally 'threatened' and 'Near Threatened' species. The observations were performed in the desert of Zait Bay in the time period between February 20 and May 6 2007.

Site	Pallid Harrier	Lesser Kestrel	Greater Spotted Eagle	Sum
Mo1	0	34	0	34
Mo2	0	36	0	36
Mo3	0	0	46	46
Mo4	0	0	0	0
Mo5	0	0	0	0
Mo6	0	135	0	135
Mo7	39	0	0	39
Mo8	64	0	0	64
Mo9	0	0	26	26
Mo10	32	62	0	94
Mo11	34	97	0	131
Mo12	0	0	77	77
Mo13	0	0	68	68
So1	33	74	28	135
So2	0	0	77	77
So3	39	37	0	75
So4	0	74	0	74
So5	0	0	0	0
So6	0	37	0	37
So7	37	74	0	110
So8	0	0	0	0
So9	0	0	0	0
So10	0	0	0	0
So11	69	0	0	69
So12	69	41	0	110
So13	33	0	0	33

numbers exceeding 1% of its flyway population, even at or below 200 m. For the area outside the IBA on average 6.5 species per site exceeded 1% of the flyway population and inside, 5.5 species.

Discussion

The study provides evidence of a generally very substantial migration through the desert of Zait Bay, a result which is also supported by spontaneous, non-systematic observations outside the recording schedule. Threatened and 'Near Threatened' species such as Egyptian Vulture, Pallid Harrier, Lesser Kestrel, Eastern Imperial Eagle and Greater Spotted Eagle, were involved.

For observation data at different sites across the world, a comparison appears difficult in light of the very different observation efforts involved. These counts were carried out by one two-person team at a time, reducing double counts to near zero, whereas in other studies – despite efforts to minimize their effect - double counts caused by simultaneous observations at several sites with overlapping sight range remain a big problem.

It would be easy to assume that soaring migrants, constrained as they are to gain height before attempting to cross the 'updraft desert' of the Gulf, will fly high over the study area and thus be of no immediate conservation concern. The fact is, however, that migrants frequently enter the stratum of the first 200 m, which around a large scale wind farm would constitute an area of very high risk. The large amount of low-flying and resting migrants might be caused by the birds'

Table 6. Number of species with more than 1% of the flyway population during the central 90% of the passage. Figures are based on extrapolations (Supplementary materials 8 and 9). The observations were performed in the desert at Zait Bay in the time period between February 20 and May 6 2007.

Site	All heights	First 200 m	Site	All heights	First 200 m
Mo1	3	1	So1	7	4
Mo2	3	2	So2	8	4
Mo3	7	4	So3	8	4
Mo4	6	5	So4	9	3
Mo5	7	3	So5	2	1
Mo6	8	4	So6	9	3
Mo7	9	3	So7	6	4
Mo8	5	3	So8	6	4
Mo9	4	4	So9	8	5
Mo10	6	4	So10	6	4
Mo11	6	1	So11	6	3
Mo12	5	1	So12	5	4
Mo13	7	2	So13	2	2

hesitation to cross the sea in bad condition, preferring to spend another night in the area. In most species (exceptions were harriers and Common Kestrel) the flight altitude varied greatly. Altitude seemed to be more an index of weather conditions than a species trait, as already recognised in Israel on the basis of radar observations (Spaar 1995).

The turbines of a wind farm, for instance, would oblige the birds to change from gliding and soaring to energy-consuming active flight, in order to avoid collisions with the rotors. Even normal migration puts birds at considerable risk (Alerstam 1990, Wilcove 2008). This is particularly evident in spring when almost constant, strong headwinds make the desert crossing extremely arduous for the birds. What would be the consequences of additional energy expenditure to circumvent the turbines? This would certainly lead to an increase in fatal casualties. They may not occur at the site of the wind farm itself, but later, further along the migration route, wherever the remaining strength of individual birds finally fails them.

Further, in spring, birds are under great time pressure, as they have to arrive at their summer quarters early enough to compete successfully for a suitable breeding site so that they are able to rear their young before leaving again for Africa. Birds arriving too late or too exhausted will not breed and reproduce successfully. Here, too, the additional energy costs incurred by circumnavigating an extensive wind farm would have a considerable negative impact. In a migration bottleneck this would involve a huge number of birds.

Fortunately there are conventions (Bern Convention, 1979) which set standards with respect to the construction of wind farms in areas such as this globally important migration bottleneck. They clearly advise against any such developments in areas that fulfil the IBA criteria (Bern Convention 1979, Hötter, *et al.* 2004, Langston and Pullan 2003, Drewitt and Langston 2006, Langston 2006).

Extensive, systematic surveys of birds during migration provide a solid base of data to characterize the study area as a whole. However, despite the systematic schedule of regular visits, the numbers of observation hours per site are not large enough to draw regional conclusions without extrapolations. It should be noted that they entail a considerable statistical margin of error. Only with long-term data would it be possible to describe regional characteristics reliably.

Extrapolating the number of birds per season and site is done on the assumption that observations were made at each site throughout the entire season. Since double sightings would be inevitable, it is not permissible to sum the extrapolated numbers of birds over several sites.

There was no detectable preference on the part of the migrants for any particular route through the study area. With the exception of Levant Sparrowhawk, raptors migrated predominantly

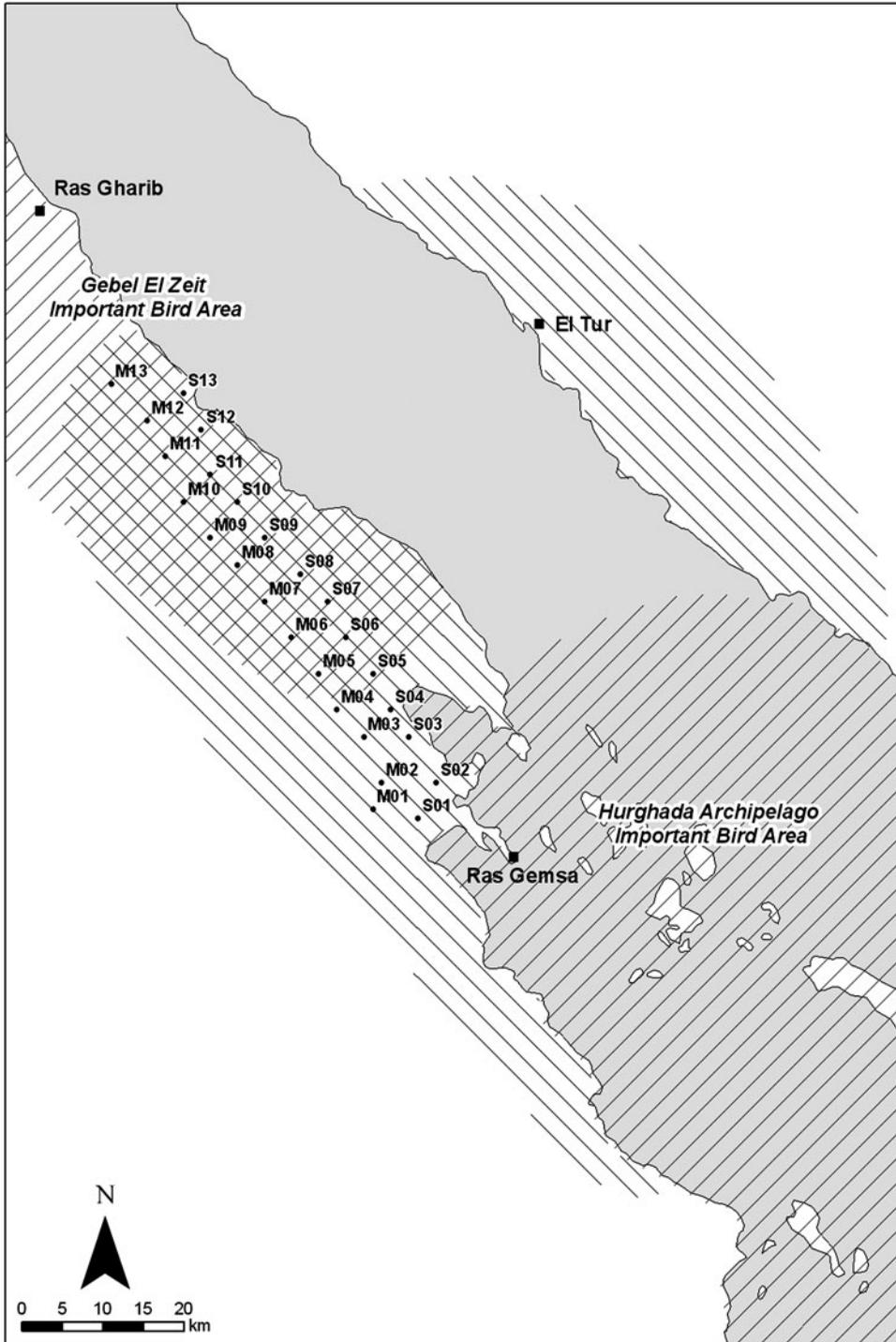


Figure 2. Suggested changes to the boundaries of the IBA 'Gebel El Zeit' and the suggestion for an additional IBA opposite Zait Bay on the other side of the Gulf of Suez (produced by BirdLife International based on IBA information in the World Bird Database and information supplied by the author).

singly or in small groups and showed a fairly regular pattern. In contrast, storks, pelicans and cranes, migrating for the most part in enormous flocks, produced very pronounced regional fluctuations. The herons, egrets and flamingos that concentrated in the area of site S13 were attracted there by a small lake in the salt depression. The comparison between the observations inside and outside the IBA revealed that criterion A1 (globally threatened species) and A4iv (> 20,000 raptors and storks) were also fulfilled at the sites outside the present IBA boundary. The risk to birds was similar to that in the IBA, as more than 40% entered the stratum of the first 200 m altitude. In view of these results, the large numbers of migrants observed to the south of the study area – often migrants are heading for Sinai at the latitude of El Gouna - and the position of the important resting site Wadi Millaha - the only wadi with fresh water - I propose an extension to the existing boundaries of the IBA to the south as suggested in Figure 2. In the north I suggest reducing the IBA to the actual area where birds cross to Sinai (Figure 2). Migrants heading for Suez concentrate mainly along the mountain ridge west of the present IBA where they should also be protected. In the north, protection of the coastal area may be needed at sites where the mountains run close to the coast. Further, it stands to reason that on the other side of the Gulf of Suez, soaring birds are no less at risk than in the study area. Even the majority of White Storks that have reached the southern tip of Sinai continue northwest along the coast of Sinai before starting the sea-crossing, thus arriving at the mainland of Egypt between Ras Gharib and Ras Gemsa (Celmins in Christensen and Jensen 2002). Therefore I suggest the designation of an IBA opposite Zait Bay on the eastern side of the Gulf of Suez (Figure 2). However, observations are needed to revise its boundaries.

Our observations revealed that migrants fly along the foothills of the Red Sea Mountains and then head for the coastal mountain chain Gebel El Zeit or the coast adjacent to the north. Especially in those species like White Stork (Creutz 1985, Schulz 1988, Goodman and Meininger 1989, Berthold *et al.* 2001), Levant Sparrowhawk (Grieve 1996, Baha El Din 1999) and Common Crane, substantial parts of the population cross the Gulf of Suez on a regular basis. Thus, many have no choice but to cross the study area. Others, like Lesser Spotted Eagle, a species that avoids any sea crossing (Meyburg *et al.* 2002, Grieve 1996), continue migration towards Suez.

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Appendix

Estimates of the flyway population sizes during spring migration. Numbers marked by an asterisk * are the estimates used in this study.

Species	Population size	Source
Great White Pelican <i>Pelecanus onocrotalus</i>	70,000–80,000	Shirihai (1996)
White Stork <i>Ciconia ciconia</i>	500,000 176,000 pairs (750,000*)	Shirihai (1996), Stork-Center Bergenhusen
Black Stork <i>Ciconia nigra</i>	10,000–20,000 9,500 pairs (40,000*)	Shirihai (1996), Dornbusch (2005)
Black Kite <i>Milvus migrans</i>	25,000–32,000 28,000 – 36,000	Leshem and Yom-Tov (1996), Shirihai (1996)
Egyptian Vulture <i>Neophron percnopterus</i>	800 – 1,000 1,720 pairs (5,000*)	Shirihai (1996), Mebs and Schmidt (2006)
Levant Sparrowhawk <i>Accipiter brevipes</i>	40,000–50,000 c. 12,000 pairs c. 40,000? (60,000*)	Leshem and Yom-Tov (1996), Mebs and Schmidt (2006), Mebs pers. comm.
European Honey Buzzard <i>Pernis apivorus</i>	190,000–850,000	Leshem and Yom-Tov (1996)
Steppe Buzzard <i>Buteo buteo vulpinus</i>	320,000–460,000	Leshem and Yom-Tov (1996)
Long-legged Buzzard <i>Buteo rufinus</i>	1,816 Suez (1981) 4,446 Baltimi c. 2,900 pairs c. 6,000? (6,000*)	Gensbol and Thieme (2004) Mebs and Schmidt (2006), Mebs pers. comm.
Steppe Eagle <i>Aquila nipalensis</i>	11,000–75,000	Leshem and Yom-Tov (1996)
Lesser Spotted Eagle <i>Aquila pomarina</i>	83,701 (1990) (85,000*)	Leshem and Yom-Tov (1996), Shirihai <i>et al.</i> 2000
Short-toed Snake-Eagle <i>Circaetus gallicus</i>	7,400–12,000	Shirihai (1996)
Booted Eagle <i>Hieraaetus pennatus</i>	800–2,000 c. 2,350 pairs 5,000 (5,000*)	Shirihai (1996), Mebs and Schmidt (2006), Mebs pers. comm.
Common Crane <i>Grus grus</i>	5,000 – 10,000 > 30,000 (50,000*)	Shirihai (1996) Total number observed at Zait Bay in spring 2007
European Bee-eater <i>Merops apiaster</i>	4,000 – 6,300	Shirihai (1996)