Spring migration of soaring birds over the highlands of southwest Jordan: flight patterns and possible implications for wind farm developments

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The general flight pattern of migrating soaring birds was compared in spring among various sites on the highland plateau of southwest Jordan east of the escarpment/rift margin. These areas are currently subject to extensive wind farm development although the use of the air space by birds was not considered during the planning phase which included selection of sites. The results suggest that areas adjacent to the escarpment/rift margin have a high density of soaring birds in the spring season and thus a larger number of collisions with wind turbines can be expected. During hot and calm weather conditions, occurring especially later in the season (*ie* end April–May), migrating birds tended to fly higher above the ground than on cool days. For a spatial comparison among sites, the data over the season for all species was pooled. The proportion of migrating birds flying at potential collision risk with rotors of 3MW turbines is *c*40% from the top of the escarpment to a distance of at least 7.5 km eastwards; further east, there is an obvious decline in the number of migratory soaring birds in general and the percentage of soaring birds flying at risk height

INTRODUCTION

The Great Rift valley extends from East Africa in the south through the Red sea and gulf of Aqaba and further north into the Levant region. The rift valley forms a linear geographic depression which runs in a north–south direction along the western borders of Jordan, and includes the tip of the gulf of Aqaba, Wadi Araba, the Dead sea depression and the valley of the river Jordan. The rift valley is bordered by highlands on the eastern, Jordanian, side and in-between are the steep slopes of the rift margin. Large numbers of the raptors migrating in spring from Africa through Sinai toward their breeding grounds in Eurasia concentrate at the tip (northernmost head) of the gulf of Aqaba. Most of these birds follow the rift margin, heading in northerly and northeasterly directions, where they appear to disperse progressively into micro-routes, often following wadis (valleys) that flow into the rift valley (Andrews 1996). Raptor migration is more prominent in the western parts of Jordan including the rift margins and highlands during spring, compared to autumn when raptors tend to migrate on a broader front over Jordan (Andrews 1996). Shirihai (1996) estimated the number of raptors crossing Eilat and Aqaba in spring at over one million birds, with Honey Buzzard *Pernis apivorus*, Steppe Buzzard *Buteo b. vulpinus*, Steppe Eagle *Aquila nipalensis*, Black Kite *Milvus migrans* and Levant Sparrowhawk *Accipiter brevipes* being numerically dominant (Andrews 1996). More recent observations show that substantial numbers of a few raptor species migrate over the southern rift margins on some days and it is not unusual to record thousands of Steppe Buzzards, Honey Buzzards and/or Levant Sparrowhawks soaring at Dana (northwest of Shobak town) during a single day (FK). Nevertheless, a reliable estimate of numbers, and accurate information about (micro-) routes and behaviour of large soaring birds migrating in different parts of Jordan is still lacking.

This report summarizes the observations on the flight behaviour of soaring birds during their spring migration in the highlands of southwest Jordan where major wind farm developments are underway and expected to increase in the coming years. BirdLife International partner in Jordan (Royal Society for the Conservation of Nature) and local experts have expressed some concerns regarding the quality of environmental impact assessments and requested high standards in assessing possible impacts on birds (http://

migratorysoaringbirds.undp.birdlife.org/en/sectors/energy). A strategic environmental assessment was also requested by local experts (including FK), because the selection of sites for wind farm development was originally carried out without taking birds or other ecological aspects into consideration. A strategic environmental assessment including the use of the airspace in this region by birds would have been required in the planning phases to avoid the selection of ecologically sensitive sites (*eg* BirdLife International statement: www.rspb.org.uk/Images/birdlifewindfarmposition_tcm9-241919.pdf). All of the sites where wind farms are to be developed in southwest Jordan are on the highland plateau between the top of the escarpment/edge of higher rift margins, which is a major route for migratory soaring birds and where the air space is used frequently by resident and breeding raptors (Andrews 1995, RSCN 2000), and the city of Ma'an *c*30 km east of the top of the escarpment (Figure 1).

Large soaring birds, particularly birds of prey, have previously been found to be particularly prone to collision with wind turbines. Large modern wind turbines pose a real threat to raptor populations because many raptors have not evolved avoidance behaviour to man-made structures like rotating blades (Hunt & Watson 2016). Collisions of raptors have been studied in other countries particularly in the USA and Spain, where most collisions occurred with turbines that were placed at or close to escarpments/ridges and on slopes along the edges of valleys, or areas that contained a high density of prey (Thelander & Smallwood 2007, Sterner *et al* 2007, Smith & Dwyer 2016). De Lucas *et al* (2008) showed that topographical features rather than bird abundance may have a major influence on bird collisions, and turbines that are positioned at higher elevations were responsible for most bird collisions. In any case, problems like high rates of bird mortalities due to collisions with wind turbines arise locally due to lack of appropriate assessments and monitoring (Hötker *et al* 2006).

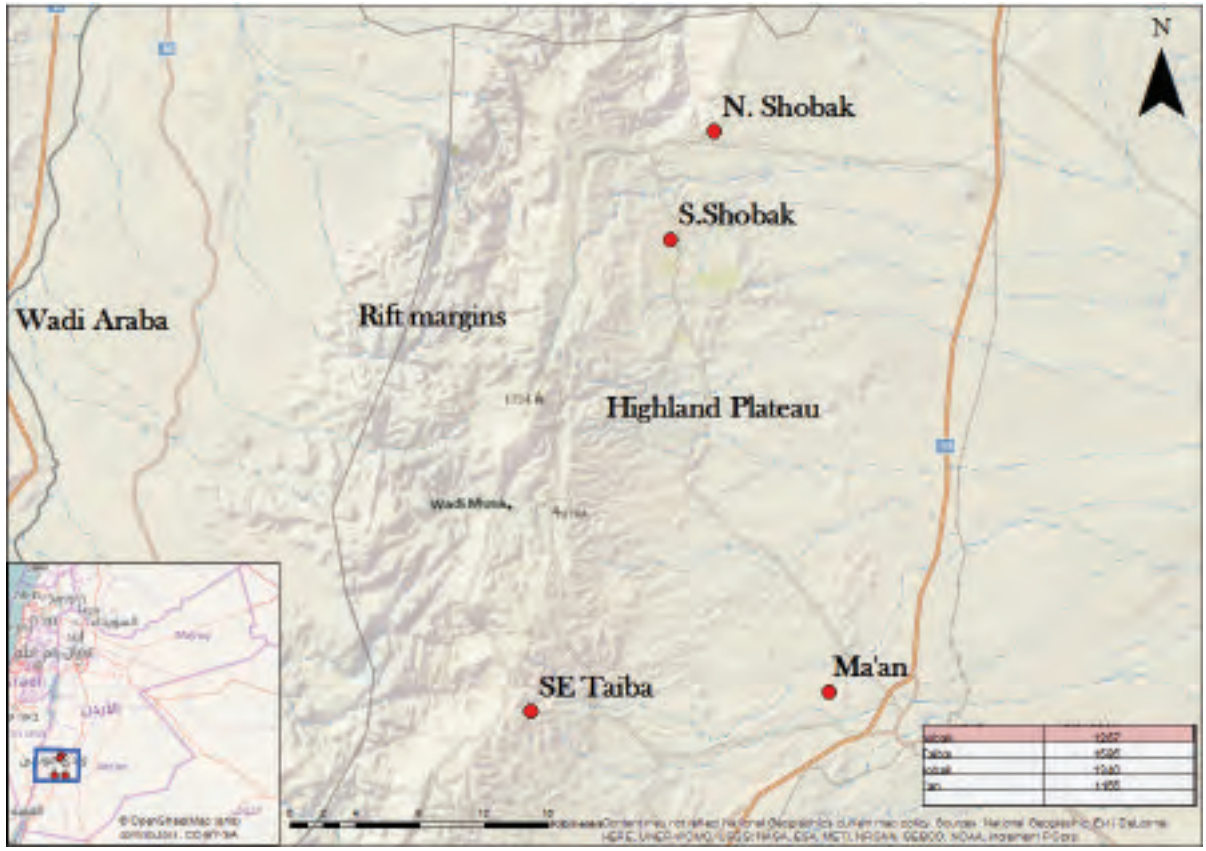

Figure 1. Map of the study area showing the location of the four study sites in relation to the top of the escarpment (upper edge of rift margins) in the highlands of southwest Jordan.

During the writing of this paper, two farms were in operation (Gharandal/Tafila and Ma'an), and construction of several were being planned from Tafila south to Rajif on the Sharrah highland plateau (Figure 1). Surveys and monitoring have been/are being carried out locally to assess the number of birds at pre-selected wind farm sites, with the goal of finding ways for mitigation rather than avoidance, but the results of these surveys are not freely accessible as most consulting and developing companies have a non-disclosure policy. This is the first published report of an independent study. It was carried out at four different sites in the southern highlands with varying distances to the top of the ridge/escarpment. The results could be used by managers and decision makers to select and reconsider the selection of sites for wind farms, previously carried out without taking into consideration precautionary avoidance regarding potential threats to birds and other wildlife.

It is expected that the density of migratory soaring birds is highest, and their average flight height lowest at and near the top of the rift margins/escarpment. This is based on the following: (a) the soaring birds flying northeastwards tend to disperse rather than taking a narrow route after crossing the escarpment and (b) they arrive at the escarpment at a relatively low elevation because they are coming from lower elevations in the rift, but then gain height while soaring north/northeastwards over the plateau.

METHODS

The observations were carried out at four sites; three of these were close to preselected sites for wind farm developments. The distances to the main escarpment varied from 200 m at a site just north of Shobak town, to 24 km at Ma'an. Two other sites had intermediate distances to the escarpment: south of Taiba/Wadi Musa at 2.2 km and south of Shobak at 7.5 km distance to the main escarpment/upper edge of the rift margin (Table 1, Figure 1). Although these areas had different elevations above sea level, and slightly different topographical features in the surroundings, the author assumed that distance to the escarpment would have the biggest impact on relative numbers and general flight pattern. One suitable vantage point was selected at each site on an elevated point overlooking the entire area to a range of 2 km eastwards, and at the same time making the observer able to detect birds coming from the west and south before reaching the vantage point. Sites also included one or more structures as reference for height above the ground (poles, towers, see below). The surveys were carried out in the springs of 2013 and 2014 and the periods of observations from March–May covered the peaks of migration of common migrants. The total time of observation at each site/vantage point ranged in any day from 3–8 hours, distributed evenly over the season and starting at different times of the day (earliest 08.00 h). Observations were not carried out during stormy weather or after 17.00h. The total duration of observations for any site over the season ranged from 63–108 hours. These discrepancies and the fact that simultaneous observations in different locations were not carried out were due to logistic difficulties and lack of resources and voluntary observers. Although the number of migratory birds varied strongly among days (FK), the data collected during this intermittent survey is sufficient to recognize and compare relative numbers and general flight patterns among sites. The following data were collected in the field during vantage point observations: weather conditions, species and number of individuals of soaring birds, start time of record, direction/route of soaring birds, height band every 15 s until bird(s) leaves site (at a distance of 1–2 km if possible). The height was estimated with the help of visible references in the area with known height, *ie* masts or transmission towers of known height *(eg* poles, masts and telecommunication towers were available in the locations or nearby with heights ranging from 10–200 m). Two bands were estimated: below 140 and above 140 m height. The flight height below 140 m is called

Table 1. Total number of soaring birds flying over the four study sites in southwest Jordan (Figure 1) during the observation periods. The number of individuals flying below 140 m is shown in brackets.

Site	N Shobak	SE Taiba	S Shobak	Ma'an
Location and elevation	30° 31′ 54″N 35° 37′ 02″E 1267 asl	30° 12′ 33″N 35° 29′ 27″E 1585 asl	30° 28′ 18″N 35° 35′ 16″E 1340 asl	30° 13′ 00″N 35° 41′ 00″E 1155 asl
Distance to main escarpment (km)	0.2	2.2	7.5	25
Total duration of observation (hrs)	108	63	90	72
Period of observation	15 March–5 May 2014	25 March–4 May 2014	9 March–12 May 2013	28 March–12 May 2014
White Stork *Ciconia ciconia*	2 (2)	0	18 (8)	0
Osprey *Pandion haliaetus*	1 (1)	0	0	0
Egyptian Vulture *Neophron percnopterus*	2 (1)	0	1 (0)	0
Short-toed Eagle* *Circaetus gallicus*	10 (8)	8 (3)	6 (2)	1 (0)
Steppe Eagle *Aquila nipalensis*	26 (19)	10 (4)	18 (6)	2 (0)
Booted Eagle *A. pennata*	2 (2)	1 (1)	1 (1)	0
Black Kite *Milvus migrans*	26 (18)	6 (6)	26 (24)	3 (1)
Marsh Harrier *Circus aeruginosus*	1 (1)	1 (1)	4 (4)	1 (0)
Pallid Harrier *C. macrourus*	1 (1)	0	1 (1)	0
Honey Buzzard *Pernis apivorus*	392 (40)	205 (132)	51 (37)	4 (2)
Steppe Buzzard *Buteo b. vulpinus*	869 (627)	170 (85)	337 (121)	10 (1)
Sparrowhawk *Accipiter nisus*	2 (0)	0	4 (3)	1 (0)
Levant Sparrowhawk *A. brevipes*	601 (31)	150 (0)	0	0
Lesser Kestrel *Falco naumanni*	14 (14)	0	0	0
Saker *F. cherrug*	0	1 (1)	0	0
Eleonora's Falcon *F. eleonorae*	1 (1)	0	0	0
Hobby *F. subbuteo*	0	0	1 (1)	0
Merlin *F. columbarius*	1	0	0	0
Total number of birds	1951	552	468	22
Total number of birds/hour	18.1	8.7	5.2	0.3
Percentage of birds flying below 140 m	40%	42%	44%	18%

*Only migrants included

here the collision risk height because it would include the rotor swept area (including a turbulence effect and margin of error of 15 m below the rotor swept area). The height close to the ground is rarely used by migrating raptors, hence the birds passing underneath the rotor-swept area is negligible. The collision risk height is estimated for a turbine that has a tower height of *c*90 m and blade length of 45 m (3 MW turbines design at the time of the field study; www.vestas.com/en/products/turbines).

RESULTS AND DISCUSSION

The results for various species are listed in Table 1. Steppe Buzzard appears to be the most numerous species to cross the sites, followed by Honey Buzzard. However, these numbers do not represent total or relative numbers of each species because numbers vary daily and the migration season was only sampled. During a few observations close to the escarpment (N Shobak and Taiba), especially when the weather was hot and calm, large numbers of soaring buzzards, Black Kites and Levant Sparrowhawks were seen flying over the rift

margins in a south–north trajectory, *ie* without crossing the escarpment. These were not counted due to big distances but their numbers definitely exceeded those of birds flying over the observation sites on the same days. The direction of migratory soaring birds after crossing the escarpment was generally northeast for Buzzards. Eagles (mainly Steppe Eagle) tended to fly in a more easterly direction near the escarpment, and then appeared to turn north/northeast a few km east of the escarpment. All this indicates differences in flight patterns among the species, depending on time of day, season and weather conditions. An analysis of general patterns and a spatial comparison was carried out for pooled data for all soaring birds observed during this study. The density of migratory, soaring birds decreases eastwards on the highland plateau (Figure 2), probably due to dispersion over a large area and increasing divergence of the routes of single birds and flocks. The larger numbers of birds recorded in the site close to the escarpment (N Shobak) is partly due to some birds reaching the vantage point which is very close to the top of the escarpment and then flying north along the top of the escarpment instead of heading northeast or east. There is no doubt that weather conditions and temperatures affecting the thermals would have an impact on the height of birds flying over. This tendency was noted: during hot weather migrating raptors appeared to soar higher as indicated by the small proportion of Honey Buzzards and Levant Sparrowhawks flying lower than 140 m at the N Shobak site. These species migrate later in the season when temperatures are significantly higher. The proportion of birds (pooled data) flying higher above the ground increases as expected towards the east, *ie* with bigger distance to the escarpment, because birds have the chance to gain height after arriving at the top of the escarpment. However, this decrease was not evident to a distance of 7.5 km, meaning that *c*40% of the soaring birds would potentially be in risk of collision with the rotors of wind turbines in a wind farm within that distance from the main escarpment/top of the rift margins. These results confirm that factors like topography and weather play a role on flight patterns and may thus have effects on bird collisions with wind farms if present along migration routes (*cf* De Lucas *et al* 2008).

We consider all birds flying below 140 m potentially at risk if an unknown number of wind farms are to be established, and this study presents an initial assessment which can

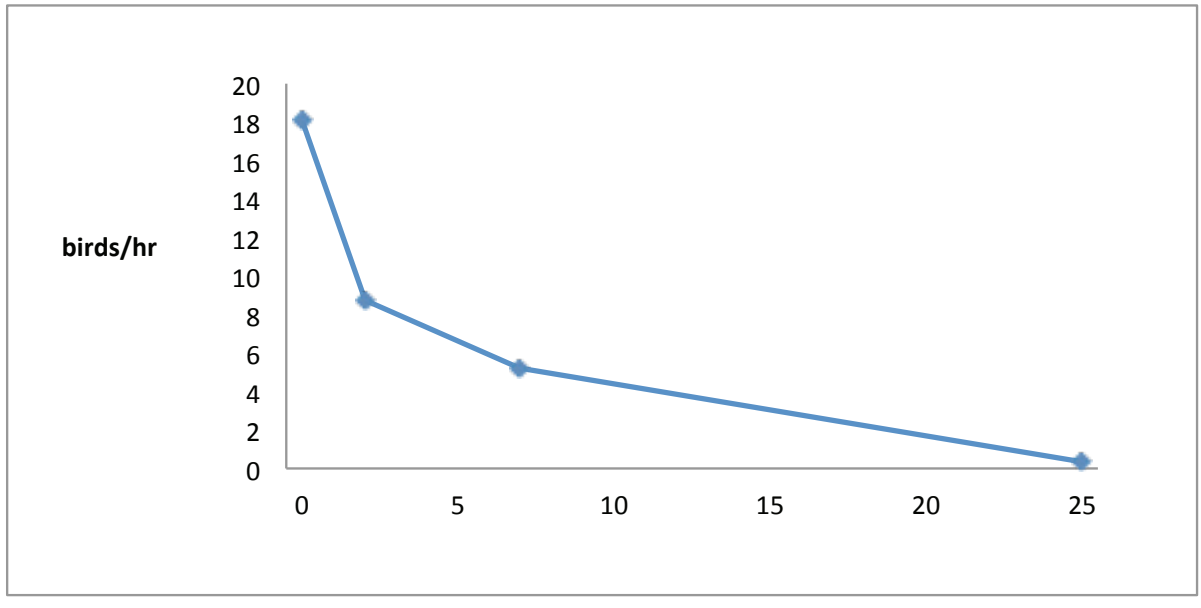

Figure 2. Total numbers of soaring birds during spring migration in southwest Jordan in relation to distance to the main escarpment of the four study sites.

be used during the site selection phase. More realistic collision risk/mortality assessments are usually carried out at later stages when the exact location and design of wind farms are known, by using collision risk models, and taking into account the expected avoidance of the birds themselves (Band *et al* 2007; also see the Scottish Natural Heritage Website (www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/bird-collision-risks-guidance/).

Observation stations within 10 km of the escarpment had ~40% of birds flying at low altitude and thus within the collision-risk zone of a turbine. Assuming that the acceptable proportion of birds in a potential risk situation is less than 30% then wind farms should not be positioned within a distance of 10 km to the escarpment according to our observations. Birds were observed flying at higher altitude at the site furthest away from the escarpment, with only 18% within the collision risk zone (Table 1). These observations could be helpful for carrying out early assessments (*eg* as part of a strategic environmental assessment) for selection and precautionary exclusion of sites.

In regard to the resident and breeding raptors which are rare or uncommon in Jordan, Griffon Vulture *Gyps fulvus*, Bonelli's Eagle *Hieraaetus fasciatus*, Short-toed Eagle *Circateus gallicus*, and Long-legged Buzzard *Buteo rufinus* are known to breed in the southern rift margins (Andrews 1995) and according to observations made by the author, they use the highland plateau frequently for feeding. The author frequently recorded Griffon Vultures in or near a wind farm site (see also Khoury 1998) just east of the Dana nature reserve, in addition to records as far as Al-Husseniyeh along the Desert Highway/25 km east of the escarpment, indicating a large home range of the small Griffon Vulture population remaining in Jordan. Short-toed Eagles belonging to the breeding population were also seen foraging at distances of up to 8 km east of the escarpment.

More research is required about numbers and flight patterns of soaring birds in different sites on the highland plateau as part of a comprehensive strategic environmental assessment for wind farm developments in southwest Jordan. The home ranges of breeding and resident raptors should also be mapped, and their flight patterns while foraging studied, as their protection should have top priority.

Ecological and other costs of wind farm developments may exceed overall economic benefits in Jordan especially in view of the increasing importance of other alternatives, namely solar energy. It is recommended that all current plans for further wind energy development be reconsidered until enough up-dated information is available about migration routes, the direct and indirect effects of wind farms on bird populations and how birds perceive existing wind farms.

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