

# Evaluation of the impact of wind farms on birds: The case study of Lebanon



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## ABSTRACT

Wind farming is a relatively new form of obtaining energy that does not cause air pollution in working conditions or other forms of environmental degradation associated with fossil fuel technologies. However, their use impacts the environment and the current rate at which they are being put into operation, combined with understanding of their medium-and long-term impact, is a cause of concern. Wind farms represent a new source of impact and disturbance for birds adds to the long list of disturbance factors caused by human activity, such as power lines, radio, television and cell phone towers, highways, glass windows or the practice of fishing and illegal hunting. Due to the precarious situation of several bird species and their decline, any additional cause of mortality may be significant and should give rise to increased attention and analysis. The aim of the present work is to analyse the impact of wind turbines located in five selected optimal sites for the installation of wind farms on birds in Lebanon. The results suggest that the presence of the wind turbines will not have a clearly negative effect on birds in the sites where wind farms could be installed. Some sites are closed to natural reserves such as Cedars and Quaraoun or near roads used by migratory birds such as Marjyoun, Klaiaat Quaraoun, but the impacts can be reduced by taking preventive measures.

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## 1. Introduction

During the last century, bird populations have been affected by different kinds of disturbances and impacts due to man-made structures such as highways, television, radio and cell phone towers, wind farms, glass windows, and also due to human activities such as fishing and illegal shooting. The increasing mortality of birds by human cause has generated an important literature evaluating the impact of these elements on bird populations and developing the application of protective measures [10].

The growing demand of energy, together with the feeling that our planet is an ecosystem in a very delicate equilibrium, has stressed the search for new mechanisms of energy transformation that preserve such an equilibrium. Therefore, besides a huge

consumption of both fossil and nuclear fuels (each of them with their advantages and drawbacks), the use of the so called renewable energy is growing spectacularly, wind energy being one of them.

Obviously, wind energy is not free of problems, although these are smaller when compared to those associated to other sources of energy.

The development of wind energy is a key factor throughout the world with the aim of increasing the proportion of renewable energy to reduce greenhouse gas emissions. However, this source of energy has an impact on environment and its current development can have significant consequences if the impact is not correctly taken into account. One of the main concerns about the potential impact of wind farms is their impact on birds and chiropters. A significant impact may occur if the location of parks is not appropriate, it basically translates into collisions, displacement, barrier effects or habitat losses. Therefore, it is necessary to avoid as much as possible the construction of wind turbines in areas of high concentration of birds, and especially when these areas harbor vulnerable species.

The rapid development of wind farms in recent decades has generated controversy regarding the negative influence of these

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structures on bird conservation [8]. Several studies show that the negative impact of wind farms on bird populations is much less than other sources of collision [6]. According to Erickson [9], the number of bird deaths due to collisions with turbine blades represent 0.01–0.02% of the total, which is far lower than impacts with other structures such as vehicles, buildings, glass windows, power lines or communication towers. On the hand, other studies report higher mortality levels and highlight raptors as being the most affected [3].

Up to now, there are no wind farms in Lebanon. Although, studies show that Lebanon has interesting windy conditions and territorial spaces available for the installation of wind turbines and that the electricity demand is largely increasing [2]. Therefore an objective has been fixed to select optimal sites for installation of large (of a few MW) wind turbines in Lebanon. The study of wind speed and its regularity shows that they are five optimal sites for the installation of wind turbines in Lebanon (Al Zohbi et al., 2013). To carry out the project of developing wind energy in Lebanon, the impact of wind turbines implantation on the environment must be studied and evaluated.

The main purpose of this paper is to determine the possible impact of wind farms on bird populations in the five selected sites for new installation of wind turbines in Lebanon.

## 2. Methodology

### 2.1. Study area

This work was performed in five sites in Lebanon that are located in the North, the South and the Lebanon Mountains, such as Klaiaat, Cedars, Daher El Baydar, Marjyoun and Qaraoun (Fig. 1). These sites are selected by assessing wind energy potential in five sites where data measurements of wind speed are available. The assessment of wind energy potentiel is realized by expressing the frequency

**Table 1**

Number of wind turbines in each selected site in Lebanon.

Site	Number of wind turbines of 7.5 MW
Klaiaat	23
Cedars	22
Marjyoun	24
Daher El Baydar	24
Quaraoun	23

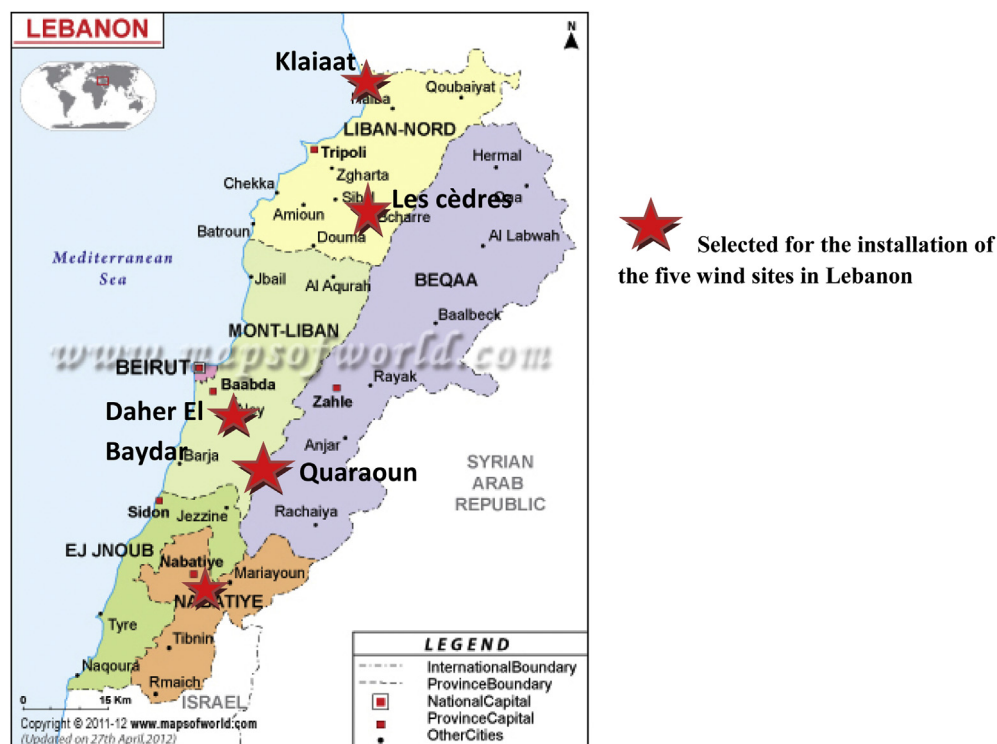
distribution of wind speed. The Weibull distribution has been widely used, accepted and recommended in the literature to express the frequency distribution of wind speed, since it gives a good agreement with the experimental data according to Darwich [5].

The five proposed wind farms will consist of 116 wind turbines (Table 1). The wind turbine chosen to be installed is the ENERCON E-126, so that each wind turbine generates 7.5 MW. It has three blades, the total height of the turbines is 135 m and the rotor diameter is 127 m.

To assess the impact of the installation of wind turbines on birds in Lebanon, we started with the identification of the main processes by which wind farms can potentially have a significant impact on birds. Then, the places of natural reserves for birds and the paths used by migratory birds that use Lebanon as a migration path in autumn and in spring must be identified. After that, the proximity of selected sites for the installation of wind turbines to natural reserves and to migration paths used by migrants is evaluated. Additionally, the bird species that are located in Lebanon as well as migratory birds that pass through Lebanon with their conservation status must be identified (see Fig. 2).

### 2.2. Ways of allocating birds by wind turbine

There are two main processes by which wind farms can potentially have a significant impact on birds. First, they can pose a



**Fig. 1.** Location of the study areas.

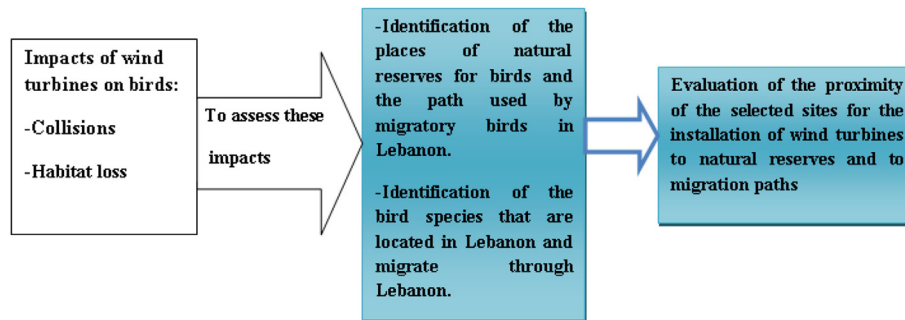


Fig. 2. Methodology to assess the impact of wind turbines on birds.

risk of collision with birds flying into rotor blades, resulting in increased mortality rates. Secondly, they can result in habitat loss, mainly through displacement of birds from an area around the wind turbines (effectively disturbing the birds from this zone) [8,12].

#### 2.2.1. Collision risk

Overall, it is clear that birds are generally able to avoid collisions and do not simply blindly fly into wind turbines (Fig. 3). Collision rates are typically in the range of only 1 in 1000–10,000 bird flights through the wind farm, even in studies such as in Zeebrugge where relatively high numbers of collisions have been reported [15]. In some cases, they are considerably lower, such as at the offshore wind farm at Utgrunden, where 500,000 eider (kind of birds) flights through the wind farm study area have been observed without a single collision being seen [15].

It is also clear, however, that bird collisions with wind turbines can be a problem under some circumstances. It would seem from the evidence available from existing wind farms that there are two main types of sites that have had birds collision problems:

- Sites with large raptors occurring regularly within the wind farm at the same height as the rotor blades.
- Sites with very high densities of birds flying at the rotor height.

#### 2.2.2. Habitat disturbance

The second main potential impact of wind farms on birds is forced relocation from an area around the wind turbines, effectively resulting in habitat loss. Numerous studies have investigated this potential problem, with a range of results. In many cases, no significant disturbance effect at all has been detected, including studies at upland, coastal and offshore wind farms [15]. However in some studies, birds have been reported to have been displaced by as much as 800 m (and up to 300 m for breeding birds) [15].

A further possible disturbance effect is the disruption to flight lines. Several studies have shown that some birds species alter their flight routes to avoid flying through wind farms (e.g. tufted duck and pochard at Lely in the Netherlands, [7]), eiders at Tuno Knob in the Danish Baltic, [15]. Whilst, this may have the beneficial effect of reducing collision risk, it could also result in the wind farm acting as a partial barrier to bird movements and confusing routes.

### 3. Results

#### 3.1. The avifauna in the Middle East

Middle East is a major migration crossroad between Central Eurasia and Africa. In both Spring and Autumn migrating soaring birds (storks and birds of prey) are funneled in Bosphorus in Istanbul which is the major concentration area of all birds breeding in Eastern Europe. A higher number of birds of prey migrate along the East Black Sea and cross East Turkey to South in Ref. [18]. Once across the Bosphorus, most birds continue South-East, crossing Turkey and concentrate along the East Mediterranean coast. During spring migration, most of the migratory soaring birds concentrate in Egypte, fly across Sinai and then disseminate in North, North-East and East directions (Fig. 4) [18].

#### 3.2. Bird migration in Lebanon

Lebanon is on a major migration route between the Southern regions (particularly sub-Saharan –Africa) occupied by birds during winter, and the North where more than 30 species of raptors come to breed in Western palearctic ([1]. Because of the position of the Black Sea, the Caspian Sea and the Mediterranean Sea, Lebanon is one of the points where the birds concentrate during these complex migration paths. Although known as the ‘bottleneck’, it hosts major migratory bird gliders concentrations during the spring and the autumn [4,18].

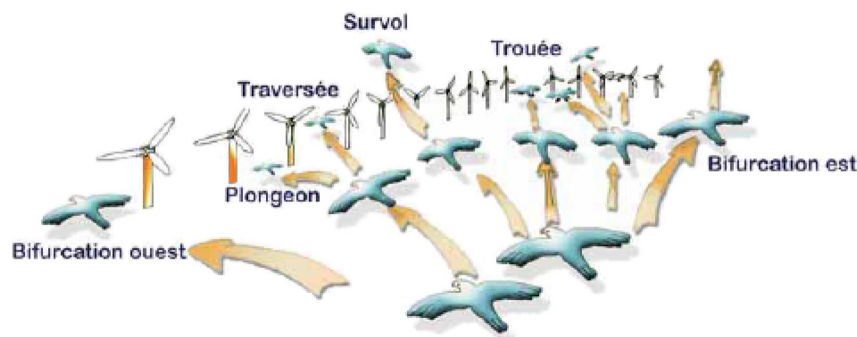


Fig. 3. Reactions of flying birds facing a wind farm on their path [11].

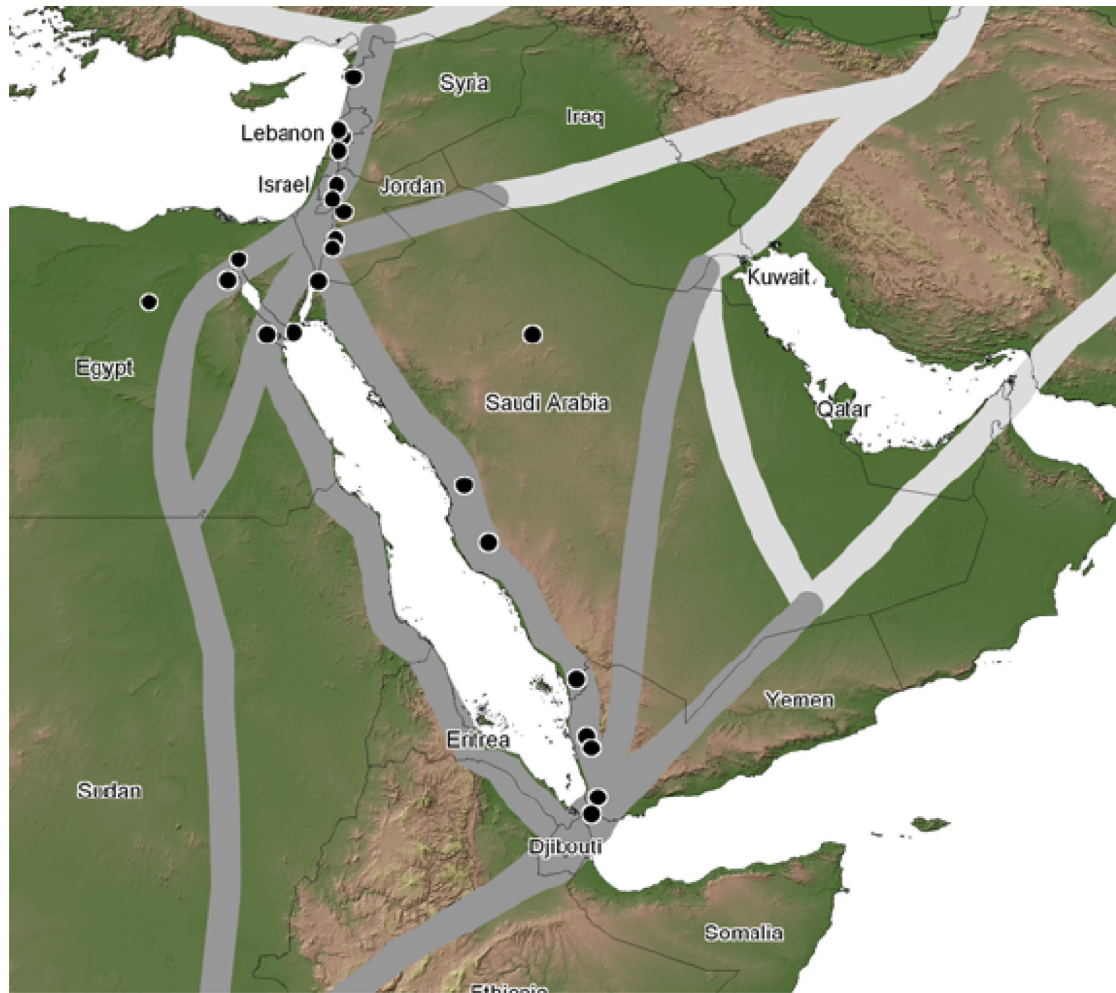


Fig. 4. Main flyways between Euroasia and Africa [16].

Thus, Lebanon is ideal for bird migration conditions. Bekaa Valley between the chains of Lebanon and Anti-Lebanon is one of the most important corridor migration in the world. Migratory raptors and storks enjoy the warm ascending air currents that is formed over the Bekaa Valley during the day, to be carried away by them hovering [18]. They thus move without flapping and without expending energy. In addition, the Bekaa Valley and the mountain ranges offer a wide variety of birds resting areas (forests, wetlands, lakes) where they can feed, reproduce and prepare their nests.

In Lebanon, spring and autumn migration present differences. In spring (Fig. 5, left) the major route through Lebanon used by migratory birds of prey and cranes is along the eastern flanks of the Mount Lebanon mountain range and the western half of the Bekaa Valley. This includes cranes, pelicans, birds of prey such as common buzzard and lesser spotted eagle, and many thousands of white storks [18].

In autumn (Fig. 5, right), most soaring birds pass down the eastern flanks of the Lebanon Mountains while some travel higher up on both sides of the ridge. These streams converge about halfway down the mountain chain, with most of the birds, particularly the large birds of prey passing together over the upper portion of the Beirut River Valley.

We note that during the spring, migratory birds pass by near Klaiaat, Quaraoun (due to the presence of lake Quaraoun) and Marjyoun. While during the fall, migratory birds pass by near

Marjyoun, and probably Daher El Baydar. It is found that Marjyoun is close to paths used by migratory birds passing through Lebanon during the spring and the fall.

### 3.3. Important bird areas in Lebanon

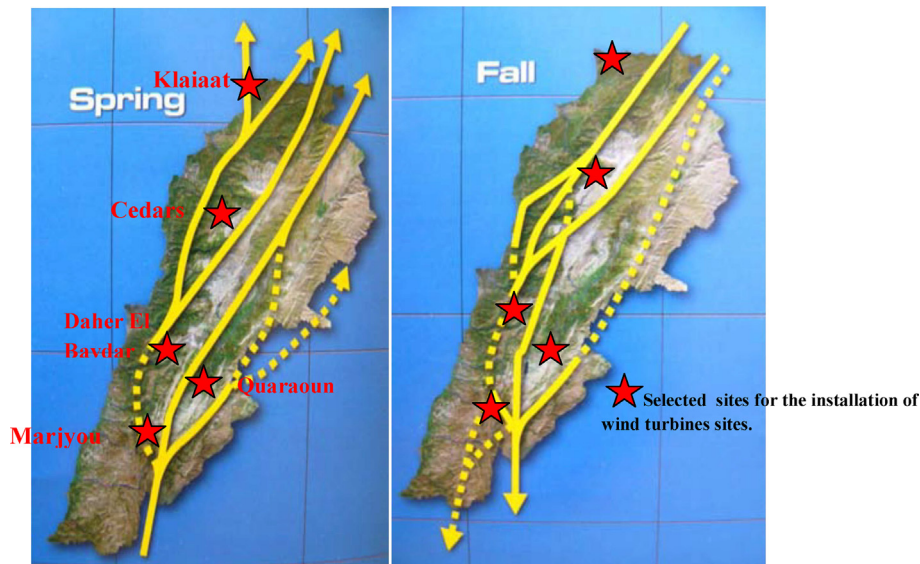
In 1994, four sites were internationally designated as Important Bird Areas by SPNL<sup>1</sup> (the Birdlife National partner) and Birdlife International. These sites were: Ehden Forest Nature Reserve, Palm Islands Nature Reserve, Aammik Wetland and the Shouf Cedar Nature Reserve. From March 2005 to February 2008, A Rocha Lebanon<sup>2</sup> and SPNL have identified and conserved new Important Bird Areas in Lebanon. 31 sites were surveyed throughout the country, through a complete yearly cycle, with repeated visits during the main migration periods. They have identified 11 new sites, with 9 new sites designated as Global IBAs<sup>3</sup> and 2 new sites designated as Regional IBAs. Table 2 shows the important bird areas in Lebanon with their eligibility criteria IBA and species of bird observed in each natural reserve. Table 3 shows the definition of Birdlife IBA criteria [1].

<sup>1</sup> Society for the Protection of Nature in Lebanon.

<sup>2</sup> Environmental organization to protect the environment.

<sup>3</sup> The selection of Important Bird Areas.





**Fig. 5.** Soaring birds main flyways in spring (left) and in autumn (right). Solid lines show established routes, dotted indicate those requiring further research (Beale&Ramadan-Jaradi 2001).

Locations of these important bird areas and the selected sites for the installation of the 7.7 MW wind turbines in Lebanon are represented in Fig. 6. It is obvious that all selected sites for the installation of wind turbines are not very close to important bird areas in Lebanon except Cedars and Quaraoun. Quaraoun nearby Lake of Quaraoun, and Cedars are located next to two natural reserves, Tannourine cedars nature reserve and Ehden Forest nature reserve. The erection of wind turbines in Quaraoun and Cedars may have an impact on birds in these two sites selected for wind turbines installation.

Table 4 summarises the known information about the soaring birds that use the Rift Valley and Red Sea Flyway and through Lebanon during their migration route, giving for each species, the period of the peak migration in spring and autumn, the highest seasonal counts, and their species conservation status according to IUCN.<sup>4</sup> The timing of migration varies between species. It can be noted that they are some species that pass through Lebanon during the spring migration as common cranes, others during the autumn migration as white pelicans and European honey buzzards, but there are also other species that pass through Lebanon during the spring and autumn migration as white storks.

We note also that the migratory birds have LC (Least Concern) as a conservation status, showing that these birds are not endangered or threatened.

#### 4. Discussion

The low risk of these new windfarms might be related to the fact that the area is used basically as a flight route and passageway, but not as a feeding, roosting or breeding area, which would induce lower flight heights [14]. In this article, we show the locations of natural reserves for birds in Lebanon, which are important areas for birds where it can feed, reproduce and prepare their nests, with their eligibility criteria IBA and observed species in each natural reserve as well soaring birds main flyways in spring and in autumn.

##### 4.1. Feeding and breeding areas

Two selected sites for the implementation of wind turbines in Lebanon, Cedars and Quaraoun are located next to natural reserves are important bird areas. Therefore the erection of wind turbines in these two sites may have an impact on birds. In order to evaluate the impact of wind turbines in both sites, the bird species that live in these sites or migrate through these sites must be determined.

It was mentioned above that the raptors are the most exposed species which have a risk of collision with wind turbines, because of their flight plan, which makes them dependant on air currents and thermals strongly related to the topography of the sites with a long delay for reactions [17]. Additional, their hunting behaviors have a double risk. Indeed, these birds can use wind towers as perches observation, particular lattice tower, and therefore not maintain safe distance with the turbine blades [17]. We note that the Ammiq wetland and Quaraoun lake are two natural reserves which have A1.iv (the site is known or thought to be a 'bottleneck' site where at least 20,000 storks, raptors or cranes regularly pass during spring or fall migration) criterion IBA Birdlife, whose several types of raptors were observed in these two sites during fall or spring migration (Table 2). Tannourine Cedars has A1.iv criterion IBA Birdlife, but no raptors were observed (Table 2). Additionally, Bentael Forest natural reserve and Ramliyah valley have B1.iv (the site is a 'bottleneck' site where over 5000 storks, or over 3000 raptors or cranes regularly pass on spring or fall migration) criterion IBA Birdlife, whose several types of raptors were observed in these two sites during fall or spring migration (Table 2).

Quaraoun is located next to Quaraoun Lake where raptors pass during migration in spring or autumn, but Cedars which is located next to Tannourine Cedars and there is not any raptors pass. Therefore, the establishment of wind turbines in Quaraoun may have an impact on raptors but not in Cedars. On the other hand, Cedars is located next to Ehden Forest natural reserve which has A.1 (important areas for threatened species of birds) and A.2 (important areas for restricted –range species) criterion IBA Birdlife, but also next to Tannourine Cedars which has also A.1 criterion IBA Birdlife. Therefore, the establishment of wind turbines in Cedars may have an impact on threatened species and restricted-range species of birds.

<sup>4</sup> International Union for Conservation of Nature.

**Table 2**  
Natural reserves in Lebanon with their eligibility criteria IBA, and observed species [1].

Designated global IBA site	Birdlife global criteria met	Species observed
Hima Aanjar/Kfar Zabad	A.1	Syrian Serins
Lake Qaraaoun	A.4.iv	Over 20,000 raptors, Storks, Pelicans and other soaring birds.
Riim/Sannine Mountain	A.3	Black-eared Wheatear, Sardinian Warbler, Spectacled Warbler, Cretschmar's Bunting, Black-headed Bunting and Western Rock Nuthatch.
	A.4.iv	More than 20,000 soaring birds
Tannourine Cedars Nature Reserve	A.1	Syrian Serins.
	A.4.iv	At least 15 species of soaring birds (large flocks of White Pelicans)
Hima Ebel es-Saqi	A.1	Soaring birds (Imperial Eagle, Lesser Kestrel, Great Spotted Eagle ...)
	A.3	5 biomes restricted species breeding: Sardinian Warbler, Masked Shrike, Upcher's Warbler, Cretschmar's Bunting and Black-headed Bunting.
	A.4.iv	At least 17 species of soaring birds (Common Crane witnessed, White Stork, Honey Buzzard)
Semi Deserts of Ras Baalbek	A.3	10 biome-restricted species: Cream-coloured Courser, Bar-tailed Lark, Desert Lark, Temminck's Lark, Mouring Wheatear, Streaked Scrub Warbler, Trumpeter Finch, Western Rock Nuthatch, Pale Rock Sparrow and Spectacled Warbler.
Beirut River Valley	A.4.iv	Large number of White Stork and White Pelican, birds of prey (Levant Sparrowhawk, Common Buzzard and Lesser Spotted Eagle).
Upper Mountains of Akkar-Donnieh	A.1 and A.2	At least 20 pairs of Syrian Serin.
	A.3	13 biome-restricted bird (White-throated Robin, Upcher's Warbler, Pale Rock Sparrow, Crimson-winged Finch, Syrian Serin and Black-headed Bunting).
Palm Island Nature Reserve	A.1	Dalmatian Pelican, Corncrack can, Audouin's Gull.
Ehden Forest Nature Reserve	A.1 and A.2	Imperial Eagle, Lesser Kestrel and Syrian Serin.
Shouf Cedar Nature Reserve	A.1 and A.2	Imperial Eagle, Greater Spotted Eagle, Lesser Kestrel and Syrian Serin.
Aammiq Wetland	A.1	Corncrake, Great Snipe and the Ferruginous Duck.
	A.4i	White Stork during spring/fall migration seasons.
	A.4.iv	White Stork, White Pelican, Common Crane and at least 31 species of raptor.
<b>Designated regional IBA site</b>	<b>Birdlife Regional Criteria met</b>	
Bentael Forest Nature Reserve	B.1.iv	Passage White Pelican, Common Crane, Honey Buzzard and Levant Sparrowhawk.
Ramlieh Valley	B.1.iv	Passage of Levant Sparrowhawk, Common Buzzard, Lesser-spotted Eagle and White Storks.

The observed soaring birds species that use the Rift Valley and Red Sea flyway and through Lebanon during its migration route, have LC as a conservation status. It means that these species have a low risk, it does not qualify for a higher risk category. We note that these species are observed in Ammiq wetland, Ebel-Es-Saqi and Harissa (Table 4), and that none of the selected sites is close to the sites where the species of birds use the Rift Valley and Red Sea flyway pass. Therefore, there is no impact on soaring birds in the selected sites.

**Table 3**  
Definition of Birdlife IBA criteria.

**Relevant Birdlife Global IBA criteria:**

- A.1 Species of global conservation concern: The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern.
- A.2 Restricted –range species: The site is known or thought to hold a significant component of the restricted-range species whose breeding distributions define an Endemic Bird Area ((SPNL)-) or Secondary Area (SA).
- A.3 Biome-restricted species: The site is known or thought to hold a significant assemblage of the species whose breeding distributions are largely or wholly confined to one biome.
- A.4.iv Congregations: The site is known or thought to be a 'bottleneck' site where at least 20,000 storks (Ciconiidae), raptors (Accipitriformes and Falconiformes) or cranes (Gruidae) regularly pass during spring or autumn migration

**Relevant Birdlife Global IBA criteria:**

- B.1.iv The site is a 'bottleneck'<sup>a</sup> site where over 5000 storks, or over 3000 raptors or cranes regularly pass on spring or autumn migration.

<sup>a</sup> These are sites whose geographic position means that birds fly over or round in the course of their regular migration. These sites are normally determined by topographic features, such as headlands and straits.

#### 4.2. Flight route and passageway

There are some selected sites for the installation of wind turbines in Lebanon, which are near roads used by migratory birds in spring and in autumn. Klaiaat and Quaraoun are two selected sites that are near a flyway used by migratory birds in spring, Daher El Baydar is near a flyway used by migratory birds in autumn. But, Marjoun is nearly two flyway used by migratory birds, one in spring other in autumn [14], reported that the area used as a flight route and passageway has less risk of the wind farm, and in addition migratory birds pass once a year next to almost selected sites except Marjoun, where they pass twice a year. So the likelihood of negative impact of wind turbines on birds in these sites is low.

Although birds can detect turbines, long lines of turbines have a potential barrier effect [7]. Shorter turbine rows could reduce this effect, allowing birds to avoid them more easily. If the area is a passageway for migration birds, the rows of turbines could have this potential barrier effect in the migratory trajectories.

In all cases, additional research before and after the construction of wind farms is needed to better understand what changes to bird populations installing a wind farm might cause. It is imperative that new wind power developments should be placed in locations of relatively low risk to birds, and that existing wind developments assess negative impacts on birds [13]. Specific location should be evaluated in priority when a wind farm is planned.

#### 5. Conclusions and prospects

The results of our study may have important implications for the future development of wind farms in Lebanon. We can conclude that there is not outstanding threat to the establishment of wind



Fig. 6. Important bird areas in Lebanon [18].

Table 4

Number of birds species using Lebanon as a flyway; species conservation status according to IUCN; migration period for each species [16].

Species	Conservation status	Number of birds	Period
White Pelican	LC	1327 (Ebel Es-Saqi)	September/December 2004
White Stork	LC	1819 (Ebel Es-Saqi)	September/December 2004
		19292(Ammiq Wetland)	March/April 1997
Black Stork	LC	331 (EBEL SAQI)	5 October 2004
		555(Ammiq wetland)	March/April 1997
European Honey Buzzard	LC	7341 (Ebel Es-Saqi)	September/December 2004
		5050 (Harissa)	
Black Kite	LC	105 (Ebel Es-Saqi)	4 October 2004
		155(Ammiq wetland)	March/April 1997
Snake Eagles	LC	18(Ebel Es-Saqi)	September/December 2004
		349 (Harissa)	
Western Marsh Harrier	LC	22 (Ebel Es-Saqi)	September/December 2004
Sparrowhawk	LC	24 (Ebel Es-Saqi)	September/December 2004
		2255 (Harisa)	
Lesser Spotted Eagle	LC	49 (Ebel Es-Saqi)	September/December 2004
		1992 (Ammiq wetland)	March/April 1997
		3474 (Harissa)	
Steppes Eagle	LC	40 (Ebel Es-Saqi)	September/December 2004
Booted Eagle	LC	12 (Ebel Es-Saqi)	September/December 2004
Levant Sparrowhawk	LC	329 (Ebel Es-Saqi)	September/December 2004
Steppe Buzzard	LC	39 (Ebel Es-Saqi)	September/December 2004
		875 (Ammiq wetland)	March/April 1997
Long Legged Buzzard	LC	50 (Ebel Es-Saqi)	May/August 2004
Kestrel	LC	13 (Ebel Es-Saqi)	September/December 2004
Common Crane	LC	60000 (Ebel Es-Saqi)	Spring 2005

farms on birds in Lebanon. We found that some selected sites are close to natural reserves or near roads used by migratory birds. The largest impact of wind turbines on birds is in Quaraoun and Cedars. Quaraoun is located next to a natural reserve where several types of raptors pass and also near a path of migration. Cedars is located next to two nature reserves where there are threatened species and retracted-range species of birds. On the other side, the least impact is in Daher El Baydar which is not near a natural reserve nor near a flyway. Marjoun and Klaiaat are located near roads used by migratory birds, therefore the impact on birds in these two selected sites is less than the sites that are close to natural reserves.

To summarize, the wind turbines discussed here could be erected in Lebanon without a noticeable threat on birds. In order to be more accurate about the impact of wind turbines on birds in Lebanon, a surveillance monitoring and additional researches before and after the construction of the wind farms is recommended and should be made.

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