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Al Mokha 60 MW Wind Farm Project (WMFP)

Republic of Yemen
Ministry of Electricity & Energy

ASSESSMENT OF RISK TO BIRDS FROM PLANNED WIND ENERGY DEVELOPMENT AT AL MOKHA

FINAL REPORT

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1. Executive summary

One of the primary ecological concerns of wind energy developments is their potential negative impact on bird life. Experience from several locations in the world has shown that wind farms can be highly damaging to bird populations, when bird conservation issues are not properly addressed in the planning of wind energy developments.

Yemen is located along a primary bird migration corridor, where many thousands of soaring birds concentrate cross the Straits of Bab Al Mandab to Africa. Wind energy development plans in the region adjoining Bab Al Mandab is thus of potential concern from the biodiversity conservation point of view.

This study was conducted in the autumn of 2009 and spring of 2010 and involved 50 days of field observations, with the primary objective of evaluating the risk to birds from planned wind energy developments near Al Mukha on the Red Sea.

The main results of the study are as follows

In autumn a constant and relatively stable volume of soaring bird migration was detected over al Mukha proposed wind farm site, with an average of passage of 440 birds per day, totaling 5544 birds belonging to 22 species during the study period, with a potential total volume of between 25-30,000 birds per season, assuming fairly constant flow of birds throughout the autumn migratory season. The average altitude was 258 m, however about 33% of all birds flew below the precautionary “safe” altitude of 200 m. There was limited landing or roosting at the project site; however several potentially highly risky areas that can attract large concentrations were identified; most importantly the municipal dump and newly cultivated areas.

The situation between Dubab and Baba Al Mandab in autumn is clearly critical for soaring migrants (as they land and fly at very low altitude in very large numbers), and the establishment of any wind turbines in the section of the coastline would be highly detrimental by all measures. The situation between Dubab and Al Mukha needs further evaluation to determine where conditions of high risk are not prevalent (probably some where between 10-20 km north of Dubab). While rapid reconnaissance indicate that the Gulf of Aden coast between Aden and Bab Al Mandab has almost no migratory activity (but this needs further verification).

In the spring observations indicate that soaring bird migration through Yemen at large is of small volume and limited significance, particularly when compared with the volume during autumn. At the project site there was a very limited number of migratory soaring birds observed (349 birds belonging to 14 species). It is likely that the lack of migrants over Al Mukha in spring is probably not only due to the position of the site away from the main migratory pathway for soaring birds (along the Tihama foothills), but is also likely due to the limited overall volume of birds returning through Yemen in spring. This was supported by our observations made at Bab El Mandab, where very few birds moving across the strait and entering the Arabian Peninsula from Africa were found during the spring. This strongly suggests that the spring migration of soaring birds largely follows a more westerly rout along the western coastline for the Red Sea, north to Egypt and Suez. The limited number of soaring birds observed at the site were either wintering or resident birds, largely composed of Black Kites and Egyptian Vultures.

Several globally threatened bird species are known to migrate through the proposed project area; however it is one species (Egyptian Vulture) which could be of particular concern due its passage in relatively large numbers, tendency to fly low and land in search for food and lack of maneuverability in the face of wind turbines. The likely negative impacts on Egyptian Vultures and other birds of prey and storks due to the presence of solid waste disposal sites in the proximity of the project site is highlighted as one of the primary concerns that must be addressed prior to turbine operation.

The natural habitats at the site do not represent any rare or restricted habitat types and are not the home for any rare or threatened species, although several Yemeni endemic species are found.

How to evaluate risk?

It is almost certain that any wind energy development will cause some bird and other wildlife mortalities, but the important question will always be: What constitutes acceptable levels of losses?

Answering this question is extremely complicated at two levels; one in attempting to anticipate with some degree of confidence mortality and risk levels from a non-existing operation (wind turbines); and the other is what are acceptable levels of loss? This varies from species to species and from one population to another greatly. In some way any losses are not acceptable. Other factors like the cumulative impact of wind farms even complicate things further.

There are no global standards that govern and regulate what constitutes an unacceptable level of loss. What the current and other similar pre-construction studies of birds primarily aim at is to exclude particular wind energy projects that would have clearly catastrophic impacts on birds, or that might have long-term cumulative negative impacts on bird populations, and to provide recommendations and mitigation measures to alleviate risks at wind farms that are deemed to have a "tolerable" level of risk (i.e. that the level of risk can be managed through prescribed mitigation measures). But as Mandville (2009) notes, that in light of our collective poor understanding about wind energy's impacts on wildlife and their habitats, the precautionary approach should used whenever possible.

Conclusions

It is concluded that the current proposed wind energy development at Al Mukha is unlikely to have impacts on birds of catastrophic nature, and that the **level of risk to migratory and local birds is within a "tolerable" or "acceptable" range**; i.e. that the level of damage that could affect birds is expected to be limited and would not have significant conservation consequences to their populations if prescribed mitigation and precautionary measures are taken.

This assessment of risk is based and supported by the following findings:

- The volume of birds flying over the site appears to be relatively modest and does not represent the main migratory flyway of soaring birds in the region;
- The size of the proposed development is relatively small ;
- The window for soaring bird migration is confined to one season (autumn), with a limited time frame of about 3 months per year;
- The majority of birds fly higher than 200 m, with only an estimated 36% of birds flying below 200 m (for both spring and autumn);
- Migration is on a broad front, i.e. is not concentrated over the proposed project site;
- There are limited species that migrate in large dense flocks, which are particularly vulnerable to wind farms (such as storks);
- With the exception of the Egyptian Vulture, there is limited occurrence or likely risks to globally threatened bird species;
- There is limited landing and roosting in the area and no natural attractions for birds;
- The terrain is simple and flat;

- Wind direction and velocity is very constant during autumn (ensuring that limited variation to observed patterns are likely to occur), but is much more variable in spring, however not much birds are present then;
- Visibility is usually good.

The conclusion made here is based on a number of important assumptions

- The size of proposed development remains limited in scale and not changed from current proposal (without further assessment);
- Existing man made risk factors (solid waste dumps and cultivations) will be relocated to a safe distance from the proposed wind farm;
- Mitigation measures are implemented.

In order to reduce potential risk levels the following recommended mitigation measures should be taken

- It is strongly recommended to adopt the first option proposed by NIPSA and Mercados (2009) which entails the use of larger and fewer wind turbines (Gamesa G90 2 MW).
- Stop and remove cultivations within and near the project site, with a minimal distance of 3 km between cultivations and the nearest wind turbines.
- Relocate all municipal and solid as well as liquid waste dumps and prevent the disposal of any animal carcasses (even small ones) in a buffer zone of at least 5 km around the outer perimeter of the site.
- Engage with local inhabitants to ensure the proper disposal of any animal carcasses and other refuse that might attract soaring birds to the project site.
- Review development plans for land adjacent to the project site to ensure that any activities in these areas are compatible with wind energy development and do not pose a threat to migratory birds, by creating potential foci of attraction for birds.
- During the construction phase measures should be taken to minimize project footprint and habitat disturbance.
- During the operational phase it is critical to establish a monitoring program to assess bird mortality at the wind farm, and provide recommendations for adaptive management and mitigation measures.

2. Introduction

Yemen is known as a center for terrestrial biodiversity given its unique geographical position, enormous diversity in habitats, high rainfall and relative isolation. Yemen above the altitude of 1200 m is considered an Endemic Bird Area (EBA), with about 14 endemic and near endemic bird species, that in addition to the island of Socotra, which is a second major center of endemicity for fauna and flora (BirdLife International 2009).

Yemen is also located at the intersection of Africa and Eurasia is situated on internationally important migration route for bird populations breeding in Asia and wintering in Africa. The Red Sea coast, coastal desert and mountains form an important flyway for migrating birds, particularly soaring birds and there is potential that relatively large numbers of migrating birds can occur on a regular basis at the project site every spring and autumn.

Wind energy is a fast growing renewable energy source throughout the world, which has gained popularity in recent years due to soaring fossil fuel prices and improved efficiency of wind harvesting technologies. Many countries around the world, including Yemen, are now assessing their potential for harvesting their wind resources. While wind energy is an environmentally friendly and clean technology, there are potential environment impacts from the wind farm and associated power lines on biodiversity, particularly birds and other airborne animals (such as bats).

The Yemen Arab Republic is considering the development of a 60 MW wind energy facility in the vicinity of Al Mukha on the Red Sea coast. This study has been commissioned to evaluate the potential impacts on biodiversity and risks to the avifauna if a wind park is developed at the proposed project site; providing possible mitigation measures and other recommendations to reduce possible bird / wind farm conflicts.

The consultant was specifically tasked with the following:

- Brief general outline about the potential impact of wind farms on bird life especially drawing upon relevant experience made so far internationally as well as in the region (i.e. Egypt)

- Assess the potential risks to birds at the proposed wind farm at Al Mukha.

- Overview of the region's biodiversity, with special emphasis on the occurrence and distribution of birds (resident and migratory) in the coastal region reaching from Al Mukha to Abian, with focus on rare and endangered species.

- In case negative impact on birds can not be excluded the consultant will provide a detailed description of further field studies to be undertaken at the project site (i.e. during bird migration periods).

2.1. Potential risks to biodiversity from wind farm development

Wind turbines and associated infrastructure such as power lines and pylons present collision and/or electrocution risk to birds, particularly soaring birds, and have been shown to injure or kill many birds in different parts of the world.

BirdLife International (2002) identified three specific risks in relation with the development of wind farms, which would be applicable at the site:

- Direct collision mortality;
- Disturbance leading to displacement, including barriers to movement;
- Loss of habitat to wind turbines and associated infrastructure**.**

To the collision risk we add collision with wind turbine-associated structures (pylons, power lines etc.), as these have proven to be quite destructive, and we treat the barrier effect as a significant potential area of conflict.

2.1.1. Collision with wind turbines and associated structures

The major concern of many impact studies of wind energy focused on the risk for birds colliding with the rotor blades of the wind turbine and getting killed or injured. The majority of studies indicate that while collision rates per turbine are low, mortality can be significant where wind farms comprise several hundred turbines, especially so for rarer longer-lived species with generally low annual productivity and slow maturity, particularly when they are already rare (BirdLife 2002). Clausager and Nøhr (1995) concluded in a review on impact of wind turbines on birds that "some species, such as birds of prey, may have an increased risk of collision during feeding. In situations of wind turbines located in areas with large concentrations of migrating birds the risk of collision may increase, but even in such cases the number of bird colliding has not been alarmingly high".

However, even relatively small increases in mortality rates may be significant for populations of large birds of prey. Evidence from the US suggests that this is a site-specific problem, with death rate varying from one site to the other according to attractiveness to birds. At the Altamont Pass Wind Resource Area in California, a wind farm with some 7000 wind mills, a mortality rate of 0.15 bird deaths/year/ turbine was estimated by Thelander and Rugge (2000) (equivalent to a total of 1050 casualties /year), with most of the casualties being large birds of prey. At the Tarifa Wind Farm located in a similarly sensitive area for migratory soaring birds near Gibraltar in Spain an even larger mortality rate was estimated at 0.34 birds/turbine/year (Montes and Jague 1995). Also high levels of mortality have been found by some studies of smaller numbers of turbines in coastal locations with large concentrations of waterfowl. For example wind farms near the coast in the Netherlands it has been estimated that between< 0.3% 1% of the birds passing on migration at night would collide with a turbine while the proportion during the day is much lower (< 0,03%), (BirdLife / UNDP 2005).

The establishment of wind parks usually requires a number of associated utility structures, especially power lines that connect the wind turbine farms with the main electrical grid. These potentially also possess a significant risk to birds; in fact power lines could pose a far more significant risk to migrants than the wind turbines. Manville (2009) estimated in the United States that wind turbine impacts on birds are in the range of 440,000 incidents, while power line electrocutions (tens to hundreds of thousands) and power line collisions (hundreds of thousands to perhaps millions). Power lines create two types of problems to birds; birds can collide with the cables or get electrocuted when landing on the towers. Collision with overhead wires is a large problem in certain areas, where particular groups of vulnerable birds concentrate. It is mostly large birds that have limited maneuverability and are large enough to make a short between wires that suffer most: flamingos, geese, ducks, storks, cranes large birds of prey and so on. Large birds of prey are particularly vulnerable to electrocution as they more readily land on power lines or pylons to rest or for a vantage point.

In Egypt, where climatic conditions similar to those in the Al Mukha site prevail, there is evidence that White Storks are killed by hitting power lines in the area of Ras Shukeir, Hurghada and at Ras Mohamed in South Sinai. In most of these cases birds have been involved in hitting thin wires that suspend communication towers at an angle (Baha El Din pers. obs.). The example of Ras Mohammed is the worst, where one telecommunication tower probably kills tens of White Storks every year, but foxes work to remove the evidence very rapidly (Baha El Din, pers. obs.).

2.1.2. Barrier to movement

There is some indication that wind turbines may be barriers to bird movement. Instead of flying between the turbines, birds may fly around the outside of a wind farm cluster. However, the cumulative effects of large wind farm installations placed perpendicular to major migration route, may be considerable. This could lead to disruption of migratory flight pattern, disorder and or local disorientation of birds (particularly those that fly in large flocks), which may lead to excessive energy loss or entanglement in the wind farm and eventual collision with wind turbines. Wind farm design may alleviate any barrier effect, for example allowing wide corridors between clusters of turbines (BirdLife International 2002).

2.1.3. Disturbance

Disturbance by wind farms can lead to displacement and exclusion of birds from areas of suitable habitat; effectively loss of habitat to the birds. The scale of such habitat loss, together with the availability of other suitable habitats that can accommodate displaced birds, will influence the impact. There are several reliable studies indicating negative effects of up to 600 m from wind turbines, i.e. a reduction in bird use of or absence from the area close to the turbines, for some species (BirdLife International 2002). Disturbance potentially may also arise from increased human activity in the vicinity of the wind farms, e.g. maintenance visits, facilitation of access via access roads and presence/noise of turbines.

2.1.4. Loss of Habitat

Wind farms are space hungry and can occupy large areas of land. This is the case when large numbers of medium size or large (650 kW - 1 MW or bigger) turbines are used. For instance, the distance between 1 MW wind turbines should be 500-750 meter to avoid a drop in performance from the turbines behind the first row (Clausen et al. 2004). The construction of a wind farm will result in both short-term (the duration of the construction phases) and long-term (during the lifetime of the wind farm) habitat loss. However, direct loss of habitat, as a result of the construction of wind farms, is generally not perceived to be a major concern for birds (BirdLife International 2002). This will depend greatly on local circumstances, the species of concern, the habitats affected and the scale of land required for the wind farm and associated infrastructure.

However, increasingly large wind farms may give cause for concern and habitat change or damage may be an issue. Supportive infrastructure including substations, access roads and management buildings, etc will also involve direct habitat loss. The effects will be dependent on the size of the wind farm and especially the extent of any road network required. Cumulative habitat loss may be an issue both onshore and offshore (BirdLife International 2002).

2.2. Project location and relevant properties

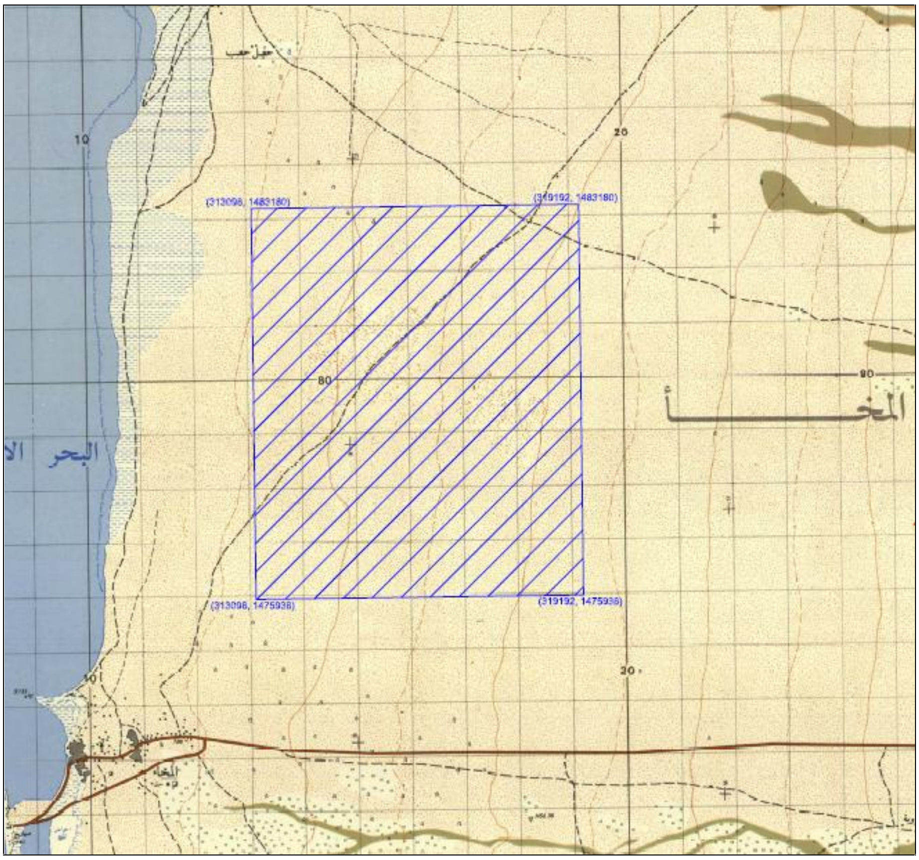

Figure 1. Location of the proposed Al Mukha 60 MW wind farm project relative to Al Mukha Town and the Red Sea.

The proposed wind farm site is located to the north east of Al Mukha town on the Red Sea and is approximately 42 km² in area.

NIPSA and Mercados (2009) proposed three options for the development of the proposed wind farm at Al Mukha, using wind turbines of various sizes, the first being the largest and requiring the fewest turbines as follows:

Option 1

- Wind turbine model: Gamesa G90 2 MW, reaching a maximum altitude of 120 m.
- Wind farm properties: 30 wind turbines, giving a power of 60 MW.

Option 2

- Wind turbine model: Gamesa Made AE-61 1,32 MW, reaching a maximum altitude of 120 m.
- Wind farm properties: 45 wind turbines, giving a power of 59,4 MW.

Option 3

- Wind turbine model: Gamesa G58 850 KW, reaching a maximum altitude of 120 m.
- Wind farm properties: 70 wind turbines, giving a power of 59,5 MW.

2.3. National and international legislative framework

Law 26 of 1995 is the most comprehensive environmental legislation in Yemen. It is the main national legislation addressing biodiversity and conservation issues. In articles 6 - 14 it provides a framework for the establishment of Protected Areas, provides legal framework for control and use of pesticides. While articles 22-29 provide framework for the control of pollution and the conservation of natural resources and the protection of wildlife and marine organism specially those endangered and threatened of extinction. Article 28 prohibits the hunting of specified types of wild birds and animals, as well as the destruction of their natural habitats. Articles 35-43 authorize the Ministry of Environment and relevant agencies to prepare and enforce environmental standards, and indicate the necessity for environmental impact assessments as a pre-requisite for all development projects (Ministry of Water and Environment 2004).

Yemen is signatory to a number of primary conventions concerned with biodiversity and the conservation of migratory species. Yemen signed the convention on Biological Diversity (CBD) in June 1992. It is also signatory to the Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention), which is the most relevant to the development of wind energy along migratory routs, as it necessitates that member countries protect and conserve certain migratory species, chief amongst them are soaring birds (such as birds of prey and storks) which are the main groups of concern at Al Mukha.

3. Methodology

The autumn ornithological investigations of Al Mukha proposed wind farm site extended between 23 October and 14 November 2009. The survey team was composed of two observers during the first part of the survey period between 23 and 30 October, and a single observer between 8 and 14 November 2009. Mr. Abdul Rahman Raweh, an experienced Yemeni ornithologist, joined the principal investigator during the initial period for training and orientation, and then he carried out the latter portion of observations independently. This serves to increase local capacity and involvement in the ecological aspect of the project in anticipation for future needs for extended monitoring of avian interactions with wind development in the region on the long run.

In total 15 days were spent in the field with an average of 5-6 hours of field observations of migration per day, with a total of 72 hours of stationary observations, in addition to observations made while travelling from one location to another, particularly during exploration of the site and its vicinity in the first three days of the field study.

Initially observations were made in the general region surrounding the proposed wind farm location, extending as far east as a few kilometers east of Mafraq Al Mukha, north to Al Khokha and south to Bab Al Mandab; in order to establish the general pattern of migration of soaring birds around the site. These widely mobile observations were made during the first three days, beyond which most observations were focused on the area inside the proposed wind farm site and more particularly at the central point of the 10 km radius, represented by the metrological mast placed at 13°21'45"N 43°16'06"E. On the 30th of October the author traveled along the coastal highway between Bab El Mandab and Aden with the objective of documenting any evident bird migration activities along this section of the coast reaching to Abian province.

The spring season ornithological investigations extended between 1 March and 7 May 2010. The survey team was composed mainly of one observer (Mr. Abdul Rahman Raweh) during much of the survey period, with the principal investigator attending between 28 March and 4 April.

Wind data for the spring season (Lahmeyer International 2007) indicated a greater variability in wind direction and velocity than in the autumn, thus suggesting the need for more extensive sampling to provide a better and more representative assessment of the migration at the site in spring to address this greater variability. In total 35 days were spent in the field with an average of 5-6 hours of field observations of migration per day, with a total of bout 175 hours of stationary observations, in addition to observations made while travelling from one location to another, during exploration of the site and its vicinity to investigate regional migration patterns.

Systematic observations were largely made at the metrological mast situated at 13°21'45"N 43°16'06"E, in addition to a few observations made in other sites in and around the general region surrounding the proposed wind farm location. These sites most importantly included the solid waste disposal site near Al Mukha and some of the farmland in close proximity to the project site, in order to determine bird utility to these points of attraction to migratory and resident birds. Visits were also made on two occasions to Bab Al Mandab and one time towards Taizz, and incidental observations were made during transit from and to Taizz and Hodeida. These visits and observations were designed to ascertain the regional migration patterns, particularly in the light of almost complete absence of migrants from Al Mukha and surroundings.

All other biodiversity resources in the site and its vicinity were recoded and documented photographically and identified to species level whenever possible. The focus was on vertebrates and flora primarily, which represent a strong indicator for overall biodiversity and are better known than other groups. Most diurnal observations were made incidentally during migration studies, but several nocturnal excursions were made to detect nocturnal wildlife in the area. These were made immediately after sunset when nocturnal activity is usually at its maximum.

Extensive literature review and consultations with local and international scientists were made to augment information collected in the field.

4. Description of site and its biodiversity resources

The proposed wind farm site is part of the coastal plain that fringes the western flanks of the Yemen highlands known as the Tihama. The Tihama coastal plain extends from Bab El Mandab in Yemen to Jeddah in Saudi Arabia, and is up to 50 km wide. It is hot year round, with a mean annual temperature of 30.20 ºC. Mean annual rainfall is 26.7mm, with most rainfall occurring in winter and spring (Hegazy et al. 1998). The region can record high levels of humidity but no coastal fogs. The Tihama at large comprises two main habitat types. First, along the coast are sandy beaches often fringed with *Phoenix dactylefera* palm groves, sabkah and intertidal mudflats and areas of mangrove *Avicennia marina*. The second habitat occurs further inland and consists of shallow sandy wadis and stony plains with xerophytic plant associations and open woodland of *Salvadora*, *Commiphora* and *Acacia*, with scattered Doum Palm *Hyphaene thebaica* groves.

Figure 2. General map of study area showing the location of bird observation sites in autumn 2009. Letters correspond to locality properties summarized in Table 7. The orange square indicates the proposed area of the proposed wind farm.

Scholte et al. (1991) identified eight plant communities on the coastal Tihama plain, three of these are applicable to the general vicinity of the project site, starting from the coast inland as follows: Sabkha, *Suaeda* sparse dwarf-shrub land and bare land; Palm groves, *Phoenix-Salvadora* woodland; and Salt-bush lands, *Salsola, Odyssea* dwarf-shrub land.

The site it self and its immediate vicinity are located on a broad alluvial plain, the topography is flat, and the surface is composed of moderately coarse alluvium made up of gravels, some stones, coarse sand with some limited aeolian sand accumulations in some sheltered areas and around the bases of some vegetation. Although the area is not within any major drainage basins and is located a distance away from the major wadis in the region (e.g. Wadi Mawza to the south or Wadi Rasyan to the north), there is clear evidence of active and regular flash flooding through the site as evidenced by erosion along newly constructed coastal highway to Al Hodeida.

The proposed wind farm site is located about 2-2.5 km from the Red Sea coast, thus there is no coastal habitat within the site, but the coast in the project vicinity is sandy with a fringe of halophytic vegetation. Much of the land area in the proposed wind farm site and immediate vicinity is covered with a dense cover of Mesquite *Prosopis juliflora*, which is an invasive shrub or small tree native to Mexico, South America and the Caribbean that has invaded many parts of Asia, Africa and Australia. However, this tree seems to be more or less restricted, in this area, to a 2-3 km band along side the coastal highway and eventually gives way to the native vegetation further inland. The natural vegetation of the site is dominated by *Acacia tortilis* trees dwarfed by the predominant strong winds of the region, with scattered *Salavadora persica* and *Capparis decidua* bushes and groves of Dom Palms. The shrub layer is dominated primarily by the spiny grass *Odyssea mucronata*, with scattered shrubs of *Panicum turgidum*, *Zygophylum simplex* and *Leptadenia pirotechnica*.

Figure 3. Vegetation in the neighborhood of the meteorological mast, showing elements of the native flora including the tree *Acacia tortilis* being encroached upon by the invasive *Prospois juliflora*.

Figure 4. The landscape at the meteorological mast located at 13°21'45"N 43°16'06"E, vegetation in the background is all made of *Prospois juliflora*.

Figure 5. Flowers of *Capparis decidua* attract many insects and birds on the Tihama.

Figure 6. The spiny grass *Odyssea mucronata* plays an important role as a refuge for many animals inhabiting this region.

Figure 7. *Salvadora persica* bushs cover extensive areas of the Tihama.

Figure 8. *Senna italica* was common at the project site.

Figure 9. View of the coastal plain showing Tamarix sp. forming large phytogenic mounds (on the right) with Odyssea mucronata conibuting much of the rest of the cover.

Figure 10. Recent floods provide opportunity for new seedlings of *Calotropis procera* and *Zygophylum simplex* to establish.

Figure 11. Doum Palm *Hyphaene thebaica* groves are commonly scattered near the coast. This grove is located in the north western part of the proposed project site.

Figure 12. The grass *Panicum turgidum*.

Figure 13. *Leptadenia pyrotechnica* in the foregrownd.

Figure 14. *Zygophylum simplex* is an annual that grows rapidly after seasonal rains.

4.1. Reptiles

Reptiles were a prominent part of the local fauna, observed on all days of the field visit. Species composition is typical of hot arid regions, with a considerable diversity of nocturnal species, particularly geckos. No evidence of amphibians was found, although the endemic toad *Bufo tihamicus* can be expected to be found.

At least three south Arabian endemic species can be expected at the project site, including *Stenodactylus yemenensis* and *Scincus hemprechii*, both of which are only found on the Tihama coastal plain and were documented during the field visit. By nature of their limited range these species are of conservation concern, however, no globally threatened species of reptiles and amphibians are known to exist in the project site.

Threatened marine turtles are known from the Red Sea in close proximity to the project site but are not directly affected by project activities.

Figure 15. The gecko *Stenodactylus yemenensis* is endemic to the Tihama, and was found in small numbers at night at the project site.

Figure 16. The diurnal Semaphore Gecko *Pristurus flavipuncatatus* was commonly seen on the vegetation throughout the project areas, including on the invasive *Prosopis juliflora*.

Figure 17. The Arabian Chamaeleon *Chamaeleo arabicus* is endemic to southern Arabia. This example was a road casualty found near the meteorological mast.

Figure 18. *Acanthodactylus boskianus* s.l. was the only Lacertid lizard to be found in the project site.

Figure 19. *Scincus hemrichii* is a nocturnal species endemic to the Tihama costal plain.

Figure 20. *Psammophis schokari* is a widespread snake and the most common at the project site, with up to five individuals documented during the field visit.

4.2. Mammals

Very little evidence of wild mammals was obtained during the field visit. Several rodent tracks and burrows (probably *Meriones* and *Gerbillus*), and fox tracks were seen at the project site. Rats *Rattus rattus* were observed at Al Mukha and a Red Fox *Vulpes vulpes* killed by traffic was seen on the road to Aden. Other wise only feral cats and dogs were observed in large numbers in and around Al Mukha.

No tracks of any ungulates were observed (beside those of domestic goats and sheep) and the local inhabitants and scientists confirmed that almost all the large mammals of the region have been exterminated due to hunting and the widespread availability of fire arms. Other than locally extirpated angulates there are no known threatened species of mammals known from the project site.

4.3. Birds

In total at least 113 species of birds are documented for the general Al Mukha region (this study, Jennings 2010). 81 species were observed during autumn 2009 and spring 2010 visit, of which 60 were observed within the project site (see Appendix 2). The majority of these are migratory however, and the resident and breeding avifauna is rather limited in diversity as well as in abundance and density. The most prominent species documented in the autumn season were Crested Lark *Galerida cristata*, Yellow-vented Bulbul *Pycnonotus xanthopygos*, Nile Valley Sunbird *Anthodiaeta metallica*, Palm Swift

Cypsiurus parvus, Palm Dove *Streptopelia senegalensis,* Chestnut-bellied Sandgrouse *Pterocles exustus*, Southern Grey Shrike *Lanius meridionalis* and Black-crowned Finch Lark *Eremopterix nigriceps*. Potential breeding birds also included White-throated Bee-eater *Merops albicollis* and Cream-colored Courser *Cursorius cursor*. House Sparrow *Passer domesticus* and Indian House Crow *Corvus splendens* are two invasive species that dominated the avifauna at Al Mukha, and regularly enter the project site.

Table 1. List of birds found breeding within the project site boundaries.

English name	**Scientific name**
Stone Curlew	*Burhinus oedicnemus*
Namaqua Dove	*Oena capensis*
African Collard Dove	*Streptopelia roseogrisea*
Palm Dove	*Streptopelia senegalensis*
Chestnut-bellied Sandgrouse	*Pterocles exustus*
Crested Lark	*Galerida cristata*
Black-crowned Finch Lark	*Eremopterix nigriceps*
Greater Hoopoe-Lark	*Alaemon alaudipes*
Blackstart	*Cercomela melanura*
Graceful Prinia	*Prinia gracilis*
Yellow-vented BulBul	*Pycnonotus xanthopygos*
Arabian Babbler	*Turdoides squamiceps*
Nile Valley Sunbird	*Anthodiaeta metallica*
Palm Swift	*Cypsiurus parvus*
Southern Grey Shrike	*Lanius meridionalis*
Indian House Crow	*Corvus splendens*
Brown-necked Raven	*Corvus ruficollis*
Arabian Golden Sparrow	*Passer euchlorus*
House Sparrow	*Passer domesticus*
Rüppell’s Weaver	*Ploceus galbula*
African Silverbill	*Euodice cantans*

During the spring season the composition of local and breeding avifauna changed somewhat from the autumn, with the appearance of several Tihama breeding species, such as the near-endemic Arabian Golden Sparrow *Passer euchlorus*, African Silver-bill *Euodice cantans*, Rüppell’s Weaver *Ploceus galbula*, and Dark-chanting Goshawk *Melierax metabates*. Most of these species are small low fliers and would not be affected directly much (except perhaps due to disturbance), with the exception of the Goshawk, which could fly within the strike zone of the wind turbines. This, however, is a widespread species, which occurs in a low density in the region and the negative impact of the wind turbines is likely to be limited.

Jennings (2010) has listed 57 potential breeding birds in the general Mukha area (see Appendix 2), however this list reflects a much larger area and includes both marine and coastal, as well as mountainous habitats, all of which are not found within the immediate vicinity of the project site. Our observations indicate that at least 18 species breed within the project site boundaries, while at least six other local breeders like Black Kite *Milvus migrans*, Egyptian Vulture *Neophron percnopterus*, Griffon Vulture *Gyps fulvus*, Long-legged Buzzard *Buteo rufinus*, African Eagle Owl *Bubo africanus* and Dark-chanting Goshawk mostly nest outside the site, but include its area as part of their home ranges.

The relatively poor avifauna at the project site could be partly attributed to the dense growth of the invasive *Prosopis*, which creates a habitat that is particularly species poor. Indeed, most birds were observed in areas with no or limited *Prosopis* cover.

In terms of migratory species soaring birds (particularly birds of prey) were the most prominent and diverse (these will be dealt with in greater detail later). An important component of waterbirds was found along the coast towards Al Khokha as well as further south towards Bab El Mandab, with many shore birds congregating in coastal lagoons, but generally not wandering inland. The exception was at newly reclaimed and irrigated (flooded) fields in the northern portion of the project site, where small numbers of wading birds were observed.

The Arabian Bustard *Ardeotis arabs*, which is Yemen’s largest bird and is a declining species throughout its range, was known from the vicinity of Al Mukha (Dr. John Grainger pers. com.). The last record in the general vicinity of Al Mukha was in 2001 (Jennings 2010). Mike Evans (in litt.) indicated that most of the recent records of the species are in the northern part of the Tihama in Yemen near Hodieda. Yemen is probably now the only country within the Arabian Peninsula with a self-sustaining population of the species, and the Tihama is the only place where this bird occurs in the country. The Arabian Bustard would be one of the few resident bird species that could be at special risk from possible wind farm developments on the Tihama due to its large size, sensitivity to disturbance and large home range requirements. No records or evidence of the species’ occurrence were obtained during the current study and its unlikely to occur in the immediate vicinity of the proposed project site as it is likely to be too densely overgrown with *Prosopis* trees for the species’ to survive.

There are several species that are considered to be globally threatened found in Yemen and which could potentially occur at the proposed project site, including: Greater Spotted Eagle *Aquila clanga*, Imperial Eagle *Aquila heliaca*, Pallid Harrier *Circus macrourus*, Lappet-faced Vulture *Torgos tracheliotos*, Ferruginous Duck *Aythya nyroca*, Houbara

Bustard *Chlamydotis undulata*, Corncrake *Crex crex*, Lesser Kestrel *Falco naumanni* and Northern Bald Ibis *Geronticus eremic* (IUCN 2009).

Table 2. Globally threatened bird species, known (in bold) or could possibly occur at the project site and adjacent areas, according to the *IUCN Red List of Threatened Species* (IUCN 2010).

English name	**Scientific name**	**Status**
Egyptian Vulture	***Neophron percnopterus***	**Endangered**
Pallid Harrier	***Circus macrourus***	**Near-threatened**
Greater Spotted Eagle	***Aquila clanga***	**Vulnerable**
Eastern Imperial Eagle	*Aquila heliaca*	Vulnerable
Sooty Falcon	***Falco concolor***	**Near-threatened**
Red-footed Falcon	*Falco vespertinus*	Near-threatened
Lesser Kestrel	*Falco naumanni*	Vulnerable
Saker Falcon	*Falco cherrug*	Endangered
White-eyed Gull	***Larus leucophthalmus***	**Near-threatened**
European Roller	*Coracias garrulus*	Near-threatened
Corncrake	*Crex crex*	Vulnerable
Cinereous Bunting	*Emberiza cineracea*	Near-threatened

BirdLife International (Evans 1994, BirdLife 2009) has also designated three Important Bird Areas (IBAs), which are found the vicinity of the project site or within the adjoining region, as follows:

Straits of Bab Al Mandab (43°29' E, 12°46' N)

Bab Al Mandab is the narrowest point in the southern Red Sea linking the Arabian Peninsula with Africa. It is a major bottleneck for soaring of international importance (Zalles and Bildstein 2000). Migratory birds, especially birds of prey, flying between Africa and their Eurasian breeding grounds, mainly Steppe Buzzard *Buteo buteo*, Steppe Eagle *Aquila nipalensis* and Egyptian Vulture concentrate here in globally significant numbers (Evans 1994, BirdLife 2009), potentially putting large numbers at risk from any adverse conditions on the ground. See further details below.

Mafraq Al Mukha (13°22'N 43°38'E)

An important soaring bird migration concentration area in autumn. Most birds pass over at high altitude, unless driven low by strong southerly headwinds, but large numbers descend to roost in the area at night, and raptors are attracted to drink at the wadis as well

(Evans 1994, BirdLife 2009). The following numbers have been counted: Black kite *Milvus migrans* 273, Steppe Buzzard 55, Greater Spotted Eagle 6, Steppe Eagle 168, Sparrowhawk 5, and Levant Sparrowhawk *A. brevipes* 100. Small numbers of White *Ciconia ciconia* and Black Stork *Ciconia nigra* migrate and winter in the area. The area also holds a representative breeding assemblage of species characteristic of Acacia-Commiphora bushland (Evans 1994, BirdLife 2009). Together with two other bottleneck IBAs Wadi Rijaf (14^o 53' N 43^o 26' E) and Al Kadan (15^o 18' N 43^o 14' E) this IBA represents a section along the main migratory rout for soaring birds along the Tihama foothills.

Al Mukha – Al Khawkhah (13^{o}35' N 43^{o}17' E)

This IBA includes about 70 km of the Red Sea coastline extending between the towns of Al Mukha in the south and Al Khawkhah in the north. The IBA is primarily a wetland composed of intertidal habitats including coastal lagoons, mangroves, mudflats and littoral habitats that provides valuable feeding habitat for coastal waterbirds, and large numbers of gulls and terns. Wintering species include Spoonbill *Platalea leucorodia* and Black-headed Gull *Larus ridibundus*. Migrants include Lesser Sand Plover *Charadrius mongolus*, Broad-billed Sandpiper *Limicola falcinellus*, Terek Sandpiper *Tringa cinerea*, Lesser Crested Tern *Sterna bengalensis*, and Common Tern *Sterna hirundo*. Breeding species of the mangroves include Green Heron *Butorides striatus*, Nubian Nightjar *Caprimulgus nubicus* and Black-crowned Tchagra *Tchagra senegala* (Evans 1994, BirdLife International 2009).

Figure 21. Crab Plover *Dromas ardeola* one of the shore birds found on intertidal flats near Al Khokha.

Figure 22. White-eyed Gull *Larus leucophthalmus* (Near Threatened) was common on the beach at Al Mukha.

Figure 23. African Eagle Owl *Bubo africanus*. Traffic casualty found at the project site. Other owl species could also occur at the site, but were not detected.

4.4. Bird migration through the project site and adjacent region

Generally there is relatively limited systematic information about bird migration through this area. Migrants can be grouped into three migration groups according to their physiology, flight behavior and ecology as follows:

4.4.1. Passerines and near passerines

The most numerous migrants are passerines and near passerines that spend the winter in sub-Saharan Africa. The number of species that pass the region during migration is relatively high and the total number entering Africa has been estimated at 800 million individuals (Biebach and Baha El Din 1995). Passerines migrate in a broad front alone or in loose groups, with little tendency for concentration in bottlenecks, they do not normally form large flocks or follow narrow migratory routes (like soaring birds do). They mostly fly at night, and stop to rest and refuel (if possible) during the day, resting on the ground, in vegetation, in rocky crevices or any available shelter, but very few also continue to fly during the daytime.

Flight usually takes place at considerable elevation where cooler and more moist air can be found. About 90% of all small migrants recorded during spring in Mauritania, were flying above 1000m, and more than 50% were above 2500m (Liechti and Schmaljohann 2007). Schmaljohann et al (2007). Found that autumn migration of songbirds across the Sahara took place at lower altitudes than spring, and migration was more highly restricted to night-time than in spring, when about 17% of the songbird migration occurred during the day. A radar study of the flight altitude of small migrants passing through Egypt at night showed that only 21% of all birds flew below 100 m (Biebach and Baha El Din 1995). It was estimated that the number of passerines flying below 100 m is between 16,000-65,000 per night per kilometer (Biebach and Baha El Din 1995). A radar study by Decon-Fichtner (2007) of nocturnal migrants at the Gebel El Zeit area found that the maximum observed number of birds per hour in one kilometre distance was 3,000 (in autumn). Decon-Fichtner (2007) also found that 30% of 10,820 night migrants detected by radar flew below 200 m and 19% below 150 m during spring. In autumn 36,420 night migrants were detected, but only 8.6% were found flying below 200m.

4.4.2. Waterbirds

The Red Sea coast in Yemen is also a route for migrating waterbirds as well as an important wintering ground, including species such as herons, gulls, terns, ducks and waders. Waterbirds mostly migrate in flocks usually offshore following the coastline, but frequently small flocks or individuals of various heron species (such as Grey Heron *Ardea cineria* , Purple Heron *A. purpurea* and Night Heron *Nycticorax nycticorax*) will fly over land and could be encountered at the project site. Indeed two Grey Herons were seen flying over the site. Soaring waterbirds such as storks and pelicans are treated under soaring birds.

4.4.3. Soaring birds

Soaring birds are birds that use thermals or warm air currents to fly. These currents form during the day time when the land is heated by the sun. There are no thermals at night so the vast majority of soaring birds come down to roost on land. As thermals also do not form over the sea, soaring birds avoid any extensive water bodies and select to cross over land bridges or narrow waterways. For this reason soaring birds tend to concentrate along narrow passage ways and well established bottlenecks, where huge numbers of these birds congregate on their migration on a predictable seasonal pattern. Entire populations of some species can pass through some of these bottlenecks.

Soaring birds are of special conservation concern because they are usually large birds that are few in number have a long life history and take a long time to reproduce and need large areas of habitat to do so, so they are by nature of conservation concern and are vulnerable to any additional impact to their populations even if it is relatively small and sustained.

There are two types of soaring birds: passive and active fliers. Passive fliers, which are birds that rely almost exclusively on thermals as a means of flight and are highly reluctant to cross any water surfaces. Passive fliers include larger birds of prey such as vultures, eagles and most buzzards and storks.

Active fliers are soaring birds that depend to a lesser extent on thermals and are capable of sustaining fairly long flights without thermals through active flapping. Active fliers include species such as pelicans, cranes and some of the smaller birds of prey such as Honey Buzzard *Pernis apivorus*, harriers, sparrow hawks and falcons. These active fliers are less reluctant to cross water bodies and are generally more flexible in their choice of migration route.

Some soaring birds like storks, pelicans and cranes fly in monospecific flocks, often in huge flocks. Birds of prey tend to migrate in multi-species streams, often forming huge kettles, where masses of various soaring birds of prey spiral together upwards on hot air thermals to gain altitude.

4.4.4. Existing knowledge of soaring bird migration in the vicinity of the project site

While the fact that Bab Al Mandab is an important bottle neck for migratory soaring birds is well known and accepted, very little field work has been carried out to document and describe this site. The first observations in the region were by Philips (1982), who observed substantial migration along the Tihama foothills at Mafraq Al Mukha. While Porter and Christensen (1987) described the migration at five different sites along the Tihama foothills (resulting in 3546 soaring migrants in 38 hours of observations), forming parts of the main flyway leading to Bab Al Mandab. Welch and Welch (1991) found that the migratory flyway extends northwards into Saudi Arabia along the Asir foothills as well.

Table 3. Summary of bird counts at Bab Al Mandab from Djibouti in the autumn of 1985 and 1987 (Welch and Welch 1988).

Species	15 October – 1 November 1985	3 October - 9 November 1987
Accipiter nisus	403	2135
Accipiter brevipes	2	7
Accipiter sp.	13	17
Aquila clanga	6	12
Aquila fassciata	2	2
Aquila heliaca	16	70
Aquila nipalensis	60897	76586
Aquila pennata	124	1123
Aquila pomarina	0	31
Aquila sp.	26	27922
Buteo buteo	17875	98339
Buteo rufinus	4	131
Ciconia ciconia	4	60
Ciconia nigra	9	166
Ciconia abdimii	0	643
Ciconia sp.	0	15
Circaetus gallicus	203	1202
Circus aeruginosus	6	45
Circus macrourus	16	67
Circus pygargus	6	17
Circus sp.	17	116
Falco subbeto	16	69
Falco tinnunculus	48	183
Falco naumanni	4	8
Falco vespertinus	0	1
Falco eleonorae	2	1
Falco biarmicus	8	9
Falco cherrug	3	0
Falco peregrinus	16	7
Falco sp.	22	48
Gyps fulvus	0	3
Milvus migrans	55	579
Neophron percnopterus	41	554
Pandion haliaetus	0	3
Grus grus	0	26
Bird of prey sp.	1	7294
Total	**80732**	**246478**

There are two previous systematic counts of birds crossing Bab Al Mandab it self during autumn: one between 15 October – 1 November 1985, and between 3 October - 9 November 1987 (Welch and Welch 1988). These counts were conducted from the Djibouti side of the Bab Al Mandab Straits. To date no systematic counts seem to have been conducted from the Yemeni side. A maximum total number of 246,478 soaring birds were counted in autumn of 1987 (Welch and Welch 1988). Key migrating species and their maximal counts are as follows: Steppe Buzzard 98,339 (plus 29,851 "*Buteo* sp."), Steppe Eagle 76,586 (plus 27,922 "*Aquila* sp."), Sparrowhawk 2,135; Short-toed Eagle 1,202; Booted Eagle 1,123; Egyptian Vulture 773 ; Black Kite 579; Abdim's Stork 643 (Welch and Welch 1988). The autumn migration season can be anticipated to extend from late September into late November (as indicated by other soaring bird studies conducted throughout the Middle East); however the bulk of migration takes place in October and the first half of November. In both the above studies the peak migration was observed between the second and fourth week of October.

During spring there is even less information available from both the Yemeni and the Djibouti sides of Bab Al Mandab, but as can be anticipated from the geography of the site the intensity of migration is less than that during autumn. Welch and Welch (1998) reported 1877 soaring birds crossing Bab Al Mandab between 5-7 March 1990, while 1677 were observed from the Yemeni side between 22-25 March 1998. The composition of migration was also very different from autumn, with Egyptian Vulture and Booted Eagle forming the bulk of migrants, with only very few Buzzards and Steppe Eagles. This information indicated that there is some soaring bird migration through the region during spring, but little was known about the orientation, elevation and potential volume of migration, particularly over Al Mukha area.

Table 4. Summary of bird counts at Bab Al Mandab from both the Yemen and Djibouti sides in the springs of 1998 and 1990 respectively (Welch and Welch 1998).

Species	Yemen 22 – 25 March 1998	Djibouti 5 - 7 March 1990
Accipiter nisus	37	0
Aquila nipalensis	1	13
Aquila pennata	736	953
Aquila sp.	1	0
Buteo buteo	26	0
Circaetus gallicus	0	134
Circus aeruginosus	2	0
Circus macrourus	12	1
Circus pygargus	14	2
Circus sp.	21	2
Falco tinnunculus	3	1
Milvus migrans	1	0
Neophron percnopterus	773	733
Pandion haliaetus	1	0
Bird of prey sp.	16	38
Total	**1644**	**1877**

5. Ornithological studies at proposed wind energy development at Al Mukha

5.1. Results of the autumn 2009 study

During the autumn 2009 field study, 607 observations were made resulting in recording a total of 18326 soaring birds belonging to 24 species.

5.1.1. Migration general orientation

As anticipated from the literature and the nature of the topography of the region, the main stream of autumn soaring bird migration moved in a southerly direction along the Tihama foothills in a fly way that leads directly to Bab Al Mandab. Observations at Al Mafraq located 40 km east of Al Mukha confirmed the heavy passage of birds along a north to south axis parallel to the mountain foothills bordering the Tihama from the east.

Birds moved south to Bab Al Mandab and congregated there in large numbers to attain altitude and attempt the crossing of the sea west wards to Djibouti. Due to the very strong southerly winds at Bab Al Mandab (prevailing throughout the region) many birds attempting to cross the sea to Djibouti fail to reach the western side and are forced northwards along the Yemeni Red Sea coast. Most of these birds are seen arriving in large numbers off the Red Sea just north of Bab Al Mandab and north to Dubab (where many land, apparently exhausted and overwhelmed by the strong winds). These birds are pushed further northwards along the coast reaching up to Al Mukha and beyond. The volume of birds at Al Mukha varies according to wind velocity, being greater during strong winds. These birds attempt to head eastwards and eventually rejoin the stream of soaring birds moving south along the Tihama foothills, where the southerly winds are much reduced and hence attempt to cross the straits of Bab Al Mandab again.

The situation at Bab Al Mandab it self was rather chaotic, with a large influx of birds coming from the north along the last of the Tihama foot hills mixing with birds coming off the Red Sea after failing to cross the Straits of Bab Al Mandab. During the day huge numbers build up over the hills of Bab Al Mandab, being held back by the violent southerly winds and attempting to gain sufficient altitude to facilitate the crossing of the sea to Djibouti. This situation makes it very difficult to assess the total volume of migrants passing through Bab Al Mandab with any accuracy as it appears that many birds might attempt the crossing several times. This leaves the counts from the Djibouti side as the best option for assessing the volume of birds utilizing this bottleneck. Welch (in litt.) made a similar observation of spring migration from the Djibouti side of Bab Al Mandab, where birds made several attempts to cross the sea in the face of strong headwinds from the north.

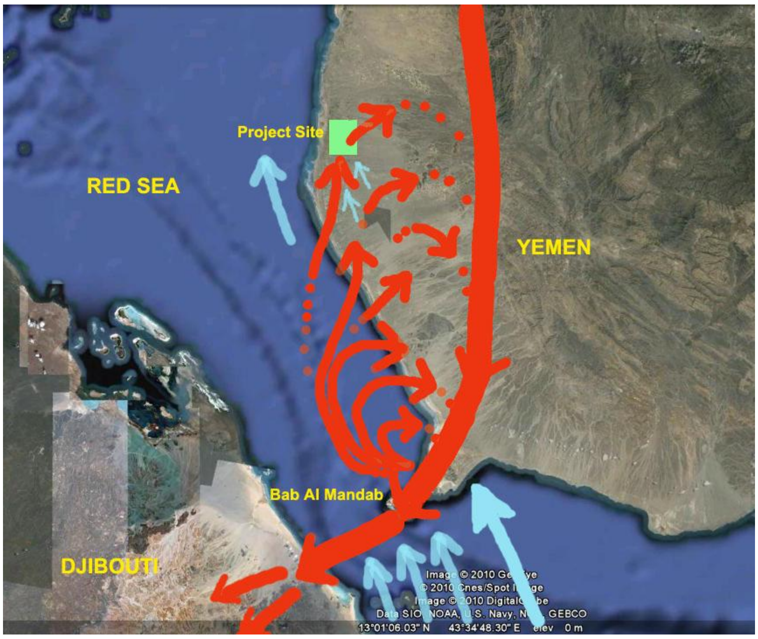

Figure 24. Schematic map of Yemen showing the soaring birds migration pattern during autumn (Red: main migration routs; Blue: predominant wind direction; Light green: project location).

At the proposed wind farm location most birds were largely observed moving in a north easterly direction (average 43º). These almost certainly represent birds that failed to make the sea crossing at Bab Al Mandab and returned to the Yemeni side in the area between Bab Al Mandab and Dubab, where they get pushed northwards by the strong southerly winds. These birds were noted to attempt to take more easterly or even southerly heading, but despite their intended orientation, they were still being pushed northwards by the very strong southerly winds. After a few attempts to correct their direction towards the south, most birds surrender to the prevailing wind. Further east towards the Tihama foot hills a more easterly direction of movement was observed, and once the Tihama foot hills were reached the relentless southerly winds die off and the normal southerly migration direction was assumed again by all the birds.

Soaring bird migration in Bab Al Mandab, Lahj and Abyan

Part of the consultant's TORs call for an assessment of bird migration in Lahj and Abyan Governorates on the Gulf of Aden including Bab Al Mandab, where there is also good potential for wind energy development. In theory there is the possibility for a secondary migratory rout along the Gulf of Aden, leading also to Bab Al Mandab during autumn.

In Autumn it was immediately obvious that the situation between Dubab and Bab Al Mandab (south of Al Mukha) was critical for soaring migrants (as they land in very large numbers and fly at very low altitude), and the establishment of any wind turbines in the section of the coastline would be detrimental by all measures.

A rapid reconnaissance of migration activity was conducted on 30 October 2009 between Bab Al Mandab and Aden. Frequent spot searches along the coastal stretch. These searches revealed no migration activity, and the only soaring bird was a Steppe Eagle recorded flying low along the coast towards Aden, half way between the latter locality and Bab Al Mandab, where it probably originated.

Indeed all signs of migration stopped within a few hundred meters from (south and east of) Bab Al Mandab on the road towards Aden. Very strong southerly winds probably prevent birds from coming too close to the Gulf of Aden, which they don't have any interest or ability to fly over in any case. So there is apparently a complete avoidance of the costal plain in this region. At Aden it self there was a number of soaring birds including Steppe Eagles, Booted Eagle, Imperial Eagle, Black Kite, but this however represent a wintering population, which is probably augmented by some of the birds that fail to cross Baba Al Mandab. These preliminary results are based on a very small sample size, and should only be seen as indicative but not definitive.

5.1.2. Volume

A total of 18326 soaring birds were counted during systematic counts at all sites visited during the entire study period (see Table.). Additionally there were huge numbers of eagles and buzzards seen at great distance spiraling above the mountains overlooking Bab Al Mandab, during the two visits made there (not included in the systematic counts). These birds were too far to identify or count to any degree of accuracy, but it could be estimated that well over 3000 birds were involved in each case. These birds seem to be accumulating over a long part of the day and did not move much, probably deterred by the strong winds and waiting for the opportunity to make an attempt of crossing the sea, when and if the winds ease off.

At the proposed project site and its vicinity, modest numbers of soaring migrants were noted on all days of observation, and up to several hundred birds were noted on some days, with a total of 5544 birds counted during the study period.

However, the intensity of migration varied greatly according to location (see Table 2, where counts made had to be adjusted to reflect observation effort at each location). For example at the metrological mast 3311 birds were counted during 49 hours of observation, while at location (Q) at Bab Al Mandab an estimated 5023 birds were counted within only 1.5 hours of observation. This represents almost a 50 fold greater volume at Bab Al Mandab than at the proposed project site. The Bab Al Mandab locations generally had the greatest volume of birds in the study area. But as indicated elsewhere this is certainly an inflated volume caused by the constant accumulation of birds that fail to cross the sea and remain circulating the area for an unknown length of time. The average volume of about 300 birds/hour documented in the locations around Al Mafraq (locations F,G,H,J, I,K,L in Fig. 1 and Table 2) probably represent the "normal" volume of migration per hour along the main migratory rout.

5.1.3. Species composition

22 species of soaring birds, as well as European Bee-eater *Merops apiaster* and Grey Heron *Ardea cinerea*, were documented during the current study. As noted on the Djibouti side of Bab Al Mandab (Welch and Welch 1988) Steppe Buzzard *Buteo buteo* and Steppe Eagle *Aquila nipalensis* were the most abundant species, making up 94% of the entire volume of birds counted during the current study. Other important migrants are Black Kite *Milvus migrans*, Egyptian Vulture *Neophron percnopterus* and Sparrowhawk *Accipiter nisus*. There was a notable difference in the abundance of Steppe Eagles at the project site and at Bab Al Mandab, being significantly more abundant at the latter locality.

Figure 25. Adult Egyptian Vulture *Neophron percnopterus* flying over project site.

Figure 26. Immature Steppe Eagle *Aquila nipalensis* flying over project site.

Table 5. Species composition at the project site and for all sites visited.

Species	**Numbers recorded at project site**	**% of total**	**Numbers recorded at all localities visited**	**% of total**
Accipiter nisus	114	2.1	132	0.7
Aquila clanga	9	0.2	10	0.1
Aquila heliaca	2	0.0	2	0.0
Aquila nipalensis	347	6.3	2886	15.7
Aquila pennata	15	0.3	24	0.1
Aquila pomarina	0	0.0	1	0.0
Aquila rapax	0	0.0	2	0.0
Aquila sp.	111	2.0	111	0.6
Buteo buteo	4393	79.2	14209	77.5
Buteo rufinus	5	0.1	5	0.0
Ciconia ciconia	2	0.0	17	0.1
Ciconia nigra	112	2.0	112	0.6
Circaetus gallicus	38	0.7	90	0.5
Circus aeruginosus	45	0.8	45	0.2
Circus macrourus	8	0.1	8	0.0
Circus pygargus	11	0.2	12	0.1
Circus sp.	1	0.0	1	0.0
Falco subbeto	1	0.0	1	0.0
Falco tinnunculus	24	0.4	28	0.2
Gyps fulvus	4	0.1	32	0.2
Milvus migrans	208	3.8	374	2.0
Neophron percnopterus	85	1.5	215	1.2
Ardea cinerea	1	0.0	1	0.0
Merops apiaster	8	0.1	8	0.0
Total	**5544**	**100.0**	**18326**	**100.0**

Figure 27. Steppe Buzzard *Buteo buteo vulpinus* taking off from the ground at Dubab.

Figure 28. Spotted Eagle *Aquila clanga* sitting on the ground in the face of fierce winds north of Bab Al Mandab.

5.1.4. Flight altitude

The altitude at which migration takes place is a critical aspect of the migration, as it is strongly linked with potential risks from wind turbines. Elevation of migrants varied according to location, time of day, season and species. Generally the birds were lower near the coast than inland.

In autumn the average flight altitude at the metrological mast was 230 m (n [observations]= 368, n [birds]= 3311, sd=163 m, range 10-1000 m), while the overall average elevation in the general vicinity of the proposed wind farm site was 258 m (n [observations]= 479, n [birds]= 5544, sd=267 m, range 0-2000 m). Towards the mountains at Al Mafraq, where the main migration route is, the average elevation was 550 m (n [observations]= 90, n [birds]= 2977, sd=394 m, range 0-2000 m); while further south on the coast near Dubab the average elevation was much lower at 108 m (n [observations]= 20, n [birds]= 2461, sd=104 m, range 0-400 m); and even lower at Bab Al Mandab at 56 m (n [observations]= 18, n [birds]= 7344, sd=24 m, range 0-100 m).

The low flight altitudes near the coast at Bab Al Mandab, Dubab during autumn is due to the fact that birds were arriving off the Red Sea after losing altitude and failing to make the crossing to Djibouti. In deed many of the birds were resting on the ground. Al Al Mukha the returning birds would have gained some altitude as the site is further inland, generating stronger thermals. At Al Mafraq the greatest altitude was achieved, due to the presence of ideal conditions for thermal formation along the mountainous Tihama foothills.

In autumn about 33% of birds recorded in the general proposed project site were documented below 200 m (1768 birds), and 31% (1710 birds) were flying between 200-300 m. While 68% of birds were above 200 m, over 50% of observations were made below 200 m, this is due mainly to the fact that much of the observations at lower altitudes were of smaller species such as harriers and falcons that normally migrate singularly or in small groups (see Table 4). When considering only the observations made at the meteorological mast, a slightly greater proportion of birds (36%) is documented below 200 m, possibly due to its relative proximity to the coast.
The altitude of migrants is affected by ground temperature and the creation of strong thermals. Ground temperature changes during the day, rising rapidly after sunrise and thus affecting the flight altitude of soaring migrants throughout the day (see Fig. 24).

Soaring birds will not start moving until the grounds starts getting heated up and some thermals form. Migrants were the lowest during the first hour of observation between 7-8 in the morning (usually below 100 m), but then rapidly gained altitude as the ground and ambient temperatures became higher, reaching an average altitude over 400 m between 11-12 noon. Around noon time some birds were estimated to be flying 2 km above ground and even higher. It is probable that many migrants were overlooked during that period as they were too high and out of sight. It is also possible that the rather abrupt absence of soaring migrants after 13 hours, is due to their reaching extreme altitudes that cannot be detected visually from the ground.

Harriers, sparrow hawks and falcons were observed at lower elevations than buzzards, eagles, storks and vultures (see Table 4). Harriers are active flyers that do not depend greatly on thermals and commonly migrate below 100 m.

Table 6. Altitudinal distribution of birds at the general project site during autumn 2009 (localities A-E).

Altitude	Number of observations	%	Number of birds	%
<100	158	32.98	750	13.52
100-200	109	22.75	1036	18.68
200-300	101	21.08	1710	30.84
300-500	71	14.82	1422	25.64
500-1000	30	6.26	463	8.35
>1000	10	2.08	163	2.94
Total	479	100	5544	100

Table 7. Altitudinal distribution of birds at the meteorological mast during autumn 2009 (locality B).

Altitude	Number of observations	%	Number of birds	%
<100	112	30.43	336	10.14
100-200	101	27.44	868	26.21
200-300	84	22.82	946	28.57
300-500	52	14.13	809	24.43
500-1000	19	5.16	352	10.63
Total	368	100	3311	100

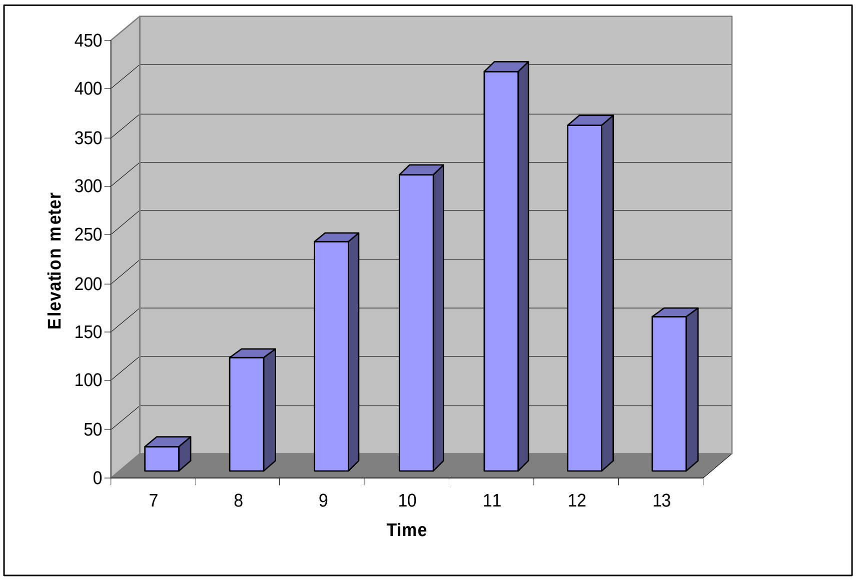

Figure 29. Showing change in average elevation of migrating soaring birds through the day during autumn 2009.

Table 8. Average altitude of soaring migrants by species in autumn 2009.

Species	Average altitude (m)
Accipiter nisus	189
Aquila clanga	100
Aquila heliaca	400
Aquila nipalensis	362
Aquila pennata	424
Aquila pomarina	50
Aquila rapax	250
Aquila sp.	264
Ardea cinerea	300
Buteo buteo	339
Buteo rufinus	145
Ciconia ciconia	340
Ciconia nigra	261
Circaetus gallicus	340
Circus aeruginosus	91
Circus macrourus	271
Circus pygargus	81
Circus sp.	10
Falco subbeto	10
Falco tinnunculus	87
Gyps fulvus	439
Merops apiaster	50
Milvus migrans	340
Neophron percnopterus	264

Table 9. Summary of observations made during the autumn 2009 ornithological studies in Al Mukha vicinity, Yemen.

Location symbol *	Location Name	Coordinates	Average direction of migration (in degrees)	Total birds observed at locality	Observation effort (hours spent at location)	Relative estimated migration intensity (total adjusted by observer effort).	Average elevation of observed birds (in meters)
A	Al Mukha Town	13°19'40"N 43°15'54"E	135	19	3.3	5.76	20
B	Metrological mast	13°21'45"N 43°16'06"E	43	3311	48.7	67.99	230
C	North wind farm	13°25'20"N 43°16'24"E	15	2146	6.5	330.15	510
D	South wind farm	13°19'12"N 43°19'32"E	11	4	1.5	2.67	170
E	North wind farm	13°27'45"N 43°18'49"E	44	66	3	22.00	100
F	West of Al Mafraq	13°19'10"N 43°25'25"E	NA	1	0.17	5.88	NA
G	West of Al Mafraq	13°19'06"N 43°25'49"E	180	11	0.17	64.71	50
H	East of Al Mafraq	13°23'41"N 43°39'46."E	180	75	0.34	220.59	100
I	East of Al Mafraq	13°22'31"N 43°38'5"E	225	271	1	271.00	400
J	West of Al Mafraq	13°20'4"N 43°33'52"E	167	2364	2	1182.00	630
K	West of Al Mafraq	13°19'59"N 43°31'18"E	135	145	1	145.00	420
L	West of Al Mafraq	13°19'11"N 43°24'12"E	180	110	0.25	440.00	2000
M	North of Dubab	13° 4'31"N 43°21'11"E	0	230	0.25	920.00	100
N	North of Dubab	12°58'12"N 43°24'24"E	0	201	0.25	804.00	50
T	North of Dubab	12°59'37"N 43°23'56"E	0	163	0.5	326.00	280
O	South of Dubab	12°55'52"N 43°25'52"E	56	305	0.25	1220.00	50
P	South of Dubab	12°49'26"N 43°29'59"E	45	1102	0.25	4408.00	30
S	South of Dubab	12°51'36"N 43°28'14"E	180	50	0.1	500.00	100
U	South of Dubab	12°50'52"N 43°29'3"E	23	410	0.17	2411.76	100
Q	Bab El Mandab	12°44'35"N 43°28'25"E	83	5032	1.5	3354.67	50
R	Bab El Mandab	12°41'48"N 43°29'12"E	90	2000	0.45	4444.44	50
V	Bab El Mandab	12°45'33"N 43°29'42"E	90	312	0.17	1835.29	100
Totals				18328	71.82	255.19	

* These letters correspond to those in Figure 1. Sites highlighted in yellow represent the general proposed wind farm locality and are combined in further discussion and evaluation in the current document.

5.2. Results of the spring 2010 study

During the spring 2010 field study, 287 observations were made resulting in recording a total of 1005 soaring birds belonging to 18 species in all areas visited.

5.2.1. Migration general orientation

Overall the spring season observations indicate that soaring bird migration through Yemen at large during this season is of small volume and limited significance, particularly when compared with the volume during autumn. There are only two published studies with limited scope about spring migration in Yemen and across the Strait of Bab Al Mandab (Welch and Welch 1991, Welch and Welch 1998). Both suggested a modest volume of passage and limited diversity of species (see Table 3). However, our more extensive study indicates that the volume of birds is even smaller than what earlier studies had indicated.

At the project site there was a very limited number of migratory soaring birds observed. The current study indicates that the lack of migrants over Al Mukha in spring is probably not only due to the position of the site away from the main migratory pathway for soaring birds (along the Tihama foothills), but is also likely due to the limited overall volume of birds returning through Yemen in spring.

This was supported by our observations made at Bab El Mandab during the spring season on 30 March, 19 April and 7 May 2010, when we found very few birds moving across the strait and entering the Arabian Peninsula from Africa. This strongly suggests that the spring migration of soaring birds largely follows a more westerly rout along the western coastline for the Red Sea, north to Egypt and Suez. This is also supported by a lack of any active migration of soaring birds in other sampled localities around Al Mukha. In the vicinity of Mafraq Al Mukha and towards Taizz fairly large numbers of soaring birds were observed, but these were either wintering or resident birds, largely composed of Black Kites, Egyptian Vulture, White Stork and some Eagles.

The movement of bird over the project site during the spring season was unlike that during autumn, when there was a clear and almost unimodal direction of flight north or north east over the site, with little interest in stopping or prospecting by the birds. In spring bird movement was almost equally divided between east, north and south orientations (see Table 8). This probably reflects the local nature of the birds observed, which are either of breeding or wintering populations.

Table 10. General orientation of soaring birds over project site in spring 2010.

Direction of flight	Number of observations	% of total
E	65	26.6
N	90	36.9
NE	4	1.6
S	64	26.2
SW	1	0.4
SE	2	0.8
W	18	7.4
	244	100.0

5.2.2. Volume

Systematic observations at the project site during the entire spring study period indicated a very limited volume of migratory soaring birds flying over the site. A total of 349 soaring birds made up of 14 species were documented flying over the proposed project site at Al Mukha.

This limited volume was evident under various wind regimes. Wind direction and speed was much more variable than during autumn; however this did not seem to have any observable effect on bird migration volume at and around the project site. During the principal investigator’s visit there were three days of weak northerly wind, when almost no migration of any form was evident. The number and variety of birds did not change much when wind direction returned to its prevailing strong southerly direction.

5.2.3. Species composition

The species richness of soaring birds was notably lower in spring than in autumn (16 species versus 22 respectively). The great majority of the birds recorded over the site seem to represent resident and breeding species or populations, rather than migratory species. For example most Black Kites, Egyptian Vultures, Griffon Vulture and possibly Kestrels, represent local breeding birds, rather than migrants. While species such as Steppe Eagle, White Stork, Booted Eagle, Sparrowhawk and Buzzard are certainly all migratory as they have no local breeding populations and most move north to breed or spend the summer. Tawny Eagle and Dark Chanting Goshawk are two breeding birds, which have not been documented previously during the autumn season at the project site.

The local resident nature of many of the birds observed was indicated by the movement patterns of these birds, showing no urgency to follow a particular direction and tending to fly around and land often in search for food. This was particularly true in the case of the Egyptian Vultures. Most Black Kites observed belonged to the local breeding race *Milvus migrans aegyptius*, often regarded as a distinct species. This taxon is abundant and breeds widely in many parts of Yemen including the Tihama.

Figure 30. Booted Eagle *Aquila pennata* over Baba Al Mandab.

Figure 31. Part of a flock of Black Kites *Milvus migrans* attracted to the solid waste dump near Taizz.

Although the number of soaring migrants at Al Mukha project site is limited, the numbers of the Endangered Egyptian Vultures there is of some concern. These birds almost certainly represent local breeding birds or wintering birds that roam around this part of the Tihama, and are attracted to the site because of the solid waste dump (which contained several dead animals during the PI visit). Dead live stock from the quarantine (which holds mostly cattle imported from Somalia) are dumped at a locality at the southern part of the project site, also acting as an attraction focal point for these birds.

The total numbers of Egyptian Vultures at both the project site and solid waste dump (69 and 92 birds respectively) is probably inflated as these figures are likely to represent the same local resident birds seen repeatedly by the study team at the same sites but on different days, and do not represent a true population estimate (this would apply to most other resident soaring bird species). The maximum of 13 Egyptian Vultures seen together at the solid waste dump probably provides a better representation of the real population size in the region.

Table 11. Soaring bird species composition at the project site and at near by solid waste dump in spring.

Species	Numbers recorded at project site	% of total	Numbers recorded At solid waste dump	% of total
Accipiter nisus	32	9.25		
Melierax metabates	13	3.76		
Aquila clanga	4	1.16		
Aquila nipalensis	17	4.91		
Aquila pennata	1	0.29		
Aquila rapax	2	0.58		
Aquila sp.	6	1.73		
Buteo buteo	37	10.69		
Buteo rufinus	1	0.29		
Ciconia ciconia	11	3.18		
Ciconia abdimii			1	0.62
Circus aeruginosus	4	1.16	1	0.62
Falco tinnunculus	11	3.18		
Gyps fulvus	6	1.73		
Milvus migrans	126	36.42	67	41.61
Neophron percnopterus	69	19.94	92	57.14
Pelecanus rufescens	6	1.73		
Total	**349**	**100**	**161**	**100**

Our observations don't correspond with those by Welch and Welch (1998), who observed a soaring bird migration at Bab Al Mandab composed of several hundred Booted Eagles and Egyptian Vultures during three days of observation in March 1998. While during the entire spring season study we only documented four Booted Eagles and a 288 Egyptian Vultures in all localities visited (including Bab Al Mandab, and areas intervening between Mafraq Al Mukha, Taizz and Hodeida). This might reflect the stochastic nature of migration in the region in response to weather or large climatic conditions, or other factors.

Table 12. Non-soaring bird species composition at the project site and at near by solid waste dump in spring.

Species	Numbers recorded at project site	% of total	Numbers recorded At solid waste dump	% of total
Bubulcus ibis	59	41.55	154	100
Merops persicus	4	0.28		
Merops albicollis	10	7.04		
Pterocles exustus	67	47.18		
Corvus ruficollis	2	1.41		
Total	**142**	**100**	**154**	**100**

5.2.4. Flight altitude

In spring the average flight altitude was significantly lower than during autumn. At the metrological mast it was 113 m (n [observations]= 241, n [birds]= 489, sd=94 m, range 0-1300 m), while the overall average elevation in all areas visited during spring was 123 m (n [observations]= 284, n [birds]= 1005, sd=110 m, range 0-1300 m). The lower flight altitude during spring is probably due to the presence of more resident or local breeding birds searching for food and being attracted to the solid waste dump and other attractions in the area.

Table 13. Altitudinal distribution of birds observed at the meteorological mast during spring.

Altitude	Number of observations	%	Number of birds	%
On ground	1	0.47	2	0.57
1-100	100	47.17	154	44.13
100-200	98	46.23	167	47.85
200-300	12	5.66	25	7.16
300-1000	0	0.00	0	0.00
>1000	1	0.47	1	0.29
Total	212	100	349	100

5.3. Weather conditions during study period and possible relationship with bird migration

During the autumn study weather conditions were similar to that recorded at the site in the year 2006 (Lahmeyer International 2007), with high temperatures reaching in the low 30ºC. Wind direction did not change much from its southerly direction, but its intensity altered during the day and between days. Wind speeds were moderately strong early in the day, gradually gaining velocity during the day and reaching their peak speeds in the after noon. Also wind velocity was exceptionally high during the first two days of observations on 23 and 24 October 2009, probably reaching over 10 m/s.

It was noted that there was a general correlation between wind velocity and the numbers of birds moving over the site, with larger numbers of birds observed during days with very windy days, and smaller numbers noted during days with milder conditions. This is likely because more birds fail to make the Bab Al Mandab crossing during days with sever southerly head winds that prevent birds from crossing over the sea, and thus get blown back north towards Al Mukha and beyond.

Wind data for the spring season (the 2006 spring season data; Lahmeyer International 2007) indicate a greater variability in wind direction and velocity than in the autumn. Our field observations during the spring of 2010, more or less confirmed this, showing that 54% of the time wind was classified as "Low" velocity, while 31% of the time it was "Moderate", with only 9% being "Strong" or 6% being "Very Strong". Wind direction was also quite variable, with only 40% coming from the south, 20% came from a south westerly direction, 17% directly from the west, and 15% from the south east, while 9% came from a north to north westerly direction. This is in strong contrast with the autumn season when the wind had a stable and constant southerly direction.

However, this variable nature of the weather in spring did not appear to have much influence on the number of birds passing over the project site, nor did it seem to have much effect on the volume of bird migration across the Straits of Bab Al Mandab (although this would require further verification).

Unfortunately the meteorological station at the site was not broken during the period of ornithological observations in both spring and autumn study periods, and thus no correlation can be made with precise wind data; however notes were taken of wind intensity every hour, but obviously this is a rather subjective measure.

6. Risks and risk assessment[1]

As indicated in the introduction, there are three main risk areas associated with wind energy development that are recognized:

- Direct collision mortality;
- Disturbance leading to displacement, including barriers to movement;
- Loss of habitat to wind turbines and associated infrastructure**.**

These are dealt with below, however this risk assessment deals mainly with the potential risk for birds from collision with wind turbines and associated structures (pylons etc.), which is deemed to be the most significant risk for this wind farm development with its current dimensions and properties.

Two wind farm developments in Egypt; Zafarana (where ornithological investigations indicated a low risk to migrants clearly, and where post construction monitoring confirmed low mortality of birds), and Gebel El Zeit (where several ornithological studies have repeatedly excluded large parts of the site due to potential high risks to

[1] This risk assessment applies to current proposed wind farm spatial dimensions with the three different options proposed for the use of different sized wind turbines, and should not be extrapolated for further expansions or extensions of the wind farm area without further risk assessment.

migratory birds) are used below as examples for risk evaluation in a similar setting to that at Al Mukha, but with differing conclusions in each case.

6.1. Risk from collision with wind turbines

6.1.1. Factors that influence level of risk

A simple risk assessment equation would include two primary factors: Hazard (H) and exposure (E), so risk = H X E. Hazard is the probability that a bird would be damaged if it enters a wind farm. Hazard essentially relates to the nature of the turbines, visibility at the site, configuration of wind mills, etc. Elements considered in the hazard factor include the nature of the wind farm development, the size of wind farm and type of turbines, the nature of the locality, topography, climate and presence of threats and man made risks in and around the proposed project site. Better understanding of wind mill design and wind farm design that reduces bird mortality is leading to a reduction in bird mortality rates per turbine.

The exposure factor is more complicated and is related primarily to the positioning of the wind farm close to bird concentrations and degree of attractiveness of the wind farm site and its surroundings to birds. The exposure factor is obviously highest where birds migrate, breed, or feed in large numbers near wind farms. The type of birds moving through the wind farm area and if they are prone to low flight or flocking also affects the exposure factor. Elements considered in the exposure factor include the nature of the birds, their volume, altitude, behavior, and conservation status.

6.1.2. Bird specific factors

Regularity, volume and density of migration

The presence of a predictable and high volume of birds, which are densely concentrated at the site of a wind farm, would obviously directly increase the risks of conflict greatly.

The preliminary results of this study suggests that there is a regular and predictable passage of soaring birds over the proposed project site during the autumn season, and that the passage is not incidental or related to aberrant weather conditions. In other words it can be predicted that soaring bird migration occurs at the site annually during autumn as a natural phenomenon. In autumn, soaring birds were observed at the proposed project site on *all* days of the autumn study in a fairly steady flow (except for increased volume during very windy days), with a total of 5544 birds observed during 63 hours of observations, represents a minimal average of 88 birds / hour or 440 birds / day (based on 5 hours of observation / day). In contrast in spring there was almost no passage, with only a total of 349 soaring birds documented over 165 hours of observation (less than that observed during a single day in the autumn season), representing an average of 2.1 birds per hour or about 11 birds per day (based on 5 hours of observation / day).

Although the robustness of the conclusions made as a result of a single relatively short study of bird migration (such as this current study) is likely to be rather weak, the observed broad patters of migration over the proposed project site during autumn (occurrence of a sustained migration from south to north) and spring (lack of migration) are certainly conclusive. In this sense one could conclude that soaring migrants occur only during 50% of the migration seasons.

At Gebel El Zeit in Egypt, Decon-Fichtner (2007) indicated that 40% of the (study) time there were no migrants at study sites, while the vast majority of soaring birds passed in just 15% of the observation time. Indicating a much more unpredictable and variable pattern of migration than at Al Mukha.

Table 14. Migration rates at two investigated sites in Egypt and Al Mukha. Based on results from this study, Baha El Din and Baha El Din (1995) and Decon-Fichtner (2007).

Location	Season	Birds counted	Hours of observation	Rate birds/hour
Zafarana	Spring	236	50	4.7
	Autumn	9	40	0.2
	Spring & autumn combined	245	90	**2.7**
Gebel Zeit	Spring	159276	604	263.7
	Autumn	71256	459	155.2
	Spring & autumn combined	230532	1063	**216.9**
Al Mukha	Spring	349	165	2.1
	Autumn	5544	63	88.0
	Spring & autumn combined	5893	228	**25.8**

The combined migration rate for both autumn and spring at the proposed project site contrasts strongly when compared with migration study results at both Zafarana and Gebel El Zeit in Egypt. While the soaring bird migration rate seems greater at Al Mukha than at Zafarana (25.8 birds/hour vs 2.7 birds/hour respectively); it is certainly much smaller than at Gebel El Zeit (216.9 birds/hour). Zafarana has had wind farm developments for some 10 years now with little evidence of adverse impacts on soaring birds (Bergen 2007), while much of Gebel El Zeit has been excluded from wind energy development.

Density of passage (for example very dense flocks) is likely to be positively correlated with increased risk levels. At the proposed project site there was a constant flow of birds during the study period, which was both spatially and temporally fairly evenly distributed, with no obvious tendency for clustering or achieving great density.

In comparison the migration pattern at Gebel El Zeit area (which is much larger in area than Al Mukha site) is highly stochastic temporally and irregular spatially. So birds were not always detectable in all parts of the site, while in some locations (in the southern part of the site) larger numbers were seen; the majority of these were contributed by a few but very large flocks of mainly white storks and honey buzzards (Decon-Fichtner 2007). At the Al Mukha site and Bab Al Mandab there are very limited numbers of the species that tend to form huge compact flocks like storks and cranes or honey buzzards.

Speed of migration (risk exposure potential)

In spring most of the time birds moved very rapidly over the site, which means that the exposure to risk per bird is very small, but it also means that a large volume is exposed to this risk factor. In spring the few birds flying over the site tended to have less urgency and were often actively searching for food. The impact on local resident species is likely to be high initially, until vulnerable populations are reduced and / or are acquainted with the wind turbines. With the exception of the Egyptian Vulture, non of the currently known resident species in the area are of particular conservation concern or are especially vulnerable to wind energy development and are most likely either avoid the wind farm area due to disturbance or continue utilizing the habitats below the turbines.

Altitude of flight

Flight elevation is one of the most important factor positively correlated with increased risk level to migrant birds. (Decon-Fichtner 2007) considered 200 m as a precautionary safe upper altitude for birds migrating through wind farms with wind mills reaching up to 100 m with their rotors. In our case the tallest of the three wind turbine options considered for this project (Gamesa G90 2 MW) reaches up to 120 m from the ground, thus we similarly adopt the 200 m as a safe lower altitude.

Our results indicate that about 36% of birds recorded (in both seasons) in the general proposed project site were documented below 200 m (2019 birds), while 15% were documented below 100 m (906 birds). This is significantly less than the rate documented at Gebel El Zeit where in autumn 2006 where 41% of birds were documented below 200 m (16,311 birds) whiles 28% (11,000 birds) were documented below 100 m (Decon-Fichtner 2007).

These figures do not mean that all birds flying within rotor range will be struck or damaged, as there are many other factors that influence any potential casualty rates, one of which is that many species will completely avoid the wind turbines (see barrier effect). One species that tends to do this id Buzzard (which is the most numerous species at the Al Mukha site) (Langston and Pullan 2004).

Roosting, staging and feeding

The basic strategy for all migrants traversing the Middle East is to pass through as fast as possible, with as few stops as possible. This also applies to soaring birds. Roosting and landing of birds in the vicinity of wind farms is obviously of great concern since it can bring them within the strike zone. Most soaring birds under normal circumstances need to roost during the night when there are no thermals (one exception is Common Crane, which is known as well to fly at night in significant numbers).

For the most part birds land opportunistically wherever they find themselves at the end of the day. Birds of prey will prefer to roost in inaccessible locations, such on mountains, trees, or also on man mad structures like pylons.

Unlike the situation at Bab El Mandab and Dubab, there was limited evidence of landing (roosting and resting) at the proposed wind farm location it self. However many birds were attracted to the nearby municipal solid waste dump. Locals also were not aware of any major roosting activity in the area, except at Al Mukha dump site and at newly reclaimed areas where locals confirmed that soaring birds were attracted to their cultivations.

Condition of Birds

Birds that are exhausted, thirsty or injured tend to land more than healthy birds to rest, seek shelter and replenishment. The amount of time spent resting is usually brief in healthy birds, at the most overnight. Stressed birds will remain on the ground for longer and tend to get attracted to anomalies on the desert surface, hence becoming more at risk of conflict with wind turbines. Increased persecution and disturbance in the region adjacent to the wind farm (as is the case with falcon catching) would increase levels of distress and reduces speed of migration through the site.

During the current study there were no indications of adversely affected migrants within the project site, and with the exception of falcon catching there were no obvious persecution or disturbance to birds.

Potential risk to threatened bird species

Threatened species and species of special conservation concern and those with small populations should be of primary concern in any risk assessment at the site, as even very small losses for these species could be significant. See Table 1 for a list of species of special conservational concern (according to the IUCN 2009 Red List) occurring or likely to occur at the proposed project site. Five globally threatened species of birds have been documented in the project site or its immidiate vicinity as follows Egyptian Vulture (Endangered), Pallid Harrier (Near-threatened), Greater Spotted Eagle (Vulnerable), Sooty Falcon (Near-threatened) and White-eyed Gull (Near-threatened).

The volume of threatened species documented at the project site in both spring and autumn are limited, with the exception of the Egyptian Vultures (Endangered), which occurred in constant and locally significant numbers, which raises some concern. These birds almost certainly represent local breeding or wintering populations that roam around this part of the Tihama, and are attracted to the site because of the solid waste dump (which contained several dead animals during the PI visit). Dead live stock from the quarantine (which holds mostly cattle imported from Somalia) are dumped at several localities at the southern edge of the project site, also acting as an attraction focal point for these birds.

More over Egyptian Vultures are by nature highly passive flyers which are likely to have minimal avoidance behavior in the face of wind turbines (Baha El Din and Baha El Din 2009), leading to a high collision risk for this species, as is the case for other vultures, such as Griffon Vultures which have very high fatalities in Spanish wind farms due to the same reasons. Thus, there is potentially a high risk for this globally threatened species from wind farm development at Al Mukha.

Decon-Fichtner (2007) predicted that Pallid Harriers (Near Threatened) and Lesser Kestrel (Vulnerable) are unlikely to be negatively affected by a wind farm development, because the former flies quite low, and would pass below the active rotors of wind turbines (a prediction which could be faulty in our opinion) and the latter because it is a very active flyer. They both also migrate over a large front and thus are not concentrated within the area. Nevertheless, Decon-Fichtner (2007) indicate a possible absence of avoidance behavior in Lesser Kestrels as that observed in Common Kestrel, which might increase the risk of collision. Collision risks for Greater Spotted Eagle (Vulnerable) and Eastern Imperial Eagle (Vulnerable) are likely to be modest, since their numbers are small in the area and they tend to migrate at higher altitudes above 200 m, although both are very passive flyers that could be sluggish in their response to wind turbines.

To assess the significance of collision risk at species level the population size of a species has to be considered. For large populations a low incremental mortality might be compensated and absorbed if these losses are not sustained over a long period or indefinitely, whereas even low numbers of fatalities can cause a population decrease in small populations. Given the small size of their global populations both the Egyptian Vulture and (to a lesser degree) Greater Spotted Eagle can be considered the most vulnerable species passing through the Al Mukha site. But since it is difficult to estimate the potential number of fatalities at a proposed wind farm, it is not possible to determine the exact weight of collision risk.

Behavioral traits and species specific avoidance capacity

Some species are more prone to collision because of inherent behavioral traits. Some species naturally fly low (such as harriers), others congregate in huge flocks, while some are more able to maneuver and avoid moving wind turbines, some don’t seem to be disturbed by wind turbines and are thus more at risk. This means that some species are inherently more at risk than others, regardless of other external factors.

Steppe Buzzards, for instance, seem to regard wind farms as barriers. In comparison to Black Kites, Steppe Buzzards appear to be more sensitive to the presence of wind turbines. As a consequence, Black Kites might be more vulnerable to collision with wind turbines than Steppe Buzzard (Bergen 2007).

Decon-Fichtner (2007) regarded collision risk to be low for harriers because they usually migrate near the ground, at altitudes below rotor height. Indeed in the United States and Germany only very few harrier fatalities were recorded (Decon-Fichtner 2007, Sterner et al. 2007). Additionally harriers tend to migrate in a broad front and do not concentrate at specific bottlenecks, thus any mortality caused by wind turbines are highly unlikely to have significant population effects.

Large and very passive fliers like eagles and vultures, which lack good maneuverability, are more vulnerable to collision with wind turbines. However, the documented average migration altitude in the proposed project site area of over 200 m puts most of these birds out of rotor range. Although as indicated above Egyptian Vultures (a species of conservation concern) could be at a higher risk than all other species due to its behavioral traits, relatively large numbers at the site and conservation status. Also the fact that some of the observed birds could be of local origin means that they would have longer exposure to the wind turbine risk.

6.1.3. Project development factors: Size, density, number and alignment of wind turbines

The design of the wind farm plays an important role in increasing or reducing the risks of collisions. As we do not have any confirmed detail of the wind farm infrastructure, only general guidance can be given here.

Size and density of wind turbines

Large and high wind turbines reach greater altitude and occupy a large air space and thus, in theory would increase the chance for bird-wind turbine collisions. However, the slower rate of rotation (rpm), smaller number of turbines, and greater visibility of the rotors is likely to make them less confusing to approaching birds; also the smaller density of turbines gives better spacing for birds to pass unscathed. Indeed, there is a general agreement in the literature that smaller, faster, turbines placed in greater density are more risky for birds, and that the use of larger turbines reduces bird casualties.

Table 15. Comparison of the spatial impacts of the largest and smallest wind turbine options identified for the project site (NIPSA and Mercados 2009). Specifications for the wind turbines are from the manufacturer catalogues of the named models, available at http://www.gamesacorp.com.

Wind turbine model	Number of turbines	Area swept by rotor per turbine m^2	Total area swept m^2	Diameter of rotor *m*	Total horizontal extent of wind mills *m*
Gamesa G90 2 MW	30	6362	190860	90	2700
Gamesa G58 850 KW	70	2642	184940	58	4060

The total area of impact is also reduced when using larger turbines, thus statistically speaking reducing the likelihood of bird collisions with the turbines. In our case, NIPSA and Mercados (2009) proposed on the large end of the spectrum the use of 30 larger wind turbines (Gamesa G90 2 MW), and on the other 70 small turbines (Gamesa G58 850 KW) to produce roughly similar energy outputs. When examining these two options (see Table 13), one can see that while the larger turbines sweep only a marginally larger air space than the smaller turbines (3% more). On the other hand when assessing the horizontal length occupied by the large turbines we find that they occupy 33% less distance than the smaller turbines do. It is desirable to reduce the spatial occupancy of the wind turbines, particularly in the horizontal aspect.

In this respect it is highly recommended to adopt the first option proposed by NIPSA and Mercados (2009) which entails the use of larger and fewer wind turbines (Gamesa G90 2 MW), rather than the other two options proposed, which would use smaller and more numerous and densely packed turbines, a setup that carries increased risk for birds.

Configuration of wind turbines

The configuration of the wind turbines in relation to the direction of migration does not appear to be significant. However, the availability of gaps or corridors is generally regarded as a good measure to reduce the potential barrier effect of wind farms. Smallwood and Thelander (2004) found that wind turbines were most dangerous at the ends of turbines strings, at the edges of gaps in strings, and at the edges of clusters of wind turbines. Furthermore, the most isolated wind turbines killed disproportionately more birds.

Size of wind farm

The overall size of the wind farm plays an obvious factor in calculating risk to birds. Simply put: the larger the wind farm (and the more the wind mills by implication) the greater the probability of risk. The relatively small size of the current development occupying some 42 km², with between 30 large – 70 small wind turbines, carries a correspondingly modest risk to birds (purely based on the scale of the development); this is given the fact that there are no evidence of any exceedingly high concentrations of birds occurring within that area.

Any increase in the size of the project site will naturally increase risks to birds by an order of magnitude equal to the intended increase in size. The size change and might also shift the wind mills into areas where birds could be more at risk.

It is thus very important to take note that the assessment of risk made herein *only* relates to the specific site, scale and size of the proposed wind farm development and is not a blanket assessment that is applicable to more extensive wind energy development throughout the region. Any further modifications in the size, extent and location of the wind farm would require further evaluation.

Wind farm associated infrastructure

Power lines create two types of problems to birds; birds can collide with the cables or get electrocuted when landing on the towers. The existing network of pylons linking the power stations at Hodiedah, Mukha and Aden along the Yemeni coast have been already cited as a potential risk factor for migratory soaring birds (BirdLife International / UNDP 2005).

6.1.4. Site specific factors

Location

The location of the proposed project site next to a major migration corridor make the area potentially vulnerable to bird / wind turbine strikes, hence this study was conducted. Our results indicate that the site is not on the main migratory rout; however there is a regular movement of migrant soaring birds on a relatively broad front over the site during the autumn. In spring the site is of no particular significance for migration and only the normal broad front “background” migration occurs and no significant numbers are found.

Proximity to the sea shore

The proximity of the site to the sea shore increases risks for migrant and resident waterbirds, which usually follow the coastline. In the mean time as indicated above the altitude of migrant soaring birds is lower near the coast and increases rapidly inland. Thus, there is a preference for having the site of any potential wind farm in the region as far inland as possible.

The current proposed locality is far enough from the coast to avert any significant coastal influences on the site.

The topography of the site

It is generally thought that there are more risks associated with migration over complex topography, as this creates turbulence that could complicate flight behavior of birds and their ability to respond to the presence of wind turbines in their flight path. Thus, flat open areas are regarded as carrying less risk in this respect. Exo et al. (2005) indicated that migration generally occurs above 100 m, if wind turbines are erected in lowlands. In contrast, about 50 % of all migrating birds used altitudes below 100 m at a site near Tangier (Morocco) which is located on a ridge (Exo et al. 2005).

The Al Mukha site is generally characterized by wide open and flat desert plains, which in terms of topography carries low risk for migrating birds.

Presence and proximity to features that can attract migrant birds to land

Any factors that attract birds to land or utilize the wind farm site or its immediate vicinity would lead to a direct and dramatic increase in risk. Any anomaly can be a potential attraction. Attractions to migrants include water (fresh and saline), green areas, gardens, buildings, garbage dumps, sewage lagoons, water leaks, even things looking like water such as petroleum oil leaks all attract tired, thirsty migrants. Towers, pylons, and even wind turbine towers can attract birds attempting to roost, especially birds of prey.

Currently the proposed project site is generally not particularly attractive to migratory birds. Overall, birds landing there would do so in a more or less purely random manner. However, as mentioned earlier there are some recently cultivated areas inside and around the site and a municipal waste dump in close proximity, all of which for critical hazard for birds. Even grazing animals can be a dangerous source of attraction. The basic and simple strategy is to keep the site as unattractive as possible to migratory birds and depriving them from any incentive to land or approach the wind farm site for any reason.

Following are some of the risk factors that were identified during our field work at the project site.

Al Mukha solid waste dump

Solid waste dumps especially those with municipal and organic content are known to be a strong attractant to wild life, particularly bird. Elsewhere in the Middle East soaring migrants are constantly attracted to these dumps (e.g. in Sharm El Sheikh and Hurghada in Egypt). The main dump for Al Mukha is located at 13°19'59"N 43°15'52"E on the southern edge of the proposed wind farm site. Some congregation of birds were observed at the site during our study period: 13 Egyptian Vultures and 5 Black Kites were seen at the dump on 8 November 2009, while House Crows and Cattle Egrets visited the site frequently. The presence of the dump in close proximity to a wind farm would be highly risky and must be relocated at a safe distance, before any wind farm development takes place.

Figure 32. Al Mukha municipal waste dump located at the southern edge of the proposed wind farm site.

Cattle carcass dumping

Dead cattle from the Al Mukha quarantine (mostly cattle from Somalia) are often dumped in a locality just north of the road to Taizz (to the south of the proposed wind farm locality). This however does not appear to be a regular dumping site, and several other localities are used on an ad hoc basis. No fresh animals were found during our study period, but older remains were found and several scavenging birds were observed in the vicinity. It is not known if this was the only dumping site for the carcasses from the quarantine and how regularly it was used.

Carcasses attract vultures and other birds of prey rapidly and can remain a strong point of attraction for many days or even weeks, until it is cleaned up.

Cultivation and irrigation

Cultivation and irrigation in arid environments create foci of attraction for migrant birds, which are gravitated to the unusual presence of water, food and potential prey. This is a known phenomenon in other parts of the Middle East, where many migrants also suffer from the over use of pesticides in these newly reclaimed lands. Near the vicinity of the proposed project site there is a rapidly growing area of recently reclaimed lands, with flooded fields and green fields, which according to local farmers, already attract many birds migrants and otherwise. The presence of such cultivations within and near a potential wind farm in this region would be highly risky. However there is no evidence of any cultivation within the project site or within 3 km of its outer boundary.

Figure 33. Cultivated field of onions near the buffer zones boundaries of the proposed project site.

Figure 34. Recently reclaimed land irrigated for the first time near the buffer zones boundaries of the proposed project site.

Power lines

Power lines are one of the main threats to soaring migrants at large. The risk associated with power lines depends to a great extent on the local context where they are found; for example if the visibility in the area they are erected is poor or if they are located across main migratory routs, and in some cases the design of the pylons can lead to increased risk from electrocution.

Al Al Mukha the main power lines leading out of the power station do not seem to pose a particularly high risk to migrant soaring birds. Although on one occasion a Griffon Vulture was observed striking these power lines after being disturbed from the ground, where it was feeding under the power lines. However, this represents a singular incident and there was no evidence that indicate a particular trend.

Figure 35. Griffon Vulture *Gyps fulvus* striking the overhanging electric wires of the main Al Mukha-Taaiz power lines after being disturbed from feeding on a carcass on the ground. This bird survived without apparent injury.

Grazing

The presence of domestic stock (sheep, goats, camels and cows) inside the wind farm area can form another risk factor to particularly birds of prey. As carcasses of dead animals would act as magnet for scavenging birds like vultures and most eagles. Several animal carcasses in the vicinity of Al Mukha were noted to attract many birds. Also the presence of domestic animals opens up the habitat and attracts other potential prey items for birds of prey.

Figure 36. Two Griffon Vultures *Gyps fulvus* feeding on a cow carcass between Al Mukha and Al Mafraq.

Falcon catching

Although not directly related to wind farm development, the presence of probably over 200 falcon catchers between Al Mukha and Bab Al Mandab poses a further pressure on the migrant soaring birds in the region

Figure 37. A falcon catcher from Hadramawt with a locally caught Hobby *Falco subbuteo* just north of Bab Al Mandab.

Risks from activities outside the proposed project area

Risks from activities outside the project site and thus beyond the control or influence of the project, could be as substantial as risks from activities within the site. The main risk here is that these activities might be currently unknown and unplanned and do not fall directly within the influence of the project management.

Potential risks outside the site include the potential future establishment of other wind farms, placement of bird attractions (as indicated previously), development and destruction of natural habitats in the general project vicinity, could reduce the general availability of alternative resting sites in the region and thus, increase the potential for birds entering the site. Similarly, increased disturbance causing undue stress to birds outside the site could lead to increased mortality within the site.

Figure 38. Newly cultivated Millet fields attract hundreds of seed eating birds and their predators to the region surrounding the proposed wind farm.

Wind direction and speed

Wind is one of the greatest factors influencing migrating birds. It affects the numbers, speed, direction and altitude. Strong winds make the birds move faster, but can also affect their altitude and ability to maneuver. The constant high wind speeds in the area during autumn at least may make it difficult for the birds to maneuver amongst wind turbines and could increase the potential risk of collisions.

The effect of wind direction on level of risk to birds is not clear. Strong tailwind (which increases a bird's rate of travel) was cited as one of the contributing factors leading birds to collide with wind turbines. While, strong head winds might force birds to land. Decon-Fichtner (2007) stated that collision rate will be higher when migrants face strong headwinds, affecting the birds' ability to control flight maneuvers. The available wind date for 2006 and observations in the field indicate a very constant southerly direction of wind at the site during autumn, which represents a tail wind for soaring migrants in this locality (prevailing migration orientation towards north, north east). This leads birds to move fast over the site, and in our opinion would reduce risks of collision, as birds tend to maintain their high elevation and tend not to want to land.

Increased risks of collision during low visibility

Poor visibility is widely cited as one of the contributing factors leading birds to collide with wind turbines. Low visibility affects birds in many ways causing them to fly at low altitudes, reducing ability to detect wind turbines, and in many cases birds might be forced to land.

Generally visibility was good, but during episodes of extremely windy conditions dust and haze reduced visibility considerably especially at lower elevations below 100 m. On one occasion (24 October 2009) blocking the sun, thus making any observations impossible (see Figures 25 and 26). No birds could be seen and it was not clear if the birds had stopped flying or were simply invisible. It is not clear from the supplied weather data for 2006 (Lahmeyer International 2007) if such dust storms or other climatic conditions that reduce visibility (like fog) are a common occurrence in either the spring or autumn seasons.

These types of conditions could pose an added risk factor to any low flying birds in the vicinity of a wind energy development in the area. The combination of extreme wind velocity and reduced visibility could be disorienting to birds and could reduce their ability to detect and maneuver around potential rotating wind mills.

Figure 39. Minaret in Al Mukha on 24 October during severe windy conditions associated with blowing dust and very reduced visibility (compare with Figure below).

Figure 40. Minaret shown in Figure above under normal wind conditions.

6.2. Risk of disturbance and the barrier effect

The risk from an extended wind farm development is the establishment of an overwhelming barrier to the normal migration pattern of birds in the region (see further under barrier effect). The risk is increased if wind farms are established without coordination or leaving corridors that might facilitate the movement of birds between the wind farms rather than around them. Obviously, there would be less risks of collisions if there was just one isolated wind farm. Birds would be more likely to see and avoid proximity of such an isolated disturbed area. However, if the entire landscape is saturated with wind turbines, risks will increase, not only in the total impact of the entire wind farm development, but probably also in terms of level of risk per wind turbine.

Given the relatively small size of the current wind farm proposal (42 km²) and its occurrence on an open unrestricted plain, there is little concern that the development would lead to any significant modification in migratory patterns of any birds. However, any future expansion of the wind farm would need more careful assessment for such a barrier effect.

6.3. Risk of habitat loss

There will certainly be some habitat loss due to the wind farm development, however the total size of the proposed project is quite small in relation to the area of habitat type concerned, which is well represented on the Tihama plain and does not appear under great immediate threat from other users (except perhaps the agricultural sector). More over the footprint of actual installations will only occupy a fraction of the total area, and habitat disturbed during construction should recover to some extent during the operational phase. Also the habitats at the proposed site are already disturbed and degraded to a variable extent (either by agricultural reclamation, vehicular use or encroachment by invasive plant species (*Prosopis juliflora*).

Thus, it is concluded that although their will be some habitat loss, this will not be significant at the current project design, also mitigation measures should be taken to reduce and minimize unnecessary habitat loss and disturbance during the construction phase.

6.4. The cumulative risk factor

When considering risks to birds from wind farms it is important not only to focus on the potential annual mortality rates (birds/turbine/year) or total number of fatalities per year in a wind farm. Attention should also be given to the long-term population-level effects of fatalities, which can affect the viability of entire regional or global bird populations and directly jeopardize their conservation status. Also, losses can be considered on an annual basis for small species which reproduce on an annual cycle; this should not be the case for long lived birds such as large soaring birds of prey and storks, which have population dynamics that entail breeding and recruitment cycles that take several years. For example, if the White Stork has a 5 year reproductive cycle, then any anticipated risks to the species should be seen and considered at this scale (i.e. the potential cumulative impact of 5 years should be considered).

Moreover, in the case of a long-term project such as a wind farm (which is there to stay for many years and is unlikely to be altered for a long time), it is critical to take into consideration the potential sustained and enduring negative impact on bird populations on a regional level when calculating the level of risk. Thus, potential risk must be calculated not as an annual or seasonal level but at a population level.

6.5. Synopsis of lessons learnt from risk assessments from Egypt

Given the general climatic similarity between Egypt and Yemen and their position along important soaring bird migration flyways it is perhaps of value to examine the Egyptian experience with dealing with bird/wind energy conflicts.

The first acknowledgement of the potential for bird and wind energy conflict in Egypt came when DANIDA was considering the financing of the establishment of the Zafarana Wind Farm on the Gulf of Suez, and hence commissioned a study of the potential impact of the now existing wind farm at Zafarana on birds prior to its construction (Baha El Din 1995, Beibach and Baha El Din 1995, Baha El Din and Baha El Din 1996) . These studies brought attention to the importance of the Red Sea coast for bird migration and the potential of collisions between wind farms and birds, but it showed that Zfarana was not located immediately on the main flyway for soaring bird migration, being positioned only 15 km to the east of the flyway. Virtually no birds were documented during autumn (in clear contrast with the situation at A l Mukha), and only a small number of birds were observed in spring when wind came from the south. The soaring birds consistently flew along this pathway falling along the Red Sea mountain spine, where the birds prefer to move between the highest points of the mountain chain and very seldom go on to the coastal plain when strong westerly wind conditions force them in that direction. The study concluded that birds maintained a consistent rout away from the wind farm location and that, despite the short distance; it was safe to construct the wind farm in its current position.

Bergen (2007) made a short study of a section of the now existing and operational Zafarana Wind Farm with 220 wind turbines (117 V 47 turbines and 103 N 43 turbines). This study confirmed the results of the studies conducted at Zafarana as part of the EIA process, which predicted the limited utility of the Zafarana locality to birds and hence, its low risk to migratory birds. Bergen (2007) did not observe any bird mortality during the study period which extended for just under a month between 22 March – 19 April, 2007; but he found remains of three birds apparently killed by the wind turbine rotors (a Grey Heron, White Stork and an eagle species). The majority of birds observed in the wind farm vicinity flew higher than the wind farm (above 100 m) and showed no alteration in flight behavior. The study also documented regular avoidance behavior by birds flying below 100 m and in range of the rotor blades, either gaining altitude above the wind farm, or maneuvering around the farm to avoid it altogether. Only a small minority flew below rotor blade height within the farm. The study showed there was little impact of wind farms on birds at the investigated locality, due primarily to the low number of birds and the ability of birds to see and avoid the wind farms.

The next area with promising wind energy potential was Gebel El Zeit at the southern entrance of the Gulf of Suez. However, several studies had predicted Gabel El Zeit as an area of potential conflict between wind energy development and birds, given the high wind energy the region's international importance for soaring bird migration.

To date, there have been three extensive field assessments conducted, extending almost three years to evaluate the potential conflicts between birds and wind park development in the Gebel El Zeit region. The most extensive of these studies (Decon-Fichtner 2007) was commissioned by the German Development Bank (KFW), which was interested in investing in the huge wind farm development in Gebel El Zeit, to assess bird wind farm interactions in the Gebel El Zeit concession area proposed for wind fenergy development. The results of this study indicated heavy migration of soaring birds in both autumn and spring, with a large percentage of birds observed flying at or below 200 m or even resting on the ground. The data gathered in the course of the one year study precluded any thought of a general construction recommendation. As an alternative to recommending a complete ban on construction, a plan was put forward whereby construction would be limited with constraints to the least critically sensitive areas in the north of the project area.

There are currently two separate studies being conducted to establish the feasibility of wind farm construction in the least bird sensitive sites of the project area, which represent about 25% of the original extent of the proposed project area.

7. Conclusions of risk assessment

It is almost certain that any wind energy development will cause some bird and other wildlife mortalities, but the important question will always be: What constitutes acceptable levels of losses?

Answering this question is extremely complicated at two levels; one in attempting to anticipate with some degree of confidence mortality and risk levels from a non-existing operation (wind turbines); and the other is what are acceptable levels of loss? This varies from species to species and from one population to another greatly. In some way any losses are not acceptable. Other factors like the cumulative impact of wind farms even complicate things further.

There are no global standards that govern and regulate what constitutes an unacceptable level of loss. What this and other similar pre-construction studies of birds primarily aim at is to exclude particular wind energy projects that would have clearly catastrophic impacts on birds, or that might have long-term cumulative negative impacts on bird populations, and to provide recommendations and mitigation measures to alleviate risks at wind farms that are deemed to have a “tolerable” level of risk (i.e. that the level of risk can be managed through prescribed mitigation measures).

It is thus concluded that the current proposed wind energy development at Al Mukha is unlikely to have impacts on birds of catastrophic nature, and that the **level of risk to migratory and local birds is within a “tolerable” or “acceptable” range**; i.e. that the level of damage that could affect birds is expected to be limited and would not have significant conservation consequences to their populations if prescribed precautionary measures are taken.

This assessment of risk is based and supported by the following findings:

- The volume of birds flying over the site is modest and does not represent the main migratory flyway of soaring birds in the region;
- The size of the proposed development is relatively small ;
- The window for soaring bird migration is confined to one season (autumn), with a limited time frame of about 3 months per year;
- The majority of birds fly higher than 200 m, with only an estimated 36% of birds flying below 200 m (for both spring and autumn);
- Migration is on a broad front, i.e. is not concentrated over the proposed project site;
- There are limited species that migrate in large dense flocks, which are particularly vulnerable to wind farms (such as storks);
- With the exception of the Egyptian Vulture, there is limited occurrence or likely risks to globally threatened bird species;
- There is limited landing and roosting in the area and no natural attractions for birds;
- The terrain is simple and flat;

- Wind direction and velocity is very constant during autumn (ensuring that limited variation to observed patterns are likely to occur), but is much more variable in spring, however not much birds are present then;
- Visibility is usually good.

The conclusion made here is based on a number of important assumptions:

- The size of proposed development remains limited in scale and not changed from current proposal (without further assessment);
- Existing man made risk factors (solid waste dumps and cultivations) will be relocated to a safe distance from the proposed wind farm;
- Mitigation measures are implemented.

8. Mitigation measures and recommendations

There is considerable literature available on mitigating the impacts of wind farms and power lines on birds. These mitigation measures can be generally categorized as either preventing or reducing impacts. As recommended by Decon–Fichtner (2007), mitigation measures to avoid impacts should be given priority over those that reduce or compensate for impacts.

Policies and guidelines for mitigating impacts on birds of wind farms and power lines have been produced by Avian Powerline Interaction Committee (2006), American Birding Conservancy (2004), Council of Europe (2004), USWFS (2003) and BirdLife International (2002) to name a number of notable examples.

8.1. Mitigation measures

8.1.1. Eliminate and prevent attractions to birds

A primary and critical mitigation strategy to reduce potential risks to birds is to make the site and its environs free of any points of attraction for birds. Every effort should be made not to create attractions for birds inside the perimeters of the wind farm and its surrounding environs. The following steps to remediate the existing situation are critical:

- Relocate all municipal and solid as well as liquid waste dumps and prevent the disposal of any animal carcasses (even small ones) in a buffer zone of at least 5 km around the outer perimeter of the site.

- Stop and remove cultivations within and near the project site, with a minimal distance of 3 km between cultivations and the nearest wind turbines. Currently there is no evidence for the existence of any cultivation within the project area or its proposed 3 km buffer zone, thus no farm removal is foreseen for the moment. However, this measure might be required if new farmland is created in the intervening period up to the establishment of the wind farm (land reclamation is rapidly transforming the landscape around the project site). The proposed monitoring plan as part of the ESIA suggested that the local authority with assistance form the PMU will work to prevent any land cultivation within the buffer zones of the wind farm.

8.1.2. Turbine design

To reduce potential bird wind turbine collisions, it is thought that fewer larger, slower wind turbines that are more widely spaced are preferable to greater numbers of smaller, faster, more densely packed wind turbines. It is strongly recommended to adopt the first option proposed by NIPSA and Mercados (2009) which entails the use of larger and fewer wind turbines (Gamesa G90 2 MW).

Lattice towers should be avoided as these afford perching and potential nesting opportunities to birds. It is preferred that the towers be smooth, tubular shells. External ladders and platforms on tubular towers should be avoided placing to minimize perching and nesting sites. No guy support wires should be used for the towers or other structures. Where guys must be used, they should be marked with the recommended bird deterrent devices (Manville 2005).

8.1.3. Wind Turbine Placement and Spacing

Turbine arrays should be configured to avoid potential avian mortality where feasible. The studies reviewed recommend that turbines be placed in a line formation parallel to the main flight direction to reduce bird strikes. The turbine arrays proposed by NIPSA and Mercados (2009) run east to west, perpendicular to the northerly bird migration orientation in autumn. However, we do not see this as a matter of concern as the size of the development is limited and spacing between turbines should be large (if the large Gamesa G90 2 MW are used).

Some studies recommend having corridors or ample space between individual turbines or rows or clusters of wind turbines to reduce collisions by providing room for birds to fly and maneuver between the wind turbines should they venture into the farm. USFWS

(2003) suggested that turbines should be grouped rather than spread widely. BirdLife International (2002) recommended a loose cluster to be the best arrangement. The American Birding Conservancy (2004) proposed wide corridors between clusters of turbines and breaking up lines of turbines. Decon-Fichtner (2008) recommended that the minimum distances between wind turbines to be not less than 3.5 x rotor-diameters. In our case if the large Gamesa G90 2 MW turbines are used (as we recommend) there should be more than 4 x rotor diameter (90 m) if three rows of turbines are regularly spaced across the available space as indicated in NIPSA and Mercados (2009), which gives a space of about 450 m between turbines. This space combined with the limited size of wind farm, should be sufficient to dilute any barrier effects and negate the need for any corridors or longitudinal arrangements of turbines.

8.1.4. Power lines

As indicated earlier, power lines are potentially more hazardous to birds than the wind turbines. This does not only applies to power lines erected inside the plant, but also those constructed to connect the grid. It is recommended that the EU Guidelines and standards on power lines bird safety be followed as detailed in "Protecting birds from power lines, Nature and Environment No. 140, Council of Europe Publishing"; "Draft Recommendation on Protection Birds from Power lines (Council of Europe 2004)" and "Suggested Practices for Avian Protection on Power lines, State of the Art in 2006*"* (Avian Power line Interaction Committee 2006).

Under ideal circumstances, it would be preferable that any new power lines be buried under ground rather than erected above ground as this is the best means to mitigate potential impacts with birds. The main deterrent is the greater cost associated with underground cables.

8.1.5. Buffer Zone

A 3 km buffer zone should be established around the wind farm. This zone would be established with the agreement of the relevant planning authorities and stakeholders. Development and land use plans in this buffer zone would be reviewed to ensure that any activities in these areas are compatible with wind energy development and do not pose a threat to migratory birds, by creating potential foci of attraction for birds

8.1.6. Lighting

The use of lights that could attract or disorient birds at night should be limited inside the wind farm area and its immediate surroundings. Lighting turbines should be avoided whenever possible. If lighting is essential, then avoid lighting all turbines. The minimum number of intermittent flashing white lights of lowest effective intensity should be used and should be flashed simultaneously on lighted structures (Decon - Fichtner 2008). Solid red or pulsating red incandescent lighting should be avoided (Manville 2005).

8.1.7. Post construction monitoring program

During the operational phase it is critical to establish a monitoring program to assess bird mortality at the wind farm, and provide recommendations for adaptive management and mitigation measures. Monitoring is a key mitigation measure that seeks to detect any bird mortality at the wind farm and understand their causes, and documenting bird flight behavior at and near the wind farm, with the aim of initiating appropriate mitigation measures wherever necessary.

Ideally, the post construction monitoring program should be conducted at a minimum for the first three years of operation. During the first year of operation monitoring should be conducted year round at regular intervals. It should include estimates of numbers and species of birds in the area, particularly low flying and globally threatened species, monitoring responses of birds to the wind turbines and searches for the remains of dead birds. Recommendations would be made as appropriate to reduce bird wind turbines conflicts. Monitoring in subsequent years depends on the level of risk detected.

8.1.8. Public awareness

It is important to engage with local inhabitants around the wind farm site to raise their awareness of conservation issue related to the wind farm, and ensure the proper disposal of any animal carcasses and other refuse that might attract soaring birds to the project site.

8.2. Other recommendations

8.2.1. Training and education

The wind farm workers should be educated to insure sustainable and long term “bird friendly” management and operation of the wind farm. They should be informed about the importance of the area for bird migration and the risks to birds posed by wind turbines. Bird related policies should be highlighted and stressed. Special education programs and materials could be produced.

The monitoring, training and awareness raising programs could involve or be conducted in cooperation with other relevant government agencies, universities and NGOs to help build capacity in these bodies.

8.2.2. Contingency planning

It is recommended that contingency measures are prepared which would specify procedures to take in the eventuality that large numbers or flocks of birds are spotted within the perimeters of the plant. If the potential risks from collisions are high then the wind turbines could be temporarily shut down. This could take the form of stopping all or some of the wind turbines for part of the day or during certain periods corresponding with the movements of birds through the area. It is unlikely; however, that such a measure would be adhered to and implemented in a sustainable manner.

8.2.3. Mitigation measures during construction phase

Measures should be taken during the construction phase to minimize project footprint and habitat disturbance and thus reduce the negative impacts on biodiversity at large.

8.2.4. Potential offset measures

Biodiversity offsets are a new approach promoted under the umbrella of the Business and Biodiversity Offset Program (BBOP), which has received much support from various major businesses throughout the world and from the Convention on Biodiversity (CBD). Biodiversity offsets essentially aim at a net zero loss of biodiversity from development projects, through offsetting the negative residual impacts of these projects.

If post construction monitoring indicates certain bird casualties which fall within the anticipated level (even after mitigation measures); these losses could be offset through positive interventions elsewhere along the fly way of the same birds. For example, by removing other known hazards along their flyway in Yemen (or elsewhere), e.g. reducing the risks of collision or electrocution from pylons elsewhere.

8.2.5. Potential collaboration with the GEF / Birdlife International Soaring Bird Project

The Global Environmental Fund (GEF) is financing a project entitled, “Mainstreaming conservation of migratory soaring birds into key productive sectors along the Rift Valley/Red Sea flyway”. This project is being implemented through the United National Development Program (UNDP) and involves eleven Middle Eastern and African countries. Yemen is one of the participating nations and is one of the countries which will implement a full range of project activities in a second phase of the project, due to be launched in the near future. The project aims to ensure that globally threatened and significant populations of soaring bird migrating along the Rift Valley/Red Sea flyway are effectively maintained through ensuring that conservation management objectives and actions for migratory soaring birds are effectively mainstreamed into key productive sectors such as energy, agriculture, waste management and tourism, thus making this a safer route for soaring birds. Wind energy production is one of the sectors targeted for mainstreaming. The wind energy sector in Yemen would be one of the most important candidates for mainstreaming in this field.

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11. Appendices

Appendix 1. List of reptiles and amphibians occurring in the vicinity of the proposed wind farm site.

Species	Species found during field visits	Species indicated for the region in the literature
Hemidactylus robustus	X	
Hemidactylus flaviviridis	X	
Pristurus crucifer	X	X
Pristurus falvipunctatus	X	X
Stenodactylus yemenensis	X	X
Ptyodactylus sp.	X	
Pseutotrapelus sinaitus	X	
Chamaeleo arabicus	X	X
Acanthodactylus boskianus	X	
Acanthodactylus felicis		X
Mesalina martini		X
Chalcides ocellata		X
Trachylepis brevicollis	X	
Scincus hemprechii	X	
Leptotyphlops nursii	X	X
Spalerosophis diadema		X
Psammophis schokari	X	X
Cerastes gasperettii	X	X
Lytorhynchus diadema	X	
Platyceps saharicus		X
Malpoln moilensis	X	X
Telescopus dhara	X	X
Echis pyramidum		X
Echis coloratus		X
Bufo tihamicus		X

Appendix 2. List of birds occurring in the vicinity of the proposed wind farm site.

English name	Scientific name	Birds recorded at the wind farm site during field visits	Birds recorded in the general Muka area during field visits	Breeding birds recorded for general Muka area (Jennings 2010).
Brown Booby	*Sula leucogaster*			X
Socotra Cormorant	*Phalacrocorax nigrogularis*			X
Pink-backed Pelican	*Pelicanus rufescens*			X
Greater Flamingo	*Phoenicopterus roseus*		X	
Spoonbill	*Platalea leucorodia*			X
Black Stork	*Ciconia nigra*	X	X	
White Stork	*Ciconia ciconia*	X	X	
Striated Heron	*Butorides striata*			X
Grey Heron	*Ardea cinerea*	X	X	
Cattle Egret	*Bubulcus ibis*	X	X	X
Western Reef Heron	*Egretta gularis*		X	X
Little Egret	*Egretta garzetta*		X	
Glossy Ibis	*Plegadis falcinellus*		X	
Black Kite	*Milvus migrans*	X	X	X
Egyptian Vulture	*Neophron percnopterus*	X	X	
Griffon Vulture	*Gyps fulvus*		X	
Long-legged Buzzard	*Buteo rufinus*	X	X	
Steppe Buzzard	*Buteo buteo*	X	X	
Steppe Eagle	*Aquila nipalensis*	X	X	
Booted Eagle	*Aquila pennata*	X	X	
Bonelli's Eagle	*Aquila fasciata*		X	
Imperial Eagle	*Aquila heliaca*	X	X	
Tawny Eagle	*Aquila rapax*	X	X	
Short-toed Eagle	*Circaetus gallicus*	X	X	
Marsh Harrier	*Circus aeuginosus*	X	X	
Montaque's Harrier	*Circus pygargus*	X	X	
Pallied Harrier	*Circus macrourus*	X	X	
Sparrowhawk	*Accipiter nisus*	X	X	
Dark Chanting Goshawk	*Melierax metabates*	X	X	X
Osprey	*Pandion haliaetus*		X	X
Hooby	*Falco subbeto*	X	X	
Kestrel	*Falco tinnunculus*	X	X	
Sooty Falcon	*Falco concolor*		X	X
African Eagle Owl	*Bubo africanus*	X	X	
Helmeted Guineafoul	*Numida meleagris*			X
Arabian Bustard	*Ardeotis arabs*			X

Crab Plover	*Dromas ardeola*		X	X
Cream-colored Courser	*Cursorius cursor*	X	X	
Kentish Plover	*Charadrius alexanderinus*		X	X
Greater Sand Plover	*Charadrius leschenaultii*		X	
Pacific Golden Plover	*Pluvialis fulva*		X	
Curlew	*Numenius arquata*		X	X
Wood Sandpiper	*Tringa glareola*	X		
Common Redshank	*Tringa totanus*		X	
Curlew Sandpiper	*Calidris ferruginea*	X		
Little Stint	*Calidris minuta*	X		
Common Sandpiper	*Actitis hypoleucos*	X		
Bar-tailed Godwit	*Limosa lapponica*		X	
Terek Sandpiper	*Xenus cinereus*		X	
Ruff	*Philomachus pugnax*		X	
Sooty Gull	*Larus hemprichii*			X
White-eyed Gull	*Larus leucophthalmus*		X	X
Caspian Gull	*Larus cachinnans*		X	X
Lesser Black-backed Gull	*Larus fuscus*		X	X
Swift Tern	*Thalasseus bergii*			X
Lesser Crested Tern	*Thalasseus bengalensis*		X	X
Caspian Tern	*Hydroprogne caspia*			X
White-cheeked Tern	*Sterna repressa*			X
Bridled Tern	*Onychoprion anaethetus*			X
Sooty Tern	*Onychoprion fuscatus*			X
Saunders's Tern	*Sternula saundersi*			X
Lichtenstein's Sandgrouse	*Pterocles lichtensteinii*	X	X	X
Chestnut-bellied Sandgrouse	*Pterocles exustus*	X	X	X
Rock Dove	*Columba livia*			X
Laughing Dove	*Stigmatopelia senegalensis*	X	X	X
African Collard Dove	*Streptopelia roseogrisea*	X	X	X
Namaqua Dove	*Oena capensis*	X	X	X
Plain Nightjar	*Caprimulgus inornatus*	X	X	
Nubian Nightjar	*Caprimulgus nubicus*			X
African Palm Swift	*Cypsiurus parvus*	X	X	X
Grey-headed Kingfisher	*Halcyon leucocephala*			X
Green Bee-eater	*Merops orientalis*	X	X	X
European Bee-eater	*Merops apiaster*	X	X	
White-throated Bea-eater	*Merops albicollis*	X	X	
European Roller	*Coracias garrulus*	X	X	
Abyssinian Roller	*Coracias abyssinica*			X
Black-crowned Finch-Lark	*Eremopterix nigriceps*	X	X	X
Singing Bush Lark	*Mirafra cantillans*			X
Crested Lark	*Galerida cristata*	X	X	X
Short-toed Lark	*Calandrella brachydactyla*	X	X	
Duun's Lark	*Eremalauda dunni*			X

Greater Hoopoe-Lark	*Alaemon alaudipes*		X	
White Wagtail	*Motacilla alba*	X	X	
Yellow Wagtail	*Motacilla flava*	X	X	
Tawny Pipit	*Anthus campestris*	X	X	
Eurasian Crag Martin	*Ptyonoprogne rupestris*	X	X	
Swallow	*Hirundo rustica*	X	X	
Red-rumped Swallow	*Cecropis daurica*	X	X	
Black Scrub Robin	*Cercotrichas podobe*	X	X	X
Blackstart	*Cercomela melanura*		X	
Isabelline Wheatear	*Oenanthe isabellina*	X	X	
Pied Wheatear	*Oenanthe pleschanka*	X	X	
Yellow-vented BulBul	*Pycnonotus xanthopygos*	X	X	X
Graceful Prinia	*Prinia gracilis*	X	X	X
Clamorous Reed Warbler	*Acrocephalus stentoreus*			X
Garden Warbler	*Sylvia borin*	X	X	
African Paradise Flycatcher	*Terpsiphone viridis*			X
Spotted Flychatcher	*Muscicapa striata*		X	
Arabian Babbler	*Turdoides squamiceps*	X	X	X
Nile Valley Sunbird	*Anthodiaeta metallica*	X	X	X
Shining Sunbird	*Cinnyris habessinicus*			X
Red-billed Oxpecker	*Buphagus erythrorhynchus*			X
Southern Grey Shrike	*Lanius meridionalis*	X	X	X
Rufous Shrike	*Lanius phoenicuroides*	X	X	
Black-crowned Tchagra	*Tchagra senegala*			X
Indian House Crow	*Corvus splendens*	X	X	X
Brown-necked Raven	*Corvus ruficollis*	X	X	X
Fan-tailed Raven	*Corvus rhipidurus*			X
Arabian Golden Sparrow	*Passer euchlorus*	X	X	X
House Sparrow	*Passer domesticus*	X	X	X
Rüppell's Weaver	*Ploceus galbula*	X	X	X
African Silverbill	*Euodice cantans*	X	X	X
Arabian Waxbill	*Estrilda rufibarba*			X