Prepared by:

Guidance on avian post construction monitoring techniques for wind and solar energy facilities with specific reference to Migrating Soaring Birds (MSB) in the Rift Valley/Red Sea Flyway

Appendix II – Literature review

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GLOSSARY

ADAPTIVE MANAGEMENT	Adaptive management can be defined as a set of actions that use scientific data generated from monitoring programmes and research results to improve management (Strickland *et al.* 2011; USFWS 2012). Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity, emphasizing the learning process to achieve environmental benefits (USFWS 2012).
AVOIDANCE (behaviour)	Action by which birds make evasive movements to prevent collision with structures (Cook *et al.* 2011). This behaviour implies that birds see a dangerous situation (*e.g*. moving turbine blade), evaluate the existence of a possible risk and fly around, over or between the obstacles.
AVOIDANCE MEASURES (mitigation)	Mitigation measures implemented proactively to avoid impacts before the construction of the proposed development, such as careful spatial or temporal placement of infrastructure (BBOP 2014).
Before-After Control Impact (BACI) study	BACI studies use data collected before the occurrence of an impact (presence of a wind/solar facility) to compare with data gathered after or during the occurrence of the impact. To allow for distinction of observed changes in the communities it is necessary to also monitor at least one reference (or control) site. Monitoring of the development and reference sites should take place concurrently (Anderson *et al.* 1999; Langston & Pullan 2003; Strickland *et al.* 2011).
BARRIER EFFECT	Barrier effect may be considered as another form of displacement by which birds alter their migration flyways or local flight paths to avoid infrastructure. The effect depends on a range of factors: species and type of bird movement, the characteristics of the wind facility, time of day and visibility, wind force and direction, topography (Gove *et al.* 2013).
BOTTLENECK SITES	Locations within migratory routes where a land-bridge is present over a large mass of water. Migratory Soaring Birds prefer to use land-bridges and avoid sea-crossings, since over water thermals (rising hot air) do not have enough uplift (Kirby *et al.* 2008).
COMPENSATION MEASURES	Compensation measures can be defined as measures taken to replace ecological functions or qualities that are impaired by the project presence. These measures generally aim to improve damaged areas or to create new habitat. Unlike mitigation measures, ecological compensation is generally undertaken outside the disturbed area. Offset can be defined as a form of compensation which is measurable and aims to achieve a minimum of “no

	net loss” (BBOP 2014). These measures are only an option when impacts would not be avoided, minimized and/or rehabilitated or restored, and so comparable environments (to the impacted ones) are improved (Hayes & Morrison-Saunders 2007).
DISTURBANCE and/or DISPLACEMENT	Displacement is considered as the absence from or reduced use of otherwise suitable habitat previously occupied by a particular species, due to changes directly or indirectly brought due to the development of a project (Strickland *et al.* 2011; Gove *et al.* 2013). Effects may be total (exclusion) if birds avoid the area altogether; partial (exclusion) if occur in small numbers; or remain in the area but suffer disturbance (*e.g*. reduced fitness, lower productivity or increase predation) (Gove *et al.* 2013).
ENVIRONMENTAL IMPACT ASSESSMENT (EIA)	The Environmental Impact assessment process aims to anticipate the effects on the environment caused by a proposed project, taking into account several factors, both beneficial and adverse. If the likely effects are unacceptable, design measures (including no-go/sensitive areas) or other relevant mitigation measures can be taken to reduce or avoid them (EPA 2014). Although legislation and practice vary around the world, the fundamental components of an EIA involve the following stages: Screening to determine which projects or developments require a full or partial impact assessment study; Scoping to identify which potential impacts are relevant to assess; Assessment and evaluation of impacts and development of alternatives; Reporting the Environmental Impact Statement (EIS); Review of the Environmental Impact Statement (EIS); Decision-making on whether to approve the project or not, and under what conditions; and Monitoring, compliance, enforcement and environmental auditing (CBD Secretariat 2014).
FLYWAY	A flyway is a geographical region within which a migratory bird species (or groups of related species or distinct populations of a single species) moves through their annual cycle (Kirby *et al.* 2008). This includes the areas where the birds breed, the areas of the main non-breeding or contra nuptial range, migration stopover areas - areas where birds that have not yet reached breeding maturity may spend the breeding season -, moulting areas, post-breeding expansion areas (Boere & Stroud, 2006 *In* Boere & Dodman, 2010).
HABITAT LOSS and/or DEGRADATION	Results from the loss of, or damage to valuable habitat for birds due to the development of infrastructures (Gove *et al.* 2013). This impact is not generally perceived to be a major concern for wind energy projects for birds outside designated or qualifying sites of national and international

	importance for biodiversity (Gove *et al.* 2013). Regarding solar energy projects this impact has raised some concerns (Hernandez *et al.* 2014).
HABITAT FRAGMENTATION	Fragmentation of habitat is defined as the changes in habitat configuration that result from the breaking apart of habitat, independent of habitat loss (Fahrig 2003). This impact may modify ecological patterns, thereby increasing the influence of edge effects, increasing the collision risk for species inhabiting the forest canopy, higher levels of disturbance (Gove *et al.* 2013). The extent of edge effects will vary according to the species, potentially resulting in a greater susceptibility to colonization by invasive species, increased risk of predation, and competing species favouring landscapes with a mosaic of vegetation (Joanes 2012).
MIGRATORY SOARING BIRD (MSB)	Birds that, during their lifecycles, perform regular movements between separate areas, usually linked to seasonal changes (Boere & Dodman 2010). Migrations are performed by several groups of birds, including birds that use soaring techniques, such as broad-winged raptors, storks, pelicans and cranes. Soaring birds use local hot air thermals formed over land to provide uplift, gaining height by circling upwards in these rising warm air columns. At the top of a thermal the soaring birds glide slowly down until they reach the next thermal where they rise again (Porter 2005).
MINIMIZATION MEASURES	Mitigation measures implemented to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided, as far as is practically feasible (BBOP 2014).
RESTORATION MEASURES	Also termed rehabilitation. Includes measures implemented to rehabilitate degraded ecosystems or restore cleared ecosystems following exposure to impacts that cannot be completely avoided and/ or minimized (BBOP 2014).
STOP-OVER SITES	Stop-over sites are locations within the migration routes that birds use for feeding, resting or moulting (Kirby *et al.* 2008).

LITERATURE REVIEW

In order to achieve the proposed objectives in the Guidance Document an extensive literature review was conducted. For this task documents were collected and analysed to gather information that could support the design and elaboration of the guidelines. Documents that were consulted include existing guidelines developed for Europe, United States, Canada, among other countries (International context). Guidelines and methodologies already developed for the countries of the Rift Valley/Red Sea Flyway and/or neighbouring countries were also included. The literature review also considered documents produced as a result of post construction bird monitoring surveys at wind energy facilities or solar power plants, both in countries in other regions of the world, and in countries of the Rift Valley/Red Sea Flyway and/or the region. Both published papers and technical documents ("grey literature") detailing the best methodologies to assess the impacts wind and solar facilities on birds (particularly MSB) and the monitoring of mitigation measures were also considered (Table 1).

The results of the literature review are presented below. This section intends to provide support to the recommendations proposed throughout the guidance document and therefore should be regarded as an auxiliary section of the report.

Table 1 – Documentation included in the literature review presented.

Literature Review						
Guidances		Post Monitoring Examples		Scientific and Technical Pappers		
International	Regional	International	Regional	Bird Surveys	Mitigation Measures	Fatality Monitoring

THE RIFT VALLEY/RED SEA FLYWAY CONTEXT

Renewable energy markets in the Middle East and North Africa (MENA) have been expanding rapidly. An increase in the number and diversity of countries producing energy through renewable sources has been observed over the last five years (Bryden, Riahi & Zissler 2013). The growth of non-hydropower energy power generation in the MENA countries has reached three terawatt-hours (TWh) (between 2008 and 2011) and for 2013 onwards an increase of 4.5-fold over the already existing production capacity is expected (Bryden, Riahi & Zissler 2013). In 2013 MENA countries had an installed capacity of 1.8 GW, with wind power contributing 1.2 GW to this total and an additional 0.56 GW from the solar sector. Although energy production in the wind sector has shown the highest installed capacity (MW) growth compared to that of the solar sector, solar energy in the form of photovoltaic generation is more widespread, being present in almost all countries considered.

The Rift Valley/Red Sea Flyway is located in the Middle East and Northern Africa (MENA) region and is considered as the second most important flyway in the world for soaring birds, considering the numbers of birds involved, especially MSB.

The Rift Valley/Red Sea Flyway includes 11 countries, crossing the Jordan Valley down through Syria, Lebanon, Jordan, and Palestine, and then splitting into three routes. Two of them cross the Gulf of Suez, one going through the Nile Valley and the other through the west coast of the Red Sea (Egypt, Sudan, Eritrea, Ethiopia and Djibouti). The third route follows the east coast of the Red Sea (Saudi Arabia and Yemen) crossing the southern end at the Strait of Bab al-Mandeb to re-join the other two before continuing south to the East African Rift Valley (**Erro! A origem da referência não foi encontrada.**). The countries that are crossed by this flyway have very little solar or wind energy production presently (only 10% of them have solar or wind energy production installed and operational) (Table 2). However it is expected that their capacity will increase in the next years (Bryden, Riahi & Zissler 2013).

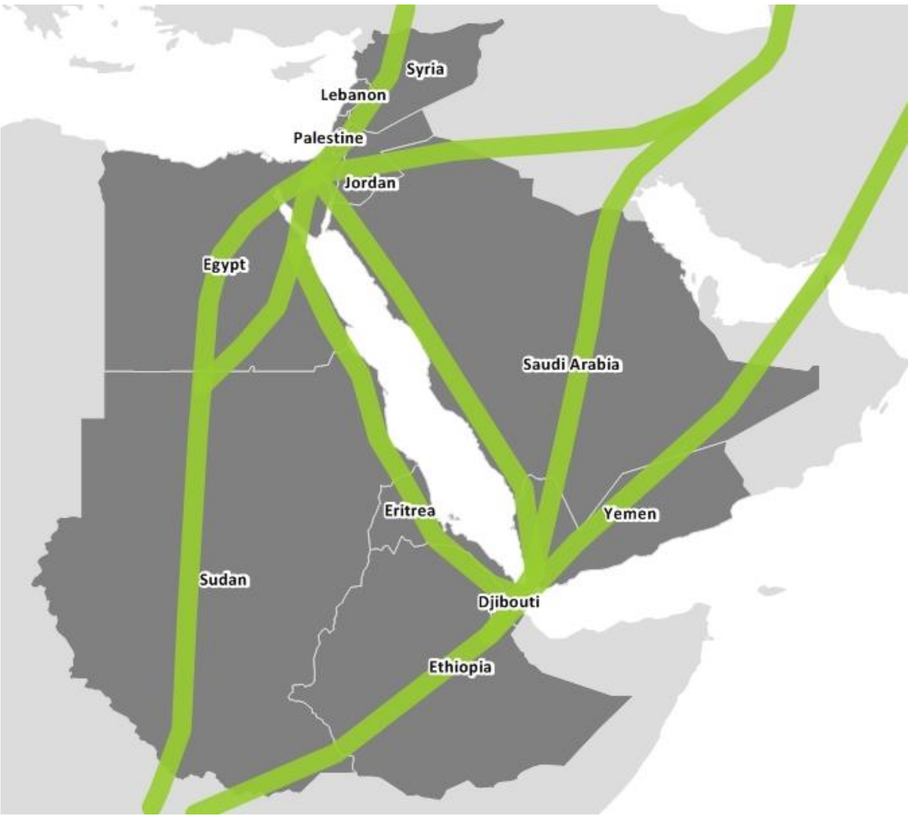

Figure 1 – Countries participating in the Migratory Soaring Birds Project. The Rift Valley/Red Sea most common migration routes are represented in green.

Table 2 – Installed Renewable Energy Capacity (Wind and Solar) in the MENA countries (source (Bryden, Riahi & Zissler 2013); The Wind Power (www.thewindpower.net); REN21 Renewables Interactive Map (www.map.ren21.net): a2013, b2012, c2011, d2010, e2009. PV – Photovoltaic; CSP – Concentrating Solar Power. Countries of the Rift Valley/ Red Sea Flyway are highlighted in grey.

Installed Capacity (MW)				
Country	**Solar**		**Wind**	**Total**
	PV	**CSP**		
Algeria	7.1[d]	25[b]	0[b]	**32.1**
Bahrain	5[c]	0[c]	0.5[b]	**5.5**
Djibouti	1.4[d]	0[c]	0[c]	**1.4**
Egypt	15[b]	20[b]	550[b]	**585**
Eritrea	1[b]	0[b]	1[e]	**2**
Ethiopia	0[b]	0[b]	171[b]	**171**
Iran	4.3[d]	17[c]	91[b]	**112.3**
Iraq	3.5[e]	0[c]	0[c]	**3.5**
Israel	269[b]	0[c]	6[c]	**275**
Jordan	1.6[b]	0[c]	1.4[b]	**3**
Kuwait	1.8[d]	0[c]	0[c]	**1.8**

Installed Capacity (MW)				
Country	Solar		Wind	Total
	PV	CSP		
Lebanon	1[b]	0[c]	0.5[b]	**1.5**
Libya	4.8[b]	0[c]	0[c]	**4.8**
Malta	12[c]	0[c]	0[c]	**12**
Morocco	15[b]	20[b]	291[b]	**326**
Oman	0.7[d]	0[c]	0[c]	**0.7**
Palestinian Territories	1[b]	0[c]	0[c]	**1**
Qatar	1.2[d]	0[b]	0[b]	**1.2**
Saudi Arabia	7[a]	0[c]	0[c]	**7**
Sudan	0[c]	0[c]	0[c]	**0**
Syria	0.84[d]	0[c]	0[c]	**0.8**
Tunisia	4[b]	0[b]	154[b]	**158**
UAE	22.5[b]	100[a]	0[c]	**122.5**
Yemen	1.5[b]	0[c]	0[c]	**1.5**
Total	**381.3**	**182**	**1266.4**	**1829.6**

The total population of these 11 countries along the flyway exceeds 309 million people, with average density of 156.4 people per km^2, with an average Gross Domestic Product (GDP) 7,028 United States Dollar (USD) per capita (taken as purchasing power parity – PPP). The economic conditions has lead in the last years to the population growth which increased the energy consumption in the region, particularly of electricity for domestic use and devices, heating, cooling and desalinization of water (Bryden, Riahi & Zissler 2013). The countries statistics are summarized in Table 3.

Table 3 - Summary of the statistics of the 11 countries within the Rift Valley/Red Sea Flyway[1].

Name of country	Area (km^2)	Population	Density (per km^2)	GDP per capita (PPP -US $)
Syria	185,180	22,530,746	118.3	5,100
Lebanon	10,452	4,822,000	473	15,522
Jordan	89,342	6,508,887	68.4	6,100
Palestine	6,220	4,550,368	731.6	2,900
Egypt	1,002,450	86,000,000	84	6,714
Sudan	1,886,068	30,894,000	16.4	2,658
Eritrea	117,600	6,233,682	51.8	776
Ethiopia	1,104,300	93,877,025	82.58	1,300

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[1] Several sources: (1) International Monetary Fund. Retrieved 2014-02-15; (2) World Population Prospects: The 2012 Revision, Highlights and Advance Tables, Table S.1 (PDF). 2012 revision. United Nations Department of Economic and Social Affairs. 2013. p. 53. Retrieved 2014-02-15; (3) "CIA – The World Fact book". cia.gov. Retrieved 2014-02-15; (4) "Population in Censuses by Sex & Sex Ratio (1882–2006)". Egypt State Information Service. "Country Level". 2007 Population and Housing Census of Ethiopia. CSA. 13 July 2010. Retrieved 2014-02-15; (6) "Key Indicators". Kingdom of Saudi Arabia – Central Department of Statistics & Information. 2012. Retrieved 2014-02-15; (7) "Statistical Yearbook 2011". Central Statistical Organisation. Retrieved 2014-02-1

Name of country	Area (km^2)	Population	Density (per km^2)	GDP per capita (PPP -US $)
Djibouti	23,200	792,198	37.2	2,676
Saudi Arabia	2,149,690	29,195,895	12.3	31,309
Yemen	527,829	23,833,000	44.7	2,249

The Rift Valley/Red Sea Flyway extends through a wide range of climatic variation which creates a large number of ecosystems in the area. There are twenty-three eco-regions situated along the flyway. These include temperate deciduous and coniferous forests, temperate and dry grasslands and scrublands, various types of hot, dry deserts, and tropical mountain forests towards. Arid habitats such as desert and semi-desert feature are prominent along the flyway. The 11 countries that exist within the Rift Valley/Red Sea Flyway have the following general characteristics:

Syria consists mostly of arid plateau. The northwest of the country at the border with Mediterranean is relatively well vegetated. The Northeast of the country "Al Jazira" and the South "Hawran" are important agricultural areas. The most important river is Euphrates that crosses the country in the east. The climate in Syria is dry and hot, and winters are mild.

Lebanon has a coastline and border of 225 kilometres on the Mediterranean Sea to the west. Lebanon is divided into four regions: the coastal plain, the Lebanon mountain range, the Beqaa valley which is a part of the Great Rift Valley system and the Anti-Lebanon Mountains. The Lebanon Mountains rise steeply parallel to the Mediterranean coast and form a ridge that runs for most of the country's length and varies in width between 10 and 56 km. The largest river of the country is Litani that has a length of 145 km. Lebanon has a moderate Mediterranean climate.

Jordan consists of an arid plateau in the east, irrigated by oasis and seasonal water streams, with highland areas to the west of the arable land and Mediterranean evergreen forestry. The Jordan Rift Valley is formed by the Jordan River. The climate in Jordan is semi-dry with warm summer and relatively cool winter.

Palestine is divided into four regions which are Jordan valley and Ghawr, coastal and inner plains, mountain and hills and Southern Desert. The climate of Palestine is dry and warm in the summer and relatively mild in winter.

Egypt is the world's 30th largest country. Most of the population centres are concentrated along the narrow Nile Valley and Delta, which means that 98% of Egyptians live on 3% of the territory. The majority of Egypt's landscape is desert, with few oases. Egypt includes parts of the Sahara Libyan Deserts. The climate is very dry. With most of Egypt's rainfall occurring in the winter months.

Sudan is the sixteenth largest country in the world. The terrain is generally flat plains, broken by several mountain ranges; in the west are Marrah Mountains and the Red Sea Hills in the east. The Blue and White Nile rivers meet in Khartoum to form the River Nile, which flows northwards through Egypt to the Mediterranean Sea. The Blue Nile's course through Sudan is nearly 800 km long and has two tributaries, Dinder and Rahad Rivers. The White Nile within Sudan has no significant tributaries. The amount of rainfall increases towards the south. In the north there is the very dry Nubian Desert; in the south there are swamps and rainforest. Sudan’s rainy season lasts for about three months (July to September) in the north, and up to six months (June to November) in the south.

Eritrea is divided by a branch of the East African Rift. It has fertile lands to the west, descending to desert in the east. The land to the south, in the highlands, is slightly drier and cooler. The Bab-el-Mandeb strait connects the coasts of Eritrea and Yemen. The highest point of the country, Emba Soira, is located in the centre of Eritrea.

Ethiopia is a vast highland complex of mountains and dissected plateaus divided by the Great Rift Valley, which runs generally southwest to northeast and is surrounded by lowlands, steppes, or semi-desert. The great diversity of terrain determines wide variations in climate, soils, natural vegetation, and settlement patterns. Ethiopia is an ecologically diverse country, ranging from the deserts along the eastern border to the tropical forests in the south. Lake Tana in the north is the source of the Blue Nile. The predominant climate type is tropical monsoon, with wide topographic-induced variation. The Ethiopian Highlands cover most of the country and have a climate which is relatively cool in general.

Djibouti has eight mountain ranges. The Mousa Ali range is considered the country's highest mountain range, with the tallest peak on the border with Ethiopia and Eritrea. The Grand Bara desert covers parts of southern Djibouti in the Arta, Ali Sabieh and Dikhil regions. Extreme geographic points include: to the north, Ras Doumera and the point at which the border with Eritrea enters the Red Sea in the Obock Region; to the east, a section of the Red Sea coast north of Ras Bir; to the south, a location on the border with Ethiopia west of the town of As Ela; and to the west, a location on the frontier with Ethiopia immediately east of the Ethiopian town of Afambo. Most of Djibouti is part of the Ethiopian xeric grasslands and scrublands ecoregion. The exception is a strip along the Red Sea coast, which is part of the Eritrean coastal desert. There is not much seasonal variation in Djibouti's climate. Hot conditions prevail year-round along with winter rainfalls.

Saudi Arabia is dominated by the Arabian Desert and associated semi-desert and scrubland. It is, in fact, a number of linked deserts. Rub' al Khali in the southern part of the country is the world's largest contiguous sand desert. There are no rivers or lakes in the country, but wadis[2] are numerous. The main

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[2] Refers to a valley that in some circumstances may contain water during periods of heavy rain or during certain seasons (*Arabic*).

topographical feature is the central plateau which rises abruptly from the Red Sea and gradually descends toward the Persian Gulf. On the Red Sea coast, there is a narrow coastal plain, known as the Tihamah parallel. The southwest province of Asir is mountainous. Except for the south-western province of Asir, Saudi Arabia has a desert climate with extremely high day-time temperatures and a sharp temperature drop at night.

Yemen can be divided geographically into four main regions: the coastal plains in the west, the western highlands, the eastern highlands, and the Rub al Khali in the east. The Tihamah form a very arid and flat coastal plain along Yemen's entire Red Sea coastline. Despite the aridity, the presence of many lagoons makes this region very marshy. There are extensive crescent-shaped sand dunes. The Tihamah ends abruptly at the escarpment of the western highlands. This area, now heavily terraced for agriculture, receives high amount of rainfall. Temperatures are hot in the day but fall dramatically at night. There are perennial streams in the highlands but these never reach the sea because of high evaporation in the Tihamah. The central highlands are an extensive high plateau. This area is drier than the western highlands. Yemen's portion of the Rub al Khali desert in the east is situated at low elevation and receives almost no rain.

THE RIFT VALLEY/RED SEA FLYWAY AND THE MIGRATORY SOARING BIRDS

More than 1.5 million of migratory soaring birds, including 1.2 million of raptors, use the Rift Valley/Red Sea flyway during seasonal migrations. At least 37 species of soaring birds (raptors, storks, pelicans and some ibis) use this route to migrate along the African Eurasian corridor between their breeding grounds in Europe and West Asia and wintering areas in Africa each year (see Table 4). Seven of these species are globally threatened (IUCN 2013). Since there are a number of bottleneck sites along the Rift Valley/Red Sea flyway (see **Erro! A origem da referência não foi encontrada.**) these areas can accumulate 50-100% of global or regional populations of those species.

MSB are particularly vulnerable to impacts during their migration, as birds are physiologically stressed along their extensive journey. Since they are generally large, long-lived birds and often naturally scarce, the reduction of their numbers may have significant impacts. These birds are vulnerable to threats such as hunting, trapping, poisoning, persecution, collisions and electrocution from overhead power-lines, disturbance and deterioration in habitats that affects their ability to feed, and most recently to the possible collision with wind turbines (Porter 2005). For more information on the impacts refer to section 1.

Presently no collisions of MSB with solar facilities have been recorded, this impact being more relevant for migratory passerines (refer to section 1.2). Considering that in some species a large percentage of the global population crosses this route, these impacts and the cumulative nature of such impacts may have severe implications on global population resilience (UNDP 2005).

Using this flyway route are represented 50-100% of the world populations of some species including: Levant Sparrowhawk (*Accipiter brevipes*) – 100% of the world population; Lesser Spotted Eagle (*Aquila pomarina*) – more than 90% of the world population; Eurasian Honey Buzzard (*Pernis apivorus*) – c. 60%; Short-toed Eagle (*Circaetus gallicus*), Booted Eagle (*Hieraaetus pennatus*), and White Stork (*Ciconia ciconia*) – c. 50% of each.

The globally-threatened species migrating through the Rift Valley/Red Sea Flyway are (Table 4): Northern Bald Ibis (*Geronticus eremite*), Egyptian Vulture (*Neophron percnopterus*), Saker Falcon (*Falco cherrug*), Greater Spotted (*Aquila clanga*), Imperial Eagles (*Aquila heliaca*), Red-footed Falcon (*Falco vespertinus*) and Pallid Harrier (*Circus macrourus*).

Table 4 - Species of MSB that use the Rift Valley/Red Sea Flyway.

	English Name	Scientific Name	Conservation Status (IUCN 2013)
1	White Pelican	*Pelecanus onocrotalus*	
2	Black Stork	*Ciconia nigra*	
3	White Stork	*Ciconia ciconia*	
4	Northern Bald Ibis	*Geronticus eremita*	Critically Endangered
5	European Honey Buzzard	*Pernis apivorus*	
6	Crested Honey Buzzard	*Pernis ptilorhyncus*	
7	Black Kite	*Milvus migrans*	
8	Red Kite	*Milvus milvus*	
9	White-tailed Eagle	*Haliaeetus albicilla*	
10	Egyptian Vulture	*Neophron percnopterus*	Endangered
11	Eurasian Griffon Vulture	*Gyps fulvus*	
12	Short-toed Snake-eagle	*Circaetus gallicus*	
13	Western Marsh-harrier	*Circus aeruginosus*	
14	Marsh Harrier	*Circus cyaneus*	
15	Pallid Harrier	*Circus macrourus*	Near-threatened
16	Montagu's Harrier	*Circus pygargus*	
17	Levant Sparrowhawk	*Accipiter brevipes*	
18	Eurasian Sparrowhawk	*Accipiter nisus*	
19	Goshawk	*Accipiter gentilis*	
20	Common Buzzard	*Buteo buteo*	
21	Long-legged Buzzard	*Buteo rufinus*	
22	Lesser Spotted Eagle	*Aquila pomarina (pomarina)*	
23	Greater Spotted Eagle	*Aquila clanga*	Vulnerable
24	Steppe Eagle	*Aquila nipalensis*	
25	Imperial Eagle	*Aquila heliaca*	Vulnerable
26	Booted Eagle	*Hieraaetus pennatus*	
27	Osprey	*Pandion haliaetus*	
28	Lesser Kestrel	*Falco naumanni*	
29	Common Kestrel	*Falco tinnunculus*	
30	Red-footed Falcon	*Falco vespertinus*	Near-Threatened
31	Eleonora's Falcon	*Falco eleonorae*	
32	Sooty Falcon	*Falco concolor*	
33	Eurasian Hobby	*Falco subbuteo*	

	English Name	**Scientific Name**	**Conservation Status (IUCN 2013)**
34	Lanner Falcon	*Falco biarmicus*	
35	Saker Falcon	*Falco cherrug*	Endangered
36	Peregrine Falcon	*Falco peregrinus*	
37	Eurasian Crane	*Grus grus*	

1. IMPACTS OF WIND AND SOLAR ENERGY ON BIRDS

Although renewable energies are considered "green energies", with less environmental impacts than other industries of energy production, they are not free from ecological impacts (McCrary *et al.* 1986; Orloff & Flannery 1992; Drewitt & Langston 2006; Arnett *et al.* 2007; Ledec, Rapp & Aiello 2011; Martin 2011; Hernandez *et al.* 2014). The installation of wind and solar power generation facilities around the world has revealed some questions regarding wildlife interactions, mostly related to bird and bat species. In 1992 Orloff & Flannery published the first records of bird fatalities related to wind turbines, raising public concerns. In 1986, McCrary *et al*. published a paper detailing bird fatality observations at a solar power plant, producing the first published findings regarding impacts of solar energy production on birds. Through time it has been observed that poorly located or designed wind and solar facilities can have negative impacts on not only vulnerable species and habitats but also on entire ecological processes. The construction and maintenance of wind and solar facilities (including the use of large machinery, transportation of turbine and solar panel elements and installation of transmission lines), even if conducted with environmental protection in mind, will undoubtedly alter ecosystem structures to some degree.

To date, the most common bird impacts associated with wind and solar power generating facilities are related to (BirdLife International 2013a; b):

- Depletion of water sources (solar power);
- Habitat loss and/or fragmentation (wind and solar power);
- Fatality due to collision with wind turbines or solar panels, as well as with associated infrastructure *i.e*. power lines, weather masts, etc.(wind and solar power);
- Pollution produced by activities during construction and ongoing maintenance *i.e.* water pollution (wind and solar power);
- Disturbance (wind and solar power);
- Change of habitat function (wind and solar power);
- Barrier effect (wind and solar power);
- Potential heat damage (solar power).

Wind and solar energy facilities may impact on migratory soaring birds and bird populations in three key ways. These can be grouped as either less direct (non-lethal) impacts that are common to most forms of development; or lethal – direct fatality impacts that affect individual birds and are specific to the renewable energy technology employed at the site (Drewitt & Langston 2006, 2008; Arnett *et al.* 2007; Hernandez *et al.* 2014):

- **Disturbance and/or Displacement** from habitats or **Barrier Effect** along preferred migratory routes.

- **Habitat loss, fragmentation** or alteration (both in terms of structure and functioning), or site specific damage; and
- **Fatality** and/or injury due to collision with turbines, turbine blades and heliostats (concentrated solar plants); or burns as a result of concentrated solar irradiance.

Table 5 provides a summary of the anticipated impacts at the various energy generating facilities.

Disturbance and/or displacement effects may affect birds by changing their distribution and/or spatial use away from favourable habitat, and cause population disruptions due to a decrease in breeding success (Gove *et al.* 2013). This impact may be caused both by wind and solar facilities, and the higher significance impacts are expected for birds with small home ranges.

Barrier effect may be regarded as a form of displacement from the area, being this impact plausible to occur over migratory birds, since it implies the creation of an obstacle over a flight path (Drewitt & Langston 2006). However it is not known how the disruption or alteration of flight paths will affect current migration patterns and stopovers.

Birds tend to collide with wind turbines or other structures due to a number of factors, including the species characteristics, such as their field of vision, manoeuvrability (Martin 2011); as well as the site and project characteristics, such as the existence of high slopes with converging wind currents, turbine arrangement or the type of turbine (e.g. height or rotor and blade size) (Barrios & Rodríguez 2004; Drewitt & Langston 2006, 2008; De Lucas *et al.* 2012; De Lucas, Ferrer & Janss 2012).

The duration and significance of the expected impacts during both the construction and operational phases of the project are dependent on various factors, including the location and size of the facility as well as the timing, duration and intensity of the construction for example. Although construction activities are temporary they can be extreme and the associated impacts can be severe (Drewitt & Langston 2006). Planning wind and solar facility developments in a strategic manner (i.e. careful sitting decisions and continued development of technology) over a broad geographical area is one of the most effective means of minimising the impacts of these infrastructures on migratory soaring birds, as well as the remaining bird community, from the start of the planning process throughout the project lifecycle (Drewitt & Langston 2006, 2008; Madders & Whitfield 2006; De Lucas, Janss & Ferrer 2008).

It is also vitally important to consider the cumulative effects of multiple facilities within a region. Even though fatality rates may be low at a single facility, the impact of several infrastructures, in an area, on regional populations of birds may be significant.

Table 5 - Impact matrix summarising key impacts associated with wind and solar energy facilities (CSP – Concentrated Solar Plant; PV – Photovoltaic Facility).

Impact Type	Project Phase		Interaction	Renewable Energy Technology		
	Construction	Operation		Wind	CSP	PV
Disturbance/ Displacement & Barrier Effect		X	Heat stress as a result of concentrated solar irradiance		X	
	X	X	Disturbance	X		
	X	X	Creation of unnatural barrier to daily movements and migration	X	X	X
Habitat alteration (loss and fragmentation)	X	X	Habitat loss, fragmentation and alteration	X	X	X
		X	Reduction in available water resources		X	
Direct: Fatality and/or injury		X	Collision with infrastructure	X	X	X
		X	Incineration as a result of concentrated solar irradiance		X	
		X	Chemical pollutants leaching into evaporation ponds and wetland systems		X	

1.1. Impacts of Renewable energies on Birds - Wind Facilities

1.1.1. Disturbance and/or Displacement

Construction and to a lesser extent operational activities result in an increase in vehicle traffic and general human activity, often in areas that were previously uninhabited (Kuvlesky *et al.* 2007). The significance of the effect is dependent on the species involved as well as the magnitude, duration and timing of the construction activities. Smaller bird species with small home ranges are particularly vulnerable as well as areas that are important for feeding and breeding (Lindeboom *et al.* 2011).

Turbine noise, visual flicker or shadow effects experienced during the operation of the wind energy facility may continue to cause disturbance to resident and/or migratory species. Usually species that are more adapted to areas with significant existing human disturbance are less affected than those species adapted to natural or semi-natural areas (Pearce-Higgins *et al.* 2009; Stevens *et al.* 2013). This level to which a species is disturbed is also variable, ranging between 100 and 800m, depending on the groups of species (Pearce-Higgins *et al.* 2009). Besides the displacement effects documented during operational phase, further studies have found that breeding populations were mostly affected during construction (Pearce-Higgins *et al.* 2012).

1.1.2. Barrier Effect

A barrier effect occurs when a facility acts as an obstacle for birds in flight. Migrant birds will therefore have to extend their flight path to avoid the obstacle. While this avoidance behaviour may reduce the collision risk, the additional distance covered can have a negative effect on the birds' ability to conserve energy.

It is not known how a disruption of migration patterns will influence regional-scale fatality or the consequences of deaths of individuals of these migrating species to the local populations they originate from. Studies in the MENA region have documented concerns regarding the impact that large wind facilities may have on migrant birds, during two seasons of the year (spring and autumn) when several bird species would have to employ various strategies to avoid colliding with rotors (*e.g*. White Stork, White Pelicans, European Honey Buzzards, among others). This could imply the use of active flight, instead of soaring and/or gliding, which is more energy-consuming, possibly causing casualties not only within the wind facility, but later in the migration (Hilgerloh, Michalik & Raddatz 2011). Barrier effects have also been detected in migratory bird species in the Baltic/Wadden Sea, resulting in birds travelling further distances to avoid the wind facility (Masden *et al.* 2009).

1.1.3. Habitat Alteration (Loss or Fragmentation)

The construction of large infrastructures may result in a loss of breeding, post-breeding, stopover, and wintering habitat through the removal of natural vegetation. Any reduction in habitat is likely to result in a depletion of food supply. For this reason careful consideration needs to be given to the sitting of the facilities. Where vegetation patches are created by the removal or destruction of vegetation(fragmentation), an increase in the movement of birds across areas can be expected, as individuals and groups are forced to move from patch to patch to forage. This can potentially increase the risk of collision.

Usually the area of land directly affected by a single wind facility and its associated infrastructure (roads, buildings and power lines) is relatively small; therefore the significance of the impact is likely to be low when compared to other long-term operational impacts. The magnitude and duration of the impact will depend largely on the type of habitat and its ability to regenerate.

In addition to this, birds are aerial species, spending much of their time above the ground. It is therefore simplistic to view the amount of habitat destroyed as the terrestrial land area only (Smallie 2013). Loss of aerial habitat was discussed in more detail above under displacement and barrier effects.

1.1.4. Direct Fatalities

Bird fatality as a result of construction activities from infrastructures, is improbable due to birds' extremely mobile behaviour. If fatality does occur it is likely to be confined to a very small area and restricted to immobile species e.g. nestlings.

During operation, similarly to bird collisions with other infrastructure (e.g. power lines), flying birds collide accidentally with the rotating blades and/or the turbine tower itself, resulting in immediate death or severe injuries. The extreme turbulence experienced in the wake of the turbine, can also drive birds forcibly to the ground with similar outcomes (Spaans *et al.* 1998). Bird fatality resulting from collisions with operational turbines has been widely documented in recent years (Kunz *et al.* 2007; Zimmerling *et al.* 2013; Bellebaum *et al.* 2013).

Certain sites, such as Altamont Pass in California and Tarifa in Spain, the latter being within a narrow migration route (De Lucas *et al.* 2008), have received a great deal of attention as a result of the significant number of collision casualties. Studies from 31 wind facilities in Europe and 28 in North America found that the average European bird fatality rates were much higher at 6.5 birds/turbine/year compared to the 1.6 for North America (Rydell *et al.* 2012). However, there are a number of factors or combinations thereof (relating to both the birds and the facility) that influence fatality rates through collision and the high number of fatalities at sites such as these, are often the exception rather than the rule (Kingsley & Whittam 2005).

Although all birds are inherently at risk of collision with wind turbines with reported casualties representative of nearly all species groups, certain taxonomic groups are more vulnerable than others (Jordan & Smallie 2010; Retief *et al.* 2012; Rydell *et al.* 2012) these include: Podicipediformes; Pelicaniformes; Ciconiiformes; Anseriformes; Falconiformes; Charadriformes; Strigiformes; Caprimulgiformes; Gruiformes; Galliformes; Psittaciformes and Passeriformes. Though there is still some uncertainty regarding why birds collide with wind turbines or other structures, studies have pointed that it may be related with:

- Morphological characteristics of the species, such as visual acuity or behaviour (Bevanger 1994; Barrios & Rodríguez 2004; De Lucas *et al.* 2008; Martin 2011);
- Characteristics of the project site, such as topography or prey abundance (Barrios & Rodríguez 2004; Ferrer *et al.* 2012);
- Characteristics of the project, such as the type of turbine and their layout (Thelander, Smallwood & Rugge 2003; De Lucas *et al.* 2008; Ferrer *et al.* 2012).

The behavioural and morphological characteristics of birds and the facility related factors that influence fatality rates through collision are presented in **Erro! A origem da referência não foi encontrada.** and **Erro! A origem da referência não foi encontrada.**.

Table 6 - Key bird related factors that influence the likelihood of collisions at wind energy facilities.

Factor	Type of Factor	Description
Behaviour	*Avoidance*	A birds' ability to react to the presence of the turbines (Rydell *et al.* 2012). Only certain species (*e.g.* ducks and geese) have been observed to exhibit this behaviour, thereby ensuring safety, while other species (raptors) forage amongst operational turbines.
	Flight height	Generally most daily or migratory flights are at altitudes well below or above that of rotor height. Birds are particularly vulnerable to collisions during take-off and landing (at stop-over or wintering sites), aerial displays and local foraging flights. Birds also tend to fly lower to the ground during poor weather conditions (fog) and strong headwinds (Richardson 2000); increasing the risk of collision since turbines are also functioning at a maximum in strong winds (Drewitt & Langston 2008; Rydell *et al.* 2012).
	Exposure	Determined by how often and for how long a bird species flies, and whether it is gregarious in nature and demonstrates flocking behaviour (Jenkins, Smallie & Diamond 2010).
	Seasonal variation	Fatalities are likely to be higher in seasons when bird activity is higher *i.e.* due to courtship, nest building, and provisioning of young (Everaert & Stienen 2007).
	Temporal variation	Recurrent flights at night or in low light are likely to result in a higher number of collisions (Smallwood *et al.* 2007).
	Habituation	No evidence exists to suggest that birds become habituated to wind energy facilities over time, thereby avoiding collisions (Smallwood & Thelander 2008; De Lucas *et al.* 2008; Rydell *et al.* 2012).
	Utilization	Collision risk can be influenced by the abundance of birds utilizing a site repeatedly (Barrios & Rodríguez 2004; Noguera, Pérez & Mínguez 2010).
Morphology	*Flight proficiency and manoeuvrability*	Large birds (with high wing loading – the ratio of wing area to mass) may be less able to adjust its flight readily to avoid an obstacle (Barrios & Rodríguez 2004; Drewitt & Langston 2006; Noguera, Pérez & Mínguez 2010; Jenkins, Smallie & Diamond 2010).
	Field of vision	Certain bird species may be unable to avoid obstacles in flight as a result of significantly reduced frontal visual acuity i.e. vultures, storks, cranes and bustards (Martin & Shaw 2010).
Age		Some studies reveal that juveniles do not seem to be affected by collisions (Smallwood & Thelander 2008; De Lucas *et al.* 2008; Rydell *et al.* 2012) while others claim that less experienced juveniles do appear to be more vulnerable to collision compared to adult birds (Drewitt & Langston 2008).

Table 7 - Key facility related factors that influence the likelihood of collisions at wind energy facilities.

Factor	Description
Site Location	Fatality rates and collision risk will be significant where wind facilities are located within or near to staging sites as well as areas or landscape features with restricted migratory access (Rydell *et al.* 2012). Similarly turbines located along mountainous ridge lines will pose considerable risk to migratory species that soar using the thermals associated with this topography type (Hotker, Thomsen & Jeromin 2006).
Turbine arrangement	Turbines arranged perpendicularly to migratory routes will pose a higher collision risk. Grouping turbines may enable easier detection (Hotker, Thomsen & Jeromin 2006). Increasing the distance between turbines or creating a corridor between groups of turbines reduces the risk of collision (Hotker, Thomsen & Jeromin 2006; Drewitt & Langston 2006).
Turbine Size	Studies suggest that taller turbines with longer blades and larger rotor swept areas do not necessarily result in more fatalities (Barclay, Baerwald & Gruver 2007).

Factor	Description
	As turbine size increases, fewer turbines are constructed to produce the same amount of power therefore resulting in fewer birds killed when expressed per megawatt.
Lighting	Earlier studies suggested that continuous red and white lighting at turbines increases the collision risk (Hotker, Thomsen & Jeromin 2006; Drewitt & Langston 2008). More recent studies claim that there is little evidence to support this theory (Rydell *et al.* 2012). It has been suggested that intermittent blue and green lighting may reduce the risk (Drewitt & Langston 2008).
Facility size/ number of turbines	Larger wind facility sites (with a larger number of turbines) do not necessarily kill more birds per (Rydell *et al.* 2012). The absolute number fatalities will only be greater for a larger facility if all other contributing factors are equal. Larger facilities would have greater habitat destruction, displacement and barrier effects.

1.2. IMPACTS OF RENEWABLE ENERGIES ON BIRDS - SOLAR FACILITIES

The literature review conducted revealed the existence of few records of solar facilities impacts on birds and other flying vertebrates. This is motivated by the only recent advances in the technology and large-scale implementation, unlike wind facilities that have been intensively studied since 1980´s. Only recently the first integrated studies on the impacts of solar energy production of wildlife have been published (Tsoutsos, Frantzeskaki & Gekas 2005; Peschel 2010; Lovich & Ennen 2011; Labinger 2012; Hernandez *et al.* 2014). Though several of the impacts caused by solar facilities are similar to those of wind facilities, the main differences are explained and discussed below, based on the most recent literature available.

1.2.1. Disturbance / Displacement

Construction of solar energy facilities requires a significant amount of machinery and labour to be present on site for a certain period of time that may be more or less long depending on the size of the facility. For the shy, sensitive species, construction activities are likely to be a cause of temporary disturbance or even result in displacement from the site entirely or at least part of it. In addition, species commuting around the area may become disorientated, avoid the site and fly longer distances than usual as a result. For some species this may have critical energy implications. This displacement impact is particularly significant if solar plants are large in size or if several smaller energy facilities are clustered together in a region (cumulative or flyway scale impacts) resulting in abandonment of resting sites and a disruption to important migratory linkages within the landscape.

1.2.2. Barrier Effect

No studies have yet documented the existence of barrier effect over migratory soaring birds caused by wind facilities. Smaller bird species may encounter a disruption in their daily movement patterns, reducing gene flow (Hernandez *et al.* 2014).

1.2.3. Habitat Alteration (Loss or Fragmentation)

Although this impact is dependent on the location and the scale of the facility, this is potentially the largest impact associated with the construction and operation (including maintenance) of solar energy facilities (Turney & Fthenakis 2011). Extensive areas of vegetation (habitat) might need to be removed and altered to accommodate the considerable amount of infrastructure required at these facilities, reducing the amount of habitat available to resident and migratory birds for foraging, roosting and breeding activities. Again, this impact has dire consequences for smaller bird species with small home ranges as entire territories could be removed during construction activities. This may create barriers to the movement of species and gene flow, increasing the risk of gene flow disruption between populations (Hernandez *et al.* 2014). It is likely that altering the nature of the sites surface from natural vegetation to infrastructure, roads, gravel, and possible paving will undoubtedly alter the way in which water moves on the site after rainfall. If this is not carefully managed this could cause soil erosion and thereby alter even more bird habitat than the site construction itself. Increased runoff could also create moister conditions on or near the site thereby attracting more birds to the area and increasing the likelihood of other impacts (Smallie 2013).

An increase in the amount of shade provided by the heliostats and photovoltaic panels, coupled with the change in water regime can result in an altered micro-climate and ultimately a change in vegetation or habitat function. This can have an impact on birds resulting in the change of food source and nesting substrate. Various bird species are relatively quick to seize a new opportunity for perching, roosting or nesting. In this landscape this is particularly relevant for locations so devoid of tall trees. Therefore it is likely that birds will use certain parts of the facilities once commissioned. Whilst this could be viewed as a positive impact for birds, it typically creates operational problems for the facility, which require additional actions such as nest management. This nesting will also bring these birds into closer proximity with dangerous hardware such as the overhead power lines. Breeding takes up a significant portion of the year, and raising young places both the adults and young at increased risk of fatality through collision and electrocution in particular (Smallie 2013).

1.2.4. Direct Fatalities

Solar facilities can have a positive effect over biological diversity, by having the opportunity to improve the quality of habitats for several species. This only applies when a careful site selection is conducted and solar parks are placed within deteriorated areas, with poor species diversity (Peschel 2010). When site selection is not as careful, solar facilities impacts may include wildlife fatalities. During operation, Concentrated Solar Plants (CSP) will potentially have greater impact on migrating and resident bird species compared to that of Photovoltaic (PV) facilities, because of the nature of infrastructure involved i.e.

central receiver tower, standby focal points and heliostats. Three key impacts associated with fatality at CSP plants include collision, incineration and pollution.

Collision

Bird fatality has been shown to occur due to direct collisions with solar panels, heliostats and the central receiver towers. In a study conducted at a CSP plant, in the USA, 81% of the birds died through collision with the infrastructure, the majority of which (75%) casualties of collisions with the heliostats. Species affected included water birds, small raptors, gulls, doves, sparrows and warblers (McCrary *et al.* 1986). The reflective surfaces of the heliostats (and in some cases PV panels) act as attractants for approaching birds. These surfaces may be confused for large water bodies, causing disorientation in the same manner as windows do, resulting in injury or death.

The risk of collision can be exacerbated by a number of factors including the size and type of structures (Drewitt & Langston 2008), the location of the plant, adverse weather conditions and species behaviour (i.e. nocturnal migrants) and morphology, particularly those birds with a large body mass e.g. cranes, bustards, geese and swans.

Incineration

Birds flying within the beam of concentrated sunlight emanating from the heliostats, particularly in the vicinity of the central receiver and standby focal points, may be burned by the extreme heat that is generated causing injury or death (McCrary *et al.* 1986; Tsoutsos, Frantzeskaki & Gekas 2005). McCrary *et al*. (1986) documented 70 bird fatalities (of 26 species) over 40 weeks of surveys. Though the majority of birds died due to collision with infrastructures, a fifth of the fatalities were caused due to burns when heliostats were oriented towards standby points. Swallows, swifts and martins are most vulnerable to this impact because a great deal of their time is spent in flight.

Pollution

There are some pollution risks associated with the development and operation of solar energy facilities. Some are common to most forms of industrial development (e.g. runoff) while others are specific to solar plants - these include chemicals used in the heat transfer and cooling fluids. It is possible that these chemicals could leach into cooling ponds and local wetland areas (Tsoutsos, Frantzeskaki & Gekas 2005) causing fatality (Joanes 2012). Steam production at one solar energy facility in the Mojave Desert of California was made with water containing selenium. The wastewater was pumped into evaporation ponds that attracted birds that fed on the invertebrates present (Lovich & Ennen 2011). Although deemed to be a relatively low risk, the magnitude of the impact is dependent on the numbers of birds using these wetland areas, which in the case of migratory species can be quite significant.

2. IMPACT MONITORING METHODS AND TECHNIQUES

Estimation of risks and potential impact of wind and solar facilities on birds' habitats in a study area is an essential component of any proposed project. The objective of any monitoring is to provide information on birds' species that are using the proposed area and their abundance, thereof outlining birds' population dynamics and comparing data from different sites over time to assess the effetcs (Gilbert, Gibbons & Evans 1998; Gregory, Gibbson & F. 2004; Strickland *et al.* 2007).

Population surveys form the basis of several ecological studies and provide data required for management decisions. As long as monitoring programmes comprise recruitment of manpower, financial resources, and have timescale, to reach effective results it is necessary to:

(i) Set objectives prior to survey implementation,

(ii) Select the study area (whole territory or sample part of it);

(iii) Select an approach of estimation of birds population size (absolute or relative abundance, density);

(iv) Outline sampling units (mapped grid squares, forest blocks etc.);

(v) Select field methods, based on research subject and study area characteristics;

(vi) In case of monitoring of breeding birds specify the recording units (individuals, singing males, breeding pairs etc.);

(vii) Standardize survey worksheet;

(viii) Develop the reporting form.

The first step is therefore to determine the goals and objectives of the study and the required parameters that need to be considered to answer the study question (e.g. species diversity, behaviour, seasonal variation, habitat characteristics).

2.1. MIGRATION SURVEYS

For surveying seasonal birds' migrations the most popular approach is the implementation of migration counts. A migration count is a cost-effective method that has been widely used since late 19th century . This technique is implemented when birds pass through migration corridors. Migration counts must pursue two objectives: (i) firstly, the determination of the seasonal migration timing of different ecological and taxonomic groups of birds in a given year, migration volume and species composition and, (ii) secondly, the migration dates adjustment for certain species.

These observations require appropriate qualifications and should be carried out systematically on certain points located along the migratory route. Often it is more efficient and easier to count large, diurnal migrants, such as raptors, cranes, storks, and pelicans in bottlenecks (Zalles & Bildstein; Kerlinger 1989; Bildstein, Smith & Yosef 2007). When the goal of a certain survey is to determine abundance or distribution of raptors in a broad area, sample units might be sections of coastline (Jacobson & Hodges 1999) or large plots (Hargis & Woodbridge 2006). In case of an outlined study area the sample units can be fixed points.

To determine daily and seasonal timing of migration, species diversity, and the volume of migration as a function of weather variables, the migration counts should be conducted over time (Haugh 1972; Kerlinger 1989). As migration can take place at high altitudes, counts are usually conducted by teams of observers, continually scanning the sky and working together. Similar coordinated raptor counts occur across North America where their potential for population monitoring has been explored (Lewis & Gould 2000). Simultaneous implementation of birds migration counts with visual observation can provide information not only about migrants ecology, but also in the detection of main migration routes, flight dynamics and other aspects of migration behaviour (Smith 1985; Kerlinger 1989; Bildstein & Zalles 2001; Hoffman, Smith & Meehan 2002).

There are, of course, many variations of point counts especially to the start and end times of observations, which may influence the subsequent estimation of data collected by extrapolation (Gavrilov 1979; Ljuleeva & Zhalkiavichus, M. M. Shumakov 1981; Bibby *et al.* 2000; Romanov & Maltzev 2005). Since many raptors and other migratory soaring birds use thermals to increase altitude, which facilitates soaring, observations usually start at 9 am and finish at 5 pm, when temperatures are high enough to generate uplift (Panuccio, Gustin & Bogliani 2011; Campedelli *et al.* 2013). To avoid observer fatigue the observers can continue observations during 3 to 4 hours with some minor interruptions. Data collected in each of these survey intervals enables the estimation of migration intensity throughout the daylight hours. When the human capacity is limited, counts should start at 9 am and observations should be continuous for 6 hours, dividing the observations into one hour sessions.

MSB flocking behaviour

Soaring birds behave differently during migration. Some species form flocks on continuous passage, stretched out in a line, making counting process simple. Others can create swirling clusters, or “kettles”, consisting of up to hundreds individuals in the updraft, creating counting difficulties. In the case of “kettling” groups the best counting results can be achieved when they begin “streaming”[3] along the migration corridor.

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[3] Streaming along the migration corridor indicates the moment when birds descend from the updraft and flow along the migration corridor forming a stream of birds.

2.2. NON MIGRATION SURVEYS

To estimate birds' species status and population changes in different types of habitats the following methods of spatial bird counts are highlighted: a) point counts, b) plot counts; c) transect counts. Line transects and point counts are the preferred survey methods under many circumstances. They are highly adaptable methods and can be used in terrestrial, freshwater, and marine systems. Both can be used to derive relative and absolute measures of bird abundance. They can be implemented to survey individual species, or groups of species. They are reasonable in respect of the quantity of data collected per unit of effort expended, so, they are particularly suited to monitoring projects. The survey design of the Breeding Bird Survey in the United Kingdom, which uses a line transect approach, provides a useful model that can be adopted elsewhere for breeding birds (Gregory 2000).

The most widely used and efficient method to track the changes in bird populations, species diversity and relative abundance is a point count survey (Ralph & Scott 1981; Toms *et al.* 2006). Comparisons in bird abundance, activity patterns, and habitat variables can then be made to determine if the changes can be attributed to development and operation of the wind facility or result of natural occurrences (Greenwood 1996; Rosenstock *et al.* 2002; Strickland *et al.* 2007).

The line transect survey is based on the search of all birds seen and heard in all the main habitat types in the study area and to estimate the number of individuals during each visit. The route could be divided into bands (20, 50, 100 m), or the perpendicular distance to the observed bird can be measured (Bibby *et al.* 2000). This method can be used to estimate the spatial and temporal use of the proposed development area by breeding resident birds.

In general, to have a good representative data sample on terrestrial breeding birds, two visits to the area per season is usually recommended (SNH 2009; Jenkins *et al.* 2012). The North American Breeding Bird Survey, which consists of a continent-wide survey, involves point counts along randomly selected road transects (Sauer, Hines & Fallon 2001). Transects can be supplemented and, to some degree, verified in combination with other count methods such as sound recording, mist netting, and tape playback (Haselmayer & Quinn 2000).

2.3. COMPLEMENTARY SURVEYS

Besides the implementation of the traditional methods referred above, new technologies have been developed that allow surveys to be conducted for a longer period of time, with less human effort. Several reviews on the theme have already been conducted, discussing the most commonly used methods and their utilization (Diehl, Larkin & Black 2003; Christensen *et al.* 2004; Fiedler 2009; Mateos & Arroyo 2012; May *et al.* 2012, 2013; Voltura & Davenport 2012; Watson, Duff & Davies 2014).

Among the technologies most commonly used can be highlighted the following (Fiedler 2009; May *et al.* 2012; Voltura & Davenport 2012):

- **Avian Radar Systems** – Radars used for bird surveys were adaptations of marine radars. These radars have two antennas (one horizontal and one vertical) that allow capturing an object position both regarding its flight direction and flight height. The immediate advantage of this technology in relation to visual observations is the ability to collect data without interruptions, and in almost all weather conditions (see Box 1 for example)

- **Camera surveillance systems** – Optic systems have been developed to detect and record the presence of birds within a pre-defined risk area. It is usually place in the infrastructure that poses risk for birds (i.e. wind turbines). These systems may be linked to automatic databases that recognize birds and may produce certain deterrence actions if a collision risk is eminent (see Box 2 for an example). This is however a very recent technology and with a limited application to migratory birds, since it has a range up to 1.5 km for large birds.

- **Radio tracking** - The localization of the bird is achieved by obtaining the radio signal of a sending device onto a receiving device. The receiver, in combination with a directional antenna is used to find the direction from which the signal comes. While the directional information can be very accurate, the distance to the sending device (i.e. the tagged bird) is not. These sending devices are usually no bigger than 5% (3%–5% for birds in Britain & Ireland) of the birds' body mass. This technique is mostly used assess home ranges, feeding grounds or dispersal flights of birds but researchers have rarely succeeded in following individual birds on real migration using this technique.

- **Satellite tracking** - In satellite tracking technology, the sender is tracked from space by a satellite (the satellite is the receiving device). This enables investigators to follow birds over much larger distances and with a higher accuracy. This accuracy makes possible, for example, to locate nests or roosting trees of birds reliably from the received data. Some long distance journeys of birds have been recorded through satellite tracking. When tags are solar powered they have the potential to operate and give useful data as long as the bird lives. Satellite tracking helps to identify migration corridors and wintering grounds where ring-recovery probabilities are low. The most obvious limitation to this technique, besides the high costs of the tags and satellite use, is currently the size of the transmitters, which do not allow a bird lighter than 100 g in body mass to be tracked (5 g transmitter) (see Box 3 for an example),

- **Geolocator loggers** - Loggers are devices that store data on a memory unit until it is read out by an external reading unit. GPS coordinates are taken at pre-programmed times and logged to the memory of the device. While loggers save weight and energy compared to satellite tags, they add some vulnerability to the studies as they need to be found again to read out the data. Therefore logger technology is widely used in seabirds and other large birds that return to the same breeding places for many years where they can be re-trapped. More recent loggers have been designed to incorporate sending units that enable users to establish a radio link between a receiver and the logger on the bird over a distance of up to 5 km.

- **Passive Integrated Transponders (PIT) tags** - PIT tags use Radio Frequency Identification (RFID) technology. It does not have its own power or memory and simply gives an identification number when it is read out. In studies of wild birds, PIT tags are either implanted or attached to a leg ring. Birds then can be identified automatically each time they approach an antenna at a feeder, a balance or a nest box. The distance between the transceiver and the PIT tag needs to be less than a metre.

- **Global System for Mobile Communication (GSM) tracking** – It can be used for animal tracking when the animal is equipped with a GSM unit that communicates with the worldwide infrastructure for mobile communication. The GSM unit can be coupled with sensors and GPS modules and thus can send coordinates and other data through the GSM system directly to the mobile phone of a researcher.

Box 1 - Radar Observations of Bird Migration over the Great Lakes (Diehl, Larkin & Black 2003)

Migration behaviour surrounding large water bodies was studied using radar technologies (weather surveillance radars and specialized radars to assess the movements consistent with lake crossing or lake avoidance, in the Great Lakes coastal habitats (USA). This information was used to assess possible stopover patterns by migratory birds in this region.

Box 2 - Evaluation of the DTBird video-system at the Smola wind-power plant (May et al., 2012).

A pilot study was conducted at Smola wind-power plant, in Norway, to test the components of the DT-Bird system. The system determined the activity within the facility each day, by the number of triggers obtained, as well as the birds groups, by visual identification of the video sequences. With this information it was also possible to relate the activity to the wind speed and wind direction, and the type and height of flight recorded. The module of dissuasion was also tested, the results of which are detailed in **Erro! A origem da referência não foi encontrada.**.

Box 3 - Habitat Utilization in White-Tailed Eagles (*Haliaeetus albicilla*) and the Displacement Impact of the Smøla Wind-Power Plant (May *et al.* 2013)**.**

A study conducted in Norway aimed at evaluating the presence of displacement effects; especially decreased breeding success in a target species (white-tailed eagles) was initiated. To analyse habitat utilization and answer the study objectives GPS systems where mounted on 44 ready-to-fledge individuals. The GPS transmitters were mostly solar-powered being collected the position of the individuals continuously between summer 2004 and 2009. Using the position information the home range size and habitat utilization was assessed. Finally displacement effect was evaluated by comparing the utilization ratios within the wind facility, with a decrease in the activity being observed with the decrease of distance from nests to the wind facility centre.

2.4. FATALITY ASSESSMENT

One of the key negative impacts associated with renewable energy developments is the occurrence of fatalities of birds and bats (Erickson *et al.* 2001; Drewitt & Langston 2008; Calvert *et al.* 2013). In order to properly evaluate these impacts it has been necessary to quantify the direct fatality caused in both groups of species, by providing methods that can be applied to estimate both fatalities (Drewitt & Langston 2006).

The quantification of this impact must take into account those factors that introduce bias into the estimations, and not be limited to the fatalities identified during carcass searches around the structures. Some factors have already been identified such as (Bernardino *et al.* 2013):

(i) Lack of detection of carcasses from the observer when conducting the searches;

(ii) Removal of carcasses between searches, by scavengers or decomposition processes; and

(iii) Partial coverage (*e.g.* due to insufficient search area and sampling of the turbines/solar plant area).

To reduce the biases introduced by these factors, it is vitally important to produce correction factors that are specific to each study area. Once defining the correction factor and the appropriate estimator, the number of fatalities can be calculated. However it needs to be taken into account that the formulas published up to date can yield varying results, indicating that the estimations may not be as accurate as desired.

The amount and variability of correction factors and estimators produced can be adapted to suit several situations and be applied to locations with different characteristics and limitations. However it is necessary to understand the consequences of implementing one estimator instead of another in each situation. A number of studies have compared the different methodologies in post-construction monitoring programmes providing valuable inputs into choosing the appropriate estimation method (Strickland *et al.* 2011; Huso 2011; Korner-Nievergelt *et al.* 2011; Warren-Hicks *et al.* 2013; Bernardino *et al.* 2013; Péron *et al.* 2013).

2.4.1. Carcass search

Carcass search techniques have varied considerably through the years, especially considering the following factors: (i) Search protocol; (ii) Search Area; and (iii) Search Frequency and duration.

i. SEARCH PROTOCOL

Depending on the area to be searched and the terrain characteristics, different search methodologies and survey effort (time spent by the observers) may be required. Most studies recommend the utilization of linear walked transects of the search area, with each transect separated by 10 m apart (Arnett 2005; University of Bristol / BCT 2009). Other studies recommend the utilization of smaller distances between transects, approximately 6 m, in order to enhance coverage (Strickland *et al.* 2011; USFWS 2012), assuming that this distance may vary from 3 to 10 m depending on the ground cover and the visibility associated (USFWS 2012).

However in difficult terrain or with inaccessible areas, conducting linear transects may not be feasible. In these cases, the observers may choose to conduct the carcass search by dividing the study area into quadrants and using a zig-zag survey pattern (Travassos *et al.* 2005; ICNB 2009; USFWS 2012). Using this methodology the observer is able to account for the differences in terrain and can adjust the survey results accordingly.

The time spent conducting surveys (search effort) may be varied, according to the size of the area and the terrain characteristics which may hinder the observer. According to Erickson (Erickson 2004) the search effort may be between 10 minutes and 2 hours, considering that the observer may walk at a speed of 30 to 60 meters per minute. Strickland *et al*. (2011) has given the following formula to estimate the effort required (T), in hours, to a given area (A):

$$T = 0.7927\, A + 0.857$$

This formula assumes that the search protocol would be made through linear walked transects, separated by 6m, and the observer walked at 35 meters per minute.

Some guidelines refer to and recommend the use of trained dogs to search for bats and birds carcasses, instead of using just human observer search protocols (Rodrigues *et al.* 2008; APA 2010; Strickland *et al.* 2011). These recommendations are based on scientific evidence of the improved efficiency of searches made by human and dog teams (Homan, Linz & Peer 2001).

Arnett (2006) performed tests in two wind energy facilities in West Virginia and Pennsylvania (U.S.A.), using a Labrador Retriever. In these efficiency tests, the human and dog team detected 71-81% of carcasses, while human observers detected 14-42% of the carcasses placed. Both the human and dog team and human observers found a higher proportion of carcasses within 10m of the turbine, mostly in open ground. In Portugal a similar study was also produced, using a German Sheppard, obtaining an average detection rate of 96% of carcasses, while human observers had an average efficiency of 9% (Paula *et al.* 2011). In the U.K. a recent study by Mathews *et al.* (Mathews *et al.* 2013) assessed the efficiency of a dog and human team through formal blinded trial where dogs located 73% of bats, and humans only found 20%. Dogs were also faster at finding carcasses, taking less 25% time than humans. This fact can help reduce the costs associated with training of the human and dog team and make this methodology more cost-efficient than expected.

Paula *et al.* (2011) also tested for the influence of environmental factors on the detection time of human and dogs teams, concluding that temperatures above 17ºC (or lower) would increase the time required for a dog to detect a carcass. Considering the climate of the MENA countries this may be a thwart the use of this methodology, as average temperatures are generally above this threshold throughout year.

SEARCH AREA

i. Wind Power

In order to establish sound fatality estimates it would be ideal if all turbines could be surfed for carcasses. However, considering the size of most commercial facilities and the number of turbines in each, surveying the area around each turbine is not an economically viable option. Therefore, in order to obtain a reasonable cost-efficient approach, turbines need to be sampled.

In the U.S.A. the search of at least 30% of the wind turbines, to a minimum of 10 turbines is recommended (Strickland *et al.* 2011). Turbines are to be selected randomly or via a systematic sample with a random point start (Strickland *et al.* 2011; USFWS 2012), and the fatality observed in these turbines is extrapolated to the wind energy facility site. Other approach is to design the systematic random sample with stratification among the different habitat types to account for differences in fatality rates among different habitats, with a sufficient number of turbines selected within each stratum (USFWS 2012).

In Europe, where wind energy facilities are generally smaller, all wind turbines are searched (Rodrigues *et al.* 2008; University of Bristol / BCT 2009). However in the few wind energy facilities with a larger number of turbines it is possible to do a sampling, though most of guidelines do not require a minimum number of turbines to search (Rodrigues *et al.* 2008).

Though in some situations sampling areas with ridges or high slopes may render a section of the area around the wind turbine non-searchable it is important to include also those turbines in the sample, as it is known that this type of relieve may influence the occurrence of fatalities on soaring bird species (De Lucas, Ferrer & Janss 2012). A recent study (Sonnenberg *et al.* 2013) performed carcass searches in a smaller section of the plot and compared it with the results of a full plot search. After applying the necessary correction factors for the smaller search area approach, the conclusion was that the fatality estimates obtained through this method were very similar to the ones obtained from the full plot search.

Once turbines are randomly selected it is recommended that the same turbines are searched in each visit. By searching the same turbines, field bias assessment trials (e.g. searcher efficiency trials) only need to be performed on these locations and the influence of habitat or other environmental variables can be ruled out. Furthermore the searches conducted in each turbine will always be regularly spaced apart, which is a requirement of some fatality estimators.

Concerning the area to be surveyed around each turbine it can be a circular plot or a square plot. Based on published studies, Strickland *et al*. (2011) in the U.S.A. recommends the search radius around each turbine (circular plot) to be equal to the maximum height of the turbines, for birds (between 90-120m), while in Europe Atienza *et al*. (2011) suggests a more cost-efficient approach, recommending the search area is minimum 10% larger than the rotor diameter, being possible to adapt to the terrain characteristics and vegetation.

Other studies in Belgium have developed a formula to determine the optimum search radius (in meters) could be achieved by a formula (Everaert 2008), in order to detect 99% of bird fatality:

*Radius = 1.0976 * Turbine height – 21.707*

Turbine height in this case is defined as the tower height plus the length of the turbine blade.

More recent studies have also presented a formula based in a Monte-Carlo model to determine the search radius around turbines to assure the detection of 95% of the fatality (Hull & Muir 2010):

$$Y_{\mathrm{Max}} = \mathrm{a}H_{\mathrm{Tower}} + \mathrm{b}R_{\mathrm{Max}} + \mathrm{c}\ ,$$

Y_{Max} is the maximum search radius, H_{Tower} is nacelle height and R_{Max} is the blade length. The constants *a*, *b* and *c* are set values defined in accordance with the size of the carcass (Bats, Small birds or Large Birds).

Using the above formulas to obtain search radius which would allow for the detection of almost all fatalities (assuming a tower height of 120m and a blade length of 60m) the search radius would amount to 110m (according to Everaert, 2008) or between 83m and 150m (according to Hull & Muir 2010, for small birds and large birds, respectively)[4].

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[4] Note however that the Hull & Muir (2010) study included different sizes of turbines for their ballistic model, but two of the sizes considered are already obsolete and no longer used in current wind energy facilities. The study also considered birds of tree different sizes: Large birds, with a mass of 4.2 (±0.3) kg and a surface area of 0.6 to 0.07 m^2; Medium birds, with a mass of 680 (±25) g and a

Such a search radius would have time and cost implications, which may not be reflected in a significantly higher number of carcasses detected in comparison with surveys conducted using a smaller search radius, as it is known that most birds and bats fall closer to the turbine tower (Hull & Muir 2010; Strickland *et al.* 2011; Sonnenberg *et al.* 2013).

If the resources can be allocated the approach of searching the total area may be more correct, however considering a cost-efficient approach, concentrating the efforts in areas closer to the tower is considered a better approach.

i. Solar power

For solar energy few publications have been found on the subject. The studies available have searched the entire area of the solar parks, around the heliostats and towers (McCrary *et al.* 1986; Labinger 2012).

SEARCH FREQUENCY AND DURATION

The number of carcasses found during searches does not necessarily correspond to the actual number of birds and bats killed at wind farms because, among other factors, carcasses can be removed (e.g. by scavengers or decay) from the site. An inappropriate search interval can therefore be an important error source in fatality estimation. Few studies have compared different search interval schemes in order to achieve an optimal design (Péron *et al.* 2013).

In the U.S.A. the search interval may vary between 1 and 90 days. Shorter intervals are generally recommended to situations where the carcass removal rate is very high and the carcasses have small dimensions (USFWS 2012). For example, if fatalities of smaller species (e.g. small birds and bats) are expected, search intervals of less than 7 days may be necessary as the carcass removal rate is expected to be higher. If on the other hand the focus of fatalities is on large birds and carcass removal is low, longer interval searches can be considered (14-28 days or more) (Strickland *et al.* 2011; USFWS 2012).

In Europe the survey protocols vary according to the objectives of the post-construction monitoring and the available resources. In Spain the maximum recommended interval between searches is of 15 days (Atienza *et al.* 2011).

However, frequent carcasses search usually imply a higher cost to the developer, so visits tend to concentrate in certain periods of the year, depending on the affected species, when higher mortality rates are known or are likely to occur. For example, if a raptor species uses the study area during the entire

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surface area of 0.1 to 0.045 m^2; and Small birds, with a mass of 11.5 (±0.25) g and a surface area of 0.0036 to 0.0013 m^2. However, the model developed for mid-sized bird was not considered robust enough by the authors. Therefore some limitations persist for the determination of the fall zone of medium sized birds.

year, then carcass searches should be conducted during the same time period. However for migrant species of for hibernating bats is not relevant to conduct carcass searches directed to these species during the time periods when they are not active in the project area (USFWS 2012).

2.4.2. Field bias assessment

As referred previously, to estimate the actual fatality caused by the infrastructures it is necessary to reduce the bias caused by at least three factors: (i) carcass persistence (due to scavengers action or decomposition); (ii) searcher efficiency and (iii) searcher area corrections.

CARCASS PERSISTENCE

Carcass persistence can be assessed through field trials, which consist of the placement of carcasses in the area where the impact is expected to happen (the area surrounding wind turbines per example). Carcasses are then surveyed at regular intervals by a human observer in order to determine the amount of time taken for the carcass to disappear.

Recent carcass persistence trials consider three types of carcass for analysis of multiple scenarios. Usually trials that consider birds use up to three classes of size, associated to small, medium and large sized birds (Bernardino *et al.* 2011; Villegas-Patraca *et al.* 2012). The exact size of each class is usually defined considering the bird community of the study area, in order to reproduce plausible scenarios of collision with wind turbines or other structures. In these trials the carcasses used were usually acquired in an aviary or were used the carcasses detected during searches. Kerns *et al.* (2005) recommends the utilization of fresh carcasses and not frozen, in order not to influence the removal rate.

The selection of locations to place carcasses can be made randomly or using a random stratified distribution considering the several biotopes present in the study site.

Carcass persistence trials should also, whenever possible, consider the several seasons of the year, due to the environmental variables that may change the carcass conditions of decomposition, and also due to changes in the predators/scavengers community, which may influence the carcass disappearance rate (Morrison 2002; Warren-Hicks *et al.* 2013).

Considering the sample dimension (i.e. the number of carcasses) Strickland *et al.* (2011) recommends the utilization of at least 50 carcasses for each combination of factors in study (carcass dimension, biotope, season, among others). Other researchers' state however that simulation results indicate that, in low removal rate scenarios, a sample of 30 carcasses is sufficient to provide statistically robust results, being therefore possible to minimize animal sacrifice (Bispo, *pers. comm.*)

The utilization of a high number of carcasses is useful in giving statistical robustness to the calculation of the estimator. However, in relatively small study areas, the area may be saturated with such a high number of carcasses and lead to a bias of the normal carcass persistence rate (Smallwood 2007).

Smallwood *et al.* (2010) has shown that the persistence rate is very different in a situation of higher or lower density of carcasses in a given area.

Despite the outcome of this study, there is still no clear indication of the maximum number of carcasses to use in a given area (density of carcasses) without changing the natural persistence rate. This value may also be variable because of own characteristics of the study site which further complicates its assessment and prediction.

Once the locations have been selected and the carcasses placed at each of these locations, it is necessary to verify and determine the moment when each carcass is decomposed or scavenged. Several visit protocols have been presented up to date:

a. Daily visits (once a day) (Johnson *et al.* 2003);
b. Regular visits, with intervals of more than 1 day (Schmidt *et al.* 2003);
c. Irregular visits, with frequent visits in the first days and far between in the next days (Young *et al.* 2003a).

A recent simulation study has compared four different visit protocols (less frequent and more frequent), concluding that whenever possible the inspection protocol should be extended up to a minimum of 21 or more; and that one week length protocols should always be discarded (Bispo, *pers. comm.*). Since usually carcasses have a higher probability of being removed during the first days after placement (Bispo *et al.* 2013), a good cost-efficient protocol is the one which considers daily visits for the first four days and then at day 7, 14 and 21 after placement (Bispo, *pers. comm.*).

SEARCHER EFFICIENCY

Even when an observer has experience performing carcass searches or a human and dog team is used, the probability of carcass detection is hardly 100%. With human observers several factors may diminish its detection probability such as: dimension and decomposition of the carcass, vegetation present, topography, weather conditions, search effort at each wind turbine, and lastly by intrinsic factors of the observer (*e.g.* motivation, fatigue) (Warren-Hicks *et al.* 2013).

In order to determine the detection success probability the most widely used methodology consists in distributing carcasses around turbines, immediately before searches (to minimize the risk of carcass disappearance). At the end of the trial the carcasses found by the observer are counted and taking into account the total number of carcasses placed, and a detection rate (%) of the observer obtained (Erickson *et al.* 2000).

Considering that the variables referred above which influence the carcass persistence probability, are similar to those that can influence the probability of detection, several authors suggest that both trials can be made simultaneously, reducing the associated costs. This situation is however dependent of the number of carcasses placed, and if all fit within the area surrounding the wind turbine.

Strickland *et al*. (2011) recommends the utilization of a sample equal to or in excess to 50, for each combination of factors. However, as referred previously, this may be a problem in certain situations. To keep the sample with an adequate dimension for statistical testing, detection trials may be done separately from the carcass persistence trails, using models to simulate the different carcass size and avoiding the sacrifice of a high number of animals. In a study conducted at two wind facilities at Serra de Candeeiros, Portugal (Bernardino 2006) three size classes were used, to simulate birds of small, medium and large size that were present in the study area and could potentially collide with wind turbines.

Bernardino (2006) also proposed a new approach to include the different types of vegetation in the experimental design of the detection tests. The search area was mapped concerning the vegetation type and the different biotopes were characterized for their visibility, through the *Vegetation Profile Board* method. The biotopes were then grouped into classes of visibility. The visibility tests were performed in representative areas of each class of visibility. In each replica the three size classes models were equally distributed, being the areas searched by several different observers. The detection probability was then estimated by averaging the probability detections of each biotope considering its representation around each turbine. This is considered to be a very accurate but requires considerable effort and cost.

Other approach can be made, though it only applies to carcass searches using linear transects. The detection probability for this methodology can be calculated by assuming that the probability to detect a carcass diminishes with the increase of distance of the carcass from transect, also a carcass that is in the transect line has 100% of being detected. For this is also necessary that the observer records at which distance from the transect (perpendicular) the carcass was found (Kerns, Erickson & Arnett 2005).

A simplest approach can also be made by assuming that searcher efficiency will only be influenced by its ability to walk through the terrain. Therefore a simple method would be to separate the areas that a searcher would cover during carcass search from the areas that would not be searchable due to topography or vegetation factors (e.g. steep areas, dense vegetation). The trials would therefore only be made in these searchable areas, considering that visibility would be equivalent within these (Bio3 2010, 2011; Stantec Consulting 2012). The estimation of the fatalities should then take into account the proportion of area effectively searched.

SEARCHER AREA CORRECTIONS

As referred above, sampling all wind turbines or the total solar plant area may not be a feasible situation, so in most cases a sampling of the turbines or the area of the solar plant will be advisable. To address this situation a simple extrapolation is usually done to infer the fatalities observed in the locations that were not monitored (Strickland *et al.* 2011).

Some authors have identified however some constraints within the turbines or the area selected to be searched. Vegetation and topography are among the main causes that hinder the progression of the observers in the field, with some surveys in some areas being almost impossible (e.g. heavily vegetated areas, high slope areas) (USFWS 2012). Therefore to provide accurate estimations it is required to accurately delineate and map the areas that are effectively searched within the search area (Bernardino 2006; USFWS 2012). The fatality estimation can then be adjusted by multiplying for the area that was not searched (Kerns, Erickson & Arnett 2005).

Other studies go beyond the simple mapping of searchable vs. non-searchable area, by establishing habitat visibility classes for each landscape within each search plot and the estimation of the field bias estimators to be assessed for those visibility classes (Arnett 2005; USFWS 2012).

Financial constraints also play an important role in selecting the search radius around each wind turbine. In many cases the search may be restricted to the smaller hypothesis possible. Since searches are limited in frequency and in the number of locations, the fatality estimation must also account for an insufficient search radius, without forgetting the hypothesis that carcasses may have fallen outside the search radius (Bernardino *et al.* 2013). This can be achieved by taking into account the fall zone of each bird, as the study of Hull & Muir (2010 suggested. However considering the limitations of this study referred to above (section 2.4.1) this may not be a viable option, being considered as a field of study still to perfect.

2.4.3. Fatality estimation

The application of correction factors to the observed fatality, for both wind and solar facilities, implies the utilization of a mathematical formula, commonly referred as the “fatality estimator”. Though several different fatality estimators have already been presented, they all have the same principle, with is to divide the number of observed fatalities by the probability of a carcass not being detected by the observer and not be decomposed or removed by predators/scavengers between searches. Although based on the same principle, the estimators developed have different statistical assumptions. According with these assumptions the estimators can be divided into empirical estimators, conceptual model estimators and model-based estimators (from less to more complex).

i. **Empirical estimators**

These were the first estimators to be developed and therefore their application is very simple and intuitive. One of the simplest estimators, and also most widely used was developed by Jain *et al.* (Jain *et al.* 2007), where the correction factor results from the following product, where *Sc* is the proportion of not decomposed or predated carcasses between searches, *Se* is the detection rate of the observer and *Ps* is the proportion of turbines of the wind energy facility searched:

$$\pi = S_c \times \mathrm{S_e} \times \mathrm{P_s}$$

There are however more complex estimators among the same group of empirical estimators, such as Erickson *et al.* (2000); Shoenfeld (2004); Kerns et al. (2005), among others. Nowadays it is widely known that these estimators are responsible for significant bias in the estimations obtained (Huso 2011; Korner-Nievergelt *et al.* 2011). Therefore these estimators should not be used nowadays for fatality estimation.

ii. Conceptual model estimators

These estimators, such as those developed by Huso (2011) and Korner-Nievergelt *et al*. (2011), when compared to the empirical estimators of Johnson *et al.* (2003) and Shoenfeld (Shoenfeld 2004), have a better performance in most of the situations assessed (Bernardino *et al.* 2013). However, still in particular situations the Huso (2011) estimator also presented high errors when intervals between searches were short and the carcass rate of persistence was very high or the opposite (see Table 8 - Estimators' assumptions and limitations (adapted from Bernardino *et al*., 2013)

Estimator	**Assumption**			
	Search area	**Search frequency**	**Carcass persistence**	**Searcher efficiency**
(Erickson *et al.* 2000)	The estimation is adjusted based on the proportion of turbines searched.	No requirements.	Adjustment based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches.
(Shoenfeld 2004)	The estimation is adjusted based on the proportion of turbines searched.	The number of searches is assumed to follow regular interval searches.	Adjustment based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow a Poisson distribution or an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass not found during the first search can be found in a subsequent search, and new and old carcass have the same detection probability
(Kerns, Erickson & Arnett 2005)	Adjustment term accounts for the area that is not searched.	Implies regular search intervals.	Carcass persistence probability is estimated by the empirical survivor function.	Detection probability estimated by distance sampling analysis. Carcass not found during the first search can be found in a subsequent search. Assumes constant detection probability over time.
(Jain *et al.* 2007)	The estimation is adjusted based on the proportion of turbines searched.	No requirements.	Adjustment term based on the empirical proportion of persisting carcass after approximately half of the search interval.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass overlooked are assumed to have zero

Estimator	Assumption			
	Search area	Search frequency	Carcass persistence	Searcher efficiency
				probability to be detected in subsequent searches.
(Pollock 2007)	Not considered in the original formula.	Implies regular search intervals.	Adjustment based on the empirical proportion of persisting carcasses. The author claims to assume that the number of verifications until the first carcass removal occurs follows a geometric model.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcasses overlooked are assumed to have zero probability to be detected in subsequent searches.
(Huso 2011)	Adjustment term based on the proportion of animals that die outside the search plot and the probability of including that plot in the sample of the turbines searched.	Considers the effective interval search based on the length of time beyond which the probability of a carcass persisting is less than 1%.	Adjustment term based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass overlooked is assumed to have zero probability to be detected in subsequent searches.
(Korner-Nievergelt *et al.* 2011)	Not considered in the original formula	Implies regular search intervals.	Adjustment term based on daily persistence probability. Carcass removal is assumed to be constant over time.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass not found during the first search can be found is a subsequent search. Assumes constant or decreasing carcass detection probability over time.

Table 9). Due to the complexity of the statistical analysis required the application of this type of estimators is still not very widespread (Bernardino *et al.* 2013).

iii. Model based estimators

Very recent studies (Korner-Nievergelt *et al.* 2013; Péron *et al.* 2013) have proposed the determination of the real fatality through the development of mathematical models for each study area. Though no comparisons with the other two types of models have been performed, it is expected that the estimations produced will have less bias. However considering the complexity of developing mathematical models, the costs associated with the data analysis and experimental design would increase, possibly decreasing the relation cost-benefit of implementing these types of estimations.

The selection of an estimator may be dependent upon the characteristics of the study area, effort and budget for the study. The choice of an estimator and the adoption of the wrong assumptions will lead to significantly biased estimations that will not assess properly the impact caused by the infrastructures evaluated. Bernardino *et al*. (2013) compared the different estimators as well as their assumptions coming to the conclusion that several other sources of bias exist, and that are still not contemplated by these estimators (see Table 8). Therefore practitioners must choose the most adequate model to the conditions of their study design; bearing in mind and taking into account its strengths and limitations (see Table 9).

Nonetheless recent reviews of the estimators developed up to date (with exception of the Model based estimators) have come to the conclusion that all estimators introduce bias, due to intrinsic violation of the own model assumptions (Warren-Hicks *et al.* 2013). Such violations include the fact that searcher efficiency and carcass persistence are time-dependent variables and that quantities are constant or sufficient well represented by their averages. Other assumptions however are common to several estimators and can be taken into account in study design (Warren-Hicks *et al.* 2013; Bernardino *et al.* 2013):

i. Number of carcasses is zero at the start of the survey period. Since carcasses can remain for long periods in the study area and in most cases is not performed a 'clean sweep' of the search plot prior to the start of the survey period, there is no guarantee that a carcass found during the first search died corresponds in fact to that survey period (e.g. in the last seven days, assuming weekly searches);

ii. All collisions to fatalities found within the search area. This assumption may be false as collision may result in fatalities that fall outside of the study area, but also in injuries non-fatal, which allow birds to move away from the search area, if they have fallen inside it;

iii. All fatalities discovered during carcass search result from impacts of the wind turbine. This assumption may not be correct, though it can be overcome by appropriate assessment in field;

iv. All fatalities occur uniformly through time. Fatalities occurrence is proven to be dependent from weather variables, diurnal and seasonal patterns, or migratory movements (Barrios & Rodríguez 2004; Barclay, Baerwald & Gruver 2007; De Lucas *et al.* 2008);

v. Carcasses overlooked have zero probability to be detected in subsequent searches. Once again, carcasses can remain for long periods in the study area (especially large birds). Thus, if a carcass is overlooked by an observer, it may remain available for detection for several searches after its death. This assumption is already taken into account by model-based estimators; however in the previous ones this assumption was used.

Table 8 - Estimators' assumptions and limitations (adapted from Bernardino *et al.*, 2013)

Estimator	**Assumption**			
	Search area	**Search frequency**	**Carcass persistence**	**Searcher efficiency**
(Erickson *et al.* 2000)	The estimation is adjusted based on the proportion of turbines searched.	No requirements.	Adjustment based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches.
(Shoenfeld 2004)	The estimation is adjusted based on the proportion of turbines searched.	The number of searches is assumed to follow regular interval searches.	Adjustment based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow a Poisson distribution or an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass not found during the first search can be found in a subsequent search, and new and old carcass have the same detection probability
(Kerns, Erickson & Arnett 2005)	Adjustment term accounts for the area that is not searched.	Implies regular search intervals.	Carcass persistence probability is estimated by the empirical survivor function.	Detection probability estimated by distance sampling analysis. Carcass not found during the first search can be found in a subsequent search. Assumes constant detection probability over time.
(Jain *et al.* 2007)	The estimation is adjusted based on the proportion of turbines searched.	No requirements.	Adjustment term based on the empirical proportion of persisting carcass after approximately half of the search interval.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass overlooked are assumed to have zero probability to be detected in subsequent searches.
(Pollock 2007)	Not considered in the original formula.	Implies regular search intervals.	Adjustment based on the empirical proportion of persisting carcasses. The author claims to assume that the number of verifications until the first carcass removal occurs follows a geometric model.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcasses overlooked are assumed to have zero probability to be detected in subsequent searches.
(Huso 2011)	Adjustment term based on the proportion of animals that die outside the search plot and the probability of including that plot in the sample of the turbines searched.	Considers the effective interval search based on the length of time beyond which the probability of a carcass persisting is less than 1%.	Adjustment term based on the mean persistence time (in days). Considers right-censored observations. Assumes that removal times follow an exponential distribution.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass overlooked is assumed to have zero probability to be detected in subsequent searches.

Estimator	Assumption			
	Search area	Search frequency	Carcass persistence	Searcher efficiency
(Korner-Nievergelt *et al.* 2011)	Not considered in the original formula	Implies regular search intervals.	Adjustment term based on daily persistence probability. Carcass removal is assumed to be constant over time.	Adjustment term based on the empirical proportion of carcasses detected by the searches. Carcass not found during the first search can be found is a subsequent search. Assumes constant or decreasing carcass detection probability over time.

Table 9 – Strengths and limitations found on some of the assessed fatality estimators (Strickland et al. 2011; Bernardino et al. 2013). NA – Not assessed.

Estimator	Strengths	Limitations
Shoenfeld (2004)	NA	Short search intervals and long persistence times tend to bias the fatality estimates
Jain *et al*. (2007)	NA	Short search intervals and long persistence times tend to bias the fatality estimates
Huso (2011)	Very low detection and high carcass removal relative to search interval the estimator appears to be less biased)	Short search intervals and long persistence times tend to bias the fatality estimates
Korner-Nievergelt *et al*. (2011)	Robust when examining a decrease of removal probability with time	Overestimate the number of fatalities when the search interval is short

3. IMPACT MITIGATION MEASURES

During pre-construction assessment mitigation measures should be suggested to reduce the foreseen impacts. These impacts are to be assessed during construction and post-construction phase of the renewable energy developments. The same impact can be mitigated through different methods, which should be applied according with the site and species characteristics. These measures may include (Cook *et al.* 2011; Northrup & Wittemyer 2012):

- Pre-development assessment;
- Avoid sitting near known nets or habitat used for nesting, migration, foraging, soaring for large birds, or other activities that may encourage collisions;
- Curtailment during sensitive seasons, high wind and when threatened species are present;
- Replace older towers (repowering);
- Removal of towers with high mortality rate (relocation);
- Move known anthropogenic food sources (scavenging birds);

- Habitat management.

According to some authors (Cook *et al.* 2011) some methods are more efficient than others, being expected to reduce more extensively the probability of impact (see Table 10). Therefore the evaluation of the effectiveness of the mitigation measures may be required when fatality or habitat impacts are expected (Strickland *et al.* 2011).

The evaluation of the effectiveness of such measures is not expected to be an easy task, as according to some authors, the best way to provide this evaluation is by relating the mitigation with presence/absence of deaths. However being bird deaths considered a rare event, statistically this methodology should not be adequate. Still presently this seems to be the only way to assess the efficiency of mitigation measures, as the quantification of dead birds can provide information regarding the influence of turbines on abundance and population dynamics (Strickland *et al.* 2011).

Table 10 - Synthesis of the main mitigation measures implemented in each stage of the mitigation hierarchy presenting their foreseen efficiency, and mitigated impacts (adapted from Cook *et al*. 2011).

Impacts	Mitigation Hierarchy Stage	Mitigation Measure	Efficiency
Fatality Disturbance and/or displacement Barrier effect Decreased fecundity and breeding success	Avoidance	Layout adjustment	High
Fatality	Minimization	Shutdown on demand of turbines	High
		Increasing turbine visibility: Blades painted with black and white patterns	Medium
		Habitat management	Medium
		Laser deterrents	Medium
		Increasing turbine visibility: Ultraviolet-reflective paint; Use of lighting	Low
		Auditory deterrents	Low
		Visual deterrents	Unknown
		Reduce Reflection effects	Unknown
Disturbance and/or displacement Decreased fecundity and breeding success	Restoration	Habitat management	Medium
Fatality Disturbance and/or displacement Decreased fecundity and breeding success	Compensation	Habitat management Removal of invasive species Construction of habitat for endemic species	Medium

Although good planning might eliminate or reduce impacts in a pre-construction phase of the project, avoiding the occurrence of impacts, they might still persist. Even if the impacts are still present through the operational phase of the project, mitigation measures can be implemented (one or several) to reduce impacts.

Most of the mitigation measures are designed to prevent the occurrence of fatalities, since this is the most definite and significant impact on most impact assessments. In addition, impacts such as displacement or barrier effect can also be mitigated though usually measures to prevent this type of impact are more effective if implement during the planning phase of the project, in a pre-construction assessment phase.

Mitigation can generally be divided into three main types including (Johnson *et al.* 2007):

- Adjustment of the sitting of entire wind/solar energy facilities as well as placement of individual turbines within wind plants to reduce the possibility of collision impacts as well as impacts related to displacement of wildlife;
- Adjustment of turbines/solar panels, weather (met) masts and other wind/solar plant structures to eliminate or reduce collision fatality;
- Alteration of habitats to affect wildlife use (e.g., reduce prey abundance within wind/solar facility, improve raptor nesting habitat away from the wind facility).

These types of mitigation measures are usually associated with specific phases of the mitigation hierarchy: modification of the sitting is associated with the avoidance phase of the mitigation, where the developer must seek to avoid causing negative effects over biodiversity; modification of the turbines can be implemented during the minimization phase, when impacts cannot be avoided, and some aspects of the project characteristics must be modified to minimize the impacts foreseen; while modification of habitats is associated with the two last phases of the hierarchy, the restoration and/or the compensation. Measures related to these types of mitigation will be discussed below.

3.1. AVOIDANCE PHASE – SITTING AND LAYOUT ADJUSTMENT

WIND AND SOLAR POWER

The most effective way to reduce or prevent the occurrence of impacts is to carefully place facilities or certain parts of facilities away from areas expected to potentiate the occurrence of impacts (European Commision 2010; Atienza *et al.* 2011; Strickland *et al.* 2011; Northrup & Wittemyer 2012; Hernandez *et al.* 2014).

Areas to avoid include areas of generally high density of birds, foraging areas, nesting areas, roosting and resting areas, wetlands, rookeries, flight paths, and foraging sites for soaring birds, migratory routes (Johnson *et al.* 2007; Kuvlesky *et al.* 2007; Smallwood *et al.* 2007; Carrete *et al.* 2009; Dahl *et al.* 2012). Also within a facility, microhabitats used by raptors also should not be considered in order to reduce collision risk such as swales, ridge tops, canyons, and rims (Johnson *et al*. 2000 *in* Johnson *et al.* 2007).

The assessment of the characteristics of the proposed development and the risks posed to the resident wildlife site can be made in a pre-development phase, however if the right variables are not considered, these assessments may poorly predict the associated impacts (Ferrer *et al.* 2012). A more accurate assessment should therefore consider the individual turbine level taking species-specific factors into account. This is particularly important for soaring birds, as the placement of turbines in certain areas with certain wind currents will increase the risk of fatalities (De Lucas *et al.* 2008; Ferrer *et al.* 2012; De Lucas, Ferrer & Janss 2012).

The study developed by Bright *et al.* (Bright *et al.* 2008) in Scotland created a map of bird sensitivities in order to help reduce conflict between sensitive bird species and onshore wind facilities. This map can help in strategic decisions regarding placement of wind energy developments in Scotland, facilitating local guidance to minimize conflict with bird species of conservation priority.

Considering the lack of long-term monitoring research studies regarding the impacts that solar parks have on biodiversity, especially on birds, this phase may be the most important to mitigate any possible negative impacts (Tsoutsos, Frantzeskaki & Gekas 2005). Therefore, during the planning stage a careful site selection is essential to avoid the placement of proposed projects within or close to areas protected by international conventions, by natural and regional regulations or with special characteristics that make them important for bird populations (Peschel 2010).

3.2. MINIMIZATION PHASE

WIND POWER

i. Shutdown on demand of turbines

Shutdown on demand techniques refer to the possibility of stopping operational turbines when dangerous situations are identified. This requires the use of real time surveillance programmes while the facility is operational or during more sensitive time periods (*e.g.* migration). Surveillance of this kind demands for specialized personnel to be involved, and as a result this option may be costly to implement.

This mitigation method has already been evaluated for its effectiveness, and regarding shutdown on demand of the turbines by human observers this seems to be the most effective mitigation technique tested so far in reducing fatalities. Studies have already been published evaluating this method for birds (De Lucas *et al.* 2012) demonstrating that through temporary shut downs griffon vulture fatalities have decreased by half, with only a slight reduction in energy production.

Other studies have tested for automated methods to stop wind turbines, in addition to human observers. Their results have shown that these systems effectively detect flying birds in real-time and take the necessary action to present the impact (by stopping the turbines). These systems are often based on video recording images, as DTBird® (Collier, Dirksen & Krijgsveld 2011; May *et al.* 2012), radar technology, as Merlin SCADA^{TM} Mortality Risk Mitigation System (Collier, Dirksen & Krijgsveld 2011) or detection by transmitters (VHF or GPS), as ReCON system (Sutter, Grandgent & Martin 2013) (Box 4).

Box 4 – Mitigation measures using shutdown on demand.

Efficiency of Shutdown on demand

Griffon vulture fatality at wind facilities in southern Spain: Distribution of fatalities and active mitigation measures

In Spain, a study was conducted to assess the consequences of stopping turbines on Griffon Vulture fatalities and on total wind energy production (De Lucas *et al.* 2012). The study was conducted in Gibraltar, a known crossing location for Palearctic soaring migrants. Thirteen wind facilities and 296 wind turbines were considered, using data on bird movements before the construction, after the construction previous to implementation of selective stopping and after construction with the implementation of minimization measure. Selective stopping was executed by observers that detected risk situations (e.g. a griffon vulture flying in a collision trajectory; a group of vultures nearby a turbine). The turbine to be stopped was communicated to the control office and within 3 min the turbine stopped rotating.

The evaluation of the selective stopping was made by determination of the extent of fatalities and their distribution in space and time, within the different wind facilities and wind turbines. Generalized linear models were used to determine differences in the distribution of fatalities among turbines, differences in fatality ages and differences in monthly fatalities before and after the implementation of selective stopping.

In result of the implemented methodology was assessed that selective stopping of turbines significantly reduced griffon fatalities, when comparing with non-selective stopping turbines during the same time period.

ii. Increasing turbine visibility: Blades painted with black and white patterns

Techniques that may increase turbine visibility include painting turbine blades to make them more visible, installing anti-perching devices to deter avian use of turbines, enclosing nacelles, and use of tubular towers (Johnson *et al.* 2007).

By increasing the visibility of the turbine blades, this method assumes that birds will have less trouble detecting dangerous situations, and will be able to see in advance the presence of the rotating blades. These mitigation measures may be effective but vary geographically and among species in the same area (Northrup & Wittemyer 2012).

There is no field evidence to substantiate the efficiency of these methods (Johnson *et al*., 2007), in spite of lab experiments showing favourable results regarding these techniques (McIsaac 2001; Hodos 2003). Laboratory experiments with American Kestrels (*Falco sparverius*) have shown that specific blade patterns have the ability to reduce the smear effect, however at a certain distance for the rotating blades, all patterns will lose visibility and the blades will look transparent (Hodos 2003).

i. Increasing turbine visibility: Blades painted with ultra-violet reflective paint

As some birds have the ability to see in spectrum of the ultraviolet, ultraviolet-reflective paint has been recommended as other option to increase blade's visibility. Although this method has shown to be effective in avoiding bird strikes against windows, as birds were able to recognize the window-covering UV stripes and grid pattern as barriers to avoid (Klem Jr. 2009), its application in wind facilities as been inconclusive to date (Young *et al.* 2003b) (Box 5).

Box 5 – Mitigation measures by increasing turbine visibility.

Effectiveness of modifying turbine characteristics - Painting turbine blades

Comparison of Avian Responses to UV-Light-Reflective Paint on Wind Turbines (Young *et al.* 2003b)

In a Wind Plant in Wyoming, North America, a study was conducted to evaluate the effects of painting the turbine blades with UV reflective paint on bird use and fatality. To do so were (i) estimated the spatial and temporal use and behaviour of birds near turbines with treatment and without treatment, (ii) compared the number of carcasses found near turbines with treatment and without treatment.

To estimate bird use were implemented point count surveys, and obtained information regarding density and abundance indexes. The observations of birds were also mapped and their position relative to turbines was estimated. Regarding fatality carcass searches were conducted and fatality estimation was calculated with the adequate correction factors for carcass removal and searcher efficiency.

ii. Reduce the use of lighting

Night-time illumination may also be used to increase turbine visibility by birds. Older studies have indicated that lights may attract or disorient birds rather than repel them (Crockford 1992; APLIC 1994), which could be a problem for nocturnal migrants. A recent study have also proven that different wavelengths may influence nocturnal birds orientation, in which white and red light interfere with the magnetic compass of migrating birds (Poot *et al.* 2008).

Besides colour, different types of illumination may have a different effect on birds, *e.g.* using intermittent lights, fatality may be reduced or eliminated according to some studies (APLIC 1994). However, other studies have not identified any relation between fatality and the presence of illumination in turbines (Johnson *et al.* 2007).

SOLAR POWER

i. Reduce reflection effects

The optimization of the characteristics of PV plants can help minimize reflections and reduce the attraction by water-insects and the birds that feed on them. Also the shadow effects caused by solar panels can alter species composition of habitat, especially in warm, dry locations (Peschel 2010).

ii. Habitat management

To diminish the attraction of areas of interest to birds, vegetation can be managed with this objective. An example of this type of management can be found on airfield in UK were grass in kept high to discourage birds to use the area, diminishing the risk of collision with aircrafts (Bishop *et al.* 2003).

Habitat can also be transformed to provide alternative areas of feeding, nesting or roosting of better quality, to drive species away from the impact locations (Bishop *et al.* 2003). For example in Scotland, a management plan was implemented to minimize habitat loss for Golden Eagle (*Aquila chrysaetos*) by creating new foraging areas away from the wind turbines (Walker *et al.* 2005) (Box 6). In Portugal a similar approach was applied by improving foraging areas of Bonelli´s Eagle (*Aquila fasciata*) away from wind turbines (Santos *et al.* 2012).

Box 6 – Mitigation measures using habitat management.

Mitigation to reduce Habitat loss Effects

Habitat management and resident Golden Eagle ranging behaviour before and after construction of a wind facility in Argyll

A study done in Scotland (Walker *et al.* 2005), assessed the spatial distribution of resident Golden Eagle before and after the construction of a wind facility. This evaluation was made because a habitat management plan was implemented to mitigate the potential habitat loss resulting from the wind facility, including forest clearance and management of existing vegetation to increase the abundance of potential eagle prey. The areas managed were located away from the wind facility to reduce the risk of eagle collisions with the turbines.

For this study vantage points were implemented and range occupancy, habitat use, foraging effort and eagle behaviour were monitored. These vantage points were surveyed before construction, during construction and during operational phase. Besides the wind facility turbine, vantage points also allowed to survey the surrounding area, considered as a reference site. Observations were made throughout the year.

Analysis of the collected data was made by calculating an index of use on a grid of 1x1km. These were used to create maps concerning the location, extent and concentration of use by eagles. Also data on eagle ranging and habitat analysed using GIS and the Animal Movement extension, to obtain maps of eagle probability movement (Kernel analysis).

Comparisons were then made regarding the maps obtained for data before and after wind facility construction for the eagles observed. The observation of a decrease in movements and in the index use in the area of the wind turbines, when comparing to a pre-construction scenario indicates an avoidance effect of the wind facility area, favouring the utilization of the felled areas.

Effectiveness of habitat management

Long term survey of wind facilities impacts on Common Kestrel's populations and definition of an appropriate mitigation plan

Due to high mortality rates of Common Kestrel observed during post-construction monitoring at one wind facility in Candeeiros, Portugal, a site-specific mitigation program was implemented to mitigate the significance of the identified impact (Cordeiro *et al.* 2013). This mitigation program aimed to reduce the fatality of this species, by using mainly habitat management techniques outside the wind facility area, which should kestrels away from the turbines.

Considering that fatality observed during the operational phase of the project occurred in the most used areas by kestrels for hunting, especially where the vegetation (mostly scrubland) was less dense, the compensation implemented was to plant native scrub below turbines (to obtain denser vegetation), and open patches inside scrub areas away from wind turbines. This way the areas around wind turbines would be less adequate for hunting and the hunting behaviour would be shifted elsewhere away from turbines.

The success of the implemented measures will be evaluated by monitoring the kestrel population and its fatalities, using the same survey methods used previous to compensation implementation for ease of comparisons. These methods include vantage points (spatial mapping and utilization of the area), nest searches, ringing of individuals and carcass searches (with application of correction factors for fatality estimation).

iii. Laser deterrents

Non-lethal laser devices can also be used to repel birds from unwanted locations. Red lasers are shone onto roosts or perch sites, forcing the individuals to leave (Glahn *et al.* 2001). This method has limited efficiency as some species seem to resist the laser beam and are not deterred, while others may present habituation to the stimulus (Blackwell, Bernhardt & Dolbeer 2002). However laser deterrents may be used to deter birds during the night, being a relevant option as a mitigation measure in wind facilities as they are visible over a large distance (Bishop *et al.* 2003; Cook *et al.* 2011).This method is pointed as having a good cost-efficiency relation as it is silent, species-specific and non-lethal, the only disadvantage being its cost (Gilsdorf, Hygnstrom & VerCauteren 2003).

iv. Auditory deterrents

Several types of deterrents based on auditory signals have been proposed over time as a form of mitigation of impacts. One of the most widely used is the use of bird alarm and distress calls to disperse birds present in unwanted areas – bioacoustics signals (Bishop *et al.* 2003; Gilsdorf, Hygnstrom & VerCauteren 2003). This method has been proved effective in several situations (Gorenzel & Salmo 1993, Mott & Timbrook 1988 in Gilsdorf *et al.* 2003; Harris & Davis 1998 in Bishop *et al*. 2003), though it may also be affected by habituation. Nonetheless bioacoustics signals are perceived as the most efficient auditory type of signal as they are based on the bird's natural instincts to avoid danger (Bishop *et al.* 2003).

Gas cannons are also used as auditory deterrents to repel birds from agricultural crops, but their effectiveness is dependent on the method used, the species and alternative sites for birds to disperse to (Bishop *et al.* 2003). Additionally pyrotechnics may also be used as a repel device due to the noise produced by its explosion, as well as the associated emission of light. This method has been tested in several scenarios, and has proven effective in scaring birds, though not a cost-efficient method, due to the labour involved (Bishop *et al.* 2003).

Besides the methods that require the emission of sound, the single modification of the structure of the turbine blade could help making them more audible to birds and therefore reduce their risk of collision (Dooling 2002).

Also, since birds are able to detect microwave signals, studies have suggested the use of this type of deterrent to warn birds of the presence of an obstacle (Kreithen 1996 *in* Johnson *et al*. 2007). However this was not perceived as effective since birds would not understand the presence of danger, but only the presence of a foreign obstacle.

Box 7 – Mitigation measures using deterrents on birds and bats.

Effectiveness of deterrents as a mitigation measure for collision with wind turbines

Evaluation of the DTBird video-system at the Smola wind-power plant

A pilot study was conducted at Smola wind-power plant, in Norway, in order to evaluate the ability of DTBird system to control and reduce bird fatality caused by wind turbines (May *et al.* 2012).

To assess the efficiency of this system the number of birds that visually responded to the audible signals, by changing their flight behaviour was determined. This was made by analysing the raw detection data of video sequences, consisting of coordinates and size of the object detected. The relative change of trajectory was calculated for each detection. The significance of this changes was tested through a linear mixed-effects model, testing for differences in bird behaviour that did not resulted in warning (control) and bird behaviour that resulted in warning, before (impact without treatment) and after dissuasion (impact with treatment).

Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent for Reducing Bat Fatalities at Wind Turbines

(Arnett *et al.* 2013) implemented a study in a wind energy facility in North America to evaluate and improve the efficiency of deterrent devices on reducing bat fatalities by comparing fatality rates at turbines with treatment and control turbines.

Fifteen of the 51 turbines were selected as control turbines for comparing with treatment turbines, those fitted with deterrent devices. The same control and treatment turbines were monitored before the implementation of deterrent devices (approximately 2 months) and after the implementation of the minimization treatment (approximately 2 months).

Carcass searches were conducted in order to assess the existence of fatalities. Only the area considered to be searchable was effectively searched for fatalities, every day, and for as long as the deterrent treatment was implemented. To account for estimation bias, searcher efficiency and removal rates were also quantified through field experiments. Fatality estimates were then determined considering the correction factors.

To assess the efficiency of the deterrents the average fatalities obtained at the different sub-sampling areas were compared using statistical analysis: differences between fatalities at control areas (turbines without treatment) and at treatment turbines (one-way ANOVA); differences between fatalities at control turbines and treatment turbines, before and after the implementation of deterrent devices (ANOVA repeated measures).

This study approach allowed determining that the average bat fatalities at turbines with treatment was significantly lower that at control turbines, indicating an effectiveness of the minimization measure implemented.

v. Visual Deterrents

Visual stimulus can be provided by effigies per example, such as scarecrows (Bishop *et al.*, 2003) and predator-mimicking devices. This type of deterrent has proved to be effective particularly with regards to reducing the presence of passerines (Gilsdorf, Hygnstrom & VerCauteren 2003).

Other type of visual stimulus can also be provided by reflective ribbons or other shiny devices. Several studies have proven the efficiency of this method in discouraging birds from using agriculture areas (Bruggers *et al.* 1986, Dolbeer *et al.* 1986 in Gilsdorf *et al*. 2003). However this method is not always effective (Conover & Dolbeer 1989), indicating that the spacing between the visual stimuli presented an important factor for its effectiveness, and that it would affect is cost-efficiency relation. This type of deterrent is also subject of habituation by birds (Gilsdorf, Hygnstrom & VerCauteren 2003).

3.3. REHABILITATION PHASE (HABITAT MANAGEMENT)

WIND AND SOLAR POWER

Rehabilitation may be implemented to reduce impacts caused by habitat loss. Though this mitigation phase is implemented in a number of projects (*e.g.* mining industry), is not a frequent consideration in wind and/or solar energy projects. Regarding wind energy, the proportion of affected area is much reduced and the rehabilitation of the removed vegetation would not have a significant impact on bird community. For solar energy frequently is not feasible to consider the rehabilitation of natural vegetation, as the area around solar panels needs to be carefully managed to prevent material damages and avoid energy production losses (Peschel 2010).

3.4. COMPENSATION PHASE

WIND AND SOLAR POWER

Compensation measures are usually species specific as they intend to balance the negative impacts, both direct and indirect, that may occur and that cannot be absolutely mitigated with resource to any of the other mitigation phases. In order to define the compensation measures to be implemented, the first step is to assess the impact and its extent (BBOP 2014). Usually compensation is obtained through habitat management actions, off-site and should restore the same natural feature, which is lost as a result of the impact.

i. Habitat management

Habitat may be managed to provide higher quality feeding locations, by improving nesting and/or roosting locations or other type of features that will improve the affected species fitness.

Improvement of feeding habitat may be achieved by creating small agriculture crops with natural landscape, supplying wildlife, both granivorous and insectivorous with additional food supplies (Santos *et al.* 2012). These small crops should provide a high edge effect offering protection from predators to the wildlife that may use these locations for feeding (Guil & Moreno-Opo 2007, 2008). This is also an indirect compensation measure for raptor species, as it increases the effectives of prey-species.

On the other hand, the improvement of already existing locations, with potential for nesting or roosting potential may compensate for other locations lost during impact. For birds, locations of interest can be old buildings (nocturnal raptors) and trees (passerines) for example.

ii. Removal of invasive species

When sections of natural habitats are affected by projects, a possible compensation measure is to recover or improve the state of other, off-site, natural habitat. Among the most common factors that lead to the decrease in quality of a natural habitat is the presence of invasive species. Therefore their removal should restore the balance of the ecosystem and improve its characteristics to the bird species that use it (among other faunal groups).

iii. Habitat creation

Creation of new habitat for affected species to replace lost one, may imply the construction of water sources, such as small ponds, in areas were the climate is dry and there are few water supplies for wildlife. Preferably, as compensation measures should be self-sustained, these locations should be built in locations where the accumulation of rainfall is sufficient to prevent the pond from drying up. Also, by promoting the occurrence of natural vegetation in the edges of the new water sources, camouflage from predators is obtained and the habitat is more adequate to a wider set of species (Nicolai 1999; Guil & Moreno-Opo 2007).

Also, besides improving the existing nesting and/or roosting locations, as referred above, new ones can also be created, such as:

- Nest boxes for passerines or raptors, depending on its characteristics (Feu 2003; Asociación Columbares 2009). These boxes have been proven to increase densities of several species (Fargallo *et al.* 2001);
- Platforms for large dimension nests, usually for large raptors that nest in large trees;
- Construction of artificial rabbit burrows (or any other roost for other prey species) will provide compensation for large birds of prey, by increasing the breeding success of the prey species and therefore the size of the population (Guil & Moreno-Opo 2007).

Box 8 – Study cases regarding the evaluation of mitigation measures efficiency – compensation phase.

Effectiveness of Compensation Measures

Compensating White-Tailed Eagle Mortality at the Smøla Wind-Power Plant Using Electrocution Prevention Measures

A study conducted in Smøla, Norway applied the Resource Equivalency analysis method to compensate for white-tailed eagle fatalities caused by a wind facility (Cole & Dahl 2013). This method implies that the size of the loss is determined (debit), the potential benefit associated with the compensation is determined (credit) and the same scale is used for both credit and debit. Is this situation the authors used the birds-year metric. The compensation measure consisted in the implementation of pylon retrofitting in the Smøla power line grid, aiming to reduce fatalities and therefore gaining credit.

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