Guidance on appropriate means of impact assessment of electricity power grids on migratory soaring birds in the Rift Valley / Red Sea Flyway

Migratory Soaring Birds Project

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Citation:
Birdlife International, 2015. Guidance on appropriate means of impact assessment of electricity power grids on migratory soaring birds in the Rift Valley / Red Sea Flyway. Regional Flyway Facility. Amman, Jordan.

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Preface

The Rift Valley / Red Sea Flyway along East Africa and the Middle East is the second most important flyway in the world for migratory soaring birds. Economic developments and the expansion of energy generation, including renewable energy (wind and solar energy) foreseen for this region, will make it necessary to considerably expand the power line network.

The objectives of this document are twofold:

1. To review and recommend the best practice (both financially viable and effective) for the EIA assessment of transmission power line development in the Rift Valley / Red Sea Flyway;
2. To develop guidance on and a framework for monitoring of post-construction mortality and effectiveness of mitigation measures.

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1 Introduction

1.1 Migratory Soaring Birds Project

The Rift Valley / Red Sea Flyway along East Africa and the Middle East is the second most important flyway in the world for migratory soaring birds (MSBs: raptors, storks, pelicans and ibises). Over 1.5 million soaring birds belonging to 37 species, five of which are globally threatened, use this corridor between their breeding grounds in Europe and West Asia and wintering areas in Africa each year. The aim of the Migratory Soaring Birds Project (http://migratorysoaringbirds.undp.birdlife.org) is to mainstream migratory soaring bird considerations into the productive sectors along the flyway that pose the greatest risk to the safe migration of these birds. These sectors comprise hunting, energy, agriculture and waste management, while activities in sectors that could benefit from these birds, such as ecotourism, are promoted by the project. Flyway issues are integrated into existing national or donor-funded "vehicles" of reform or change management in the key sectors through the provision of technical tools, content, services and support.

The Migratory Soaring Birds Project focuses on 37 species, which all have an unfavourable conservation status and are threatened to varying levels by electrocution and collisions with power lines (Table 1.1). The Rift Valley / Red Sea Flyway crosses eleven countries, namely Djibouti, Egypt, Eritrea, Ethiopia, Jordan, Lebanon, Palestine, Saudi Arabia, Sudan, Syria and Yemen.

Under the auspices of the Migratory Soaring Birds Project, the present report investigates the potential conflict between migratory soaring birds and the development of electric power lines along the Rift Valley / Red Sea Flyway. The report focuses on conflicts during the migration period of these species and does not consider conflicts during breeding and wintering, although some migratory soaring bird species may breed or winter within the study area. The intention of the report is to enable the mainstreaming of the needs of migratory soaring birds into the planning, development and mitigation of the effects of power lines at the national and regional level.

1.2 Conflict between electric power lines and soaring birds

The existing transmission line network across the Rift Valley / Red Sea Flyway will need to expand to support the requirement for affordable energy and the growth of renewable and conventional energy resources across the region. This energy requires transportation to the consumer, which requires construction of new power lines and modernisation of existing transmission networks.

Inappropriately routed and located transmission lines and poor design can potentially have significant impacts upon migratory soaring birds. The primary threats are *collisions* and *electrocution*, although *habitat loss* and *disturbance* can also be an issue. Exact numbers of birds killed through electrocution or collisions are difficult to estimate, although up to 10,000 electrocutions and many hundreds of thousands of collisions are estimated to occur in the African-Eurasian region annually (Prinsen *et al.* 2011).

There are documented events of significant mortality being experienced along the Rift Valley / Red Sea Flyway (Angelov *et al.* 2011, Shobrak 2012). Collision frequency is thought to be a contributing factor in on-going population declines in several species of cranes, bustards and diurnal raptors. Bird interactions with power lines can also cause economic losses and reduction in power availability. At the consumer level, bird strikes and roosting behaviour can cause power outages, and require expensive repair. Minimising bird collision and electrocution risk is therefore a win-win for biodiversity and the power sector.

Direct impacts on birds are primarily associated with medium and high voltage lines.

- *High voltage* power or transmission lines (60 kV up to 700 kV) form the backbone of many national grids. The design of high voltage power lines along a vertical (upward) plane with cables of low visibility is associated with *collision* risks, especially during adverse weather conditions. Higher collision risk is associated with the thin earth (shield) wire, which is found above the thicker high voltage conductor wire. As these are usually connected to pylons with long suspended insulators, electrocution risk at high voltage power lines is typically low.
- *Medium and low voltage* power lines or distribution lines (~1 kV to 60 kV) are more likely to result in *electrocution*, due to birds making a connection between two live components. This electrocution risk is most commonly associated with poles and perching areas. There is also a risk of collision, but generally less so than for high voltage power lines because the conductors are usually arranged at the same height and, compared to high voltage power lines, low above the ground.

Table 1.1 Conservation status and severity of impacts of electrocution and collision with power lines on the 37 species of the Migratory Soaring Bird Project. CMS Appendix I = Migratory species that have been categorized as being in danger of extinction throughout all or a significant proportion of their range. CMS Appendix II = Migratory species that have an unfavourable conservation status or would benefit significantly from international co-operation organised by tailored agreements. AEWA Annex 2: Species to which the Agreement on the Conservation of African-Eurasian Migratory Waterbirds applies. MoU Birds of Prey: Species of the Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia. Level of impact per species: I = casualties reported, but no apparent threat to the bird population; II = regionally or locally high casualties, but with no significant impact on the overall species population; III = casualties are a major mortality factor; threatening a species with extinction, regionally or at a larger scale (after Prinsen et al. 2011).

Species of the MSB Project		CMS Appendix I	CMS Appendix II	AEWA Annex 2	MoU Birds of Prey	Casualties due to electrocution	Casualties due to collision
Pelecanus onocrotalus	White Pelican	X	X	X		I	II - III
Ciconia ciconia	White Stork		X	X		III	III
Ciconia nigra	Black Stork		X	X		III	III
Geronticus eremita	Northern Bald Ibis	X	X	X		II (Ibises general)	II (Ibises general)
Pandion haliaetus	Osprey		X		X	III	II
Gyps fulvus	Griffon Vulture		X		X	III	II
Neophron percnopterus	Egyptian Vulture	X	X		X	III	II
Buteo buteo	Common Buzzard		X		X	III	II
Buteo rufinus	Long-legged Buzzard		X		X	III	II
Pernis apivorus	European Honey-buzzard		X		X	III	II
Pernis ptilorhyncus	Oriental Honey-Buzzard		X		X	III	II
Aquila pennata	Booted Eagle		X		X	III	II
Aquila heliaca	Eastern Imperial Eagle	X	X		X	III	II
Aquila nipalensis	Steppe Eagle		X		X	III	II
Aquila clanga	Greater Spotted Eagle	X	X		X	III	II
Aquila pomarina	Lesser Spotted Eagle		X		X	III	II
Circus pygargus	Montagu's Harrier		X		X	III	II
Circus cyaneus	Hen Harrier		X		X	III	II
Circus macrourus	Pallid Harrier		X		X	III	II
Circus aeruginosus	Western Marsh Harrier		X		X	III	II
Milvus milvus	Red Kite		X		X	III	II
Milvus migrans	Black Kite		X		X	III	II
Accipiter gentilis	Northern Goshawk		X		X	III	II
Accipiter nisus	Eurasian Sparrowhawk		X		X	III	II
Circaetus gallicus	Short-toed Eagle		X		X	III	II
Accipiter brevipes	Levant Sparrowhawk		X		X	III	II
Haliaeetus albicilla	White-tailed Eagle	X	X		X	III	II
Falco tinnunculus	Common Kestrel		X		X	II - III	II
Falco naumanni	Lesser Kestrel	X	X		X	II - III	II
Falco concolor	Sooty Falcon		X		X	II - III	II
Falco eleonorae	Eleonora’s Falcon		X		X	II - III	II
Falco vespertinus	Red-footed Falcon	X	X		X	II - III	II
Falco subbuteo	Hobby		X		X	II - III	II
Falco biarmicus	Lanner Falcon		X		X	II - III	II
Falco cherrug	Saker Falcon	X	X		X	II - III	II
Falco peregrinus	Peregrine Falcon		X		X	II - III	II
Grus grus	Common Crane		X	X		I	III

1.3 Scope of the report

Rather than being a strictly scientific document, this guidance document report is aimed at the environmental consultancy audience. The report specifies requirements in assessment techniques whilst balancing the need to be financially viable in consideration of the size and scale of the proposed power line development.

This report builds on the already existing body of information summarized in published and online reviews, articles and reports. Unfortunately, publications on the conflict of birds with power lines are scarcely available from the Middle East and East Africa. The CMS/AEWA “Guidelines on how to avoid or mitigate impact of electricity power grids on migratory soaring birds in the African-Eurasian region” (Prinsen *et al.* 2012) and the APLIC “Reducing Avian Collisions with Powerlines: State of Art in 2012” refer to some specific rationale needed when designing any assessment and monitoring protocols, and these documents form the basis of the present guidance report.

This guidance document is structured in two main sections, namely 1) a review on existing methods of environmental impact assessments (EIA) and appropriate assessments (AA) of power lines and 2) guidance on post-construction monitoring techniques. Figure 1.1 presents a schematic overview of the steps required and output.

1.3.1 Review of assessment methods

The first part of the report reviews existing methods of Environmental Impact Assessments (EIA) and Appropriate Assessments (AA) of power transmission lines, also including examples of previous EIAs and AAs. Here we also outline the information base needed for EIA/AA studies, as required by the best means of appropriately assessing the potential impacts upon MSBs.

The size and scale of networks of transmission lines being proposed present real challenges to appropriately assess the potential impacts efficiently within the EIA process and this study recommends the best practice for financially viable and effective assessment of transmission line development. We present the approaches that are required when evaluating high and medium transmission line designs, also encompassing different approaches for different lengths of transmission lines.

Consequently, the first step in scoping the development is identifying priority areas for assessment by carrying out a hotspot analysis within the relevant areas of the Rift Valley / Red Sea Flyway. The potential mortality impacts from transmission lines (i.e. electrocution and collision) coincide with different conflict hotspots, and are thus considered separately. Such hotspot analysis results in regional or national zoning maps that identify conflict hotspots as well as knowledge gaps where further data collection is needed. The Soaring Bird Sensitivity Map Tool has been designed for this very reason and provides developers, planning authorities and other interested stakeholders access to information on the distribution of soaring bird species along the Rift Valley / Red Sea Flyway (see Chapter 2.3 for a full explanation. The current report describes data collection methods and survey requirements for the collection of relevant bird data at these specific locations.

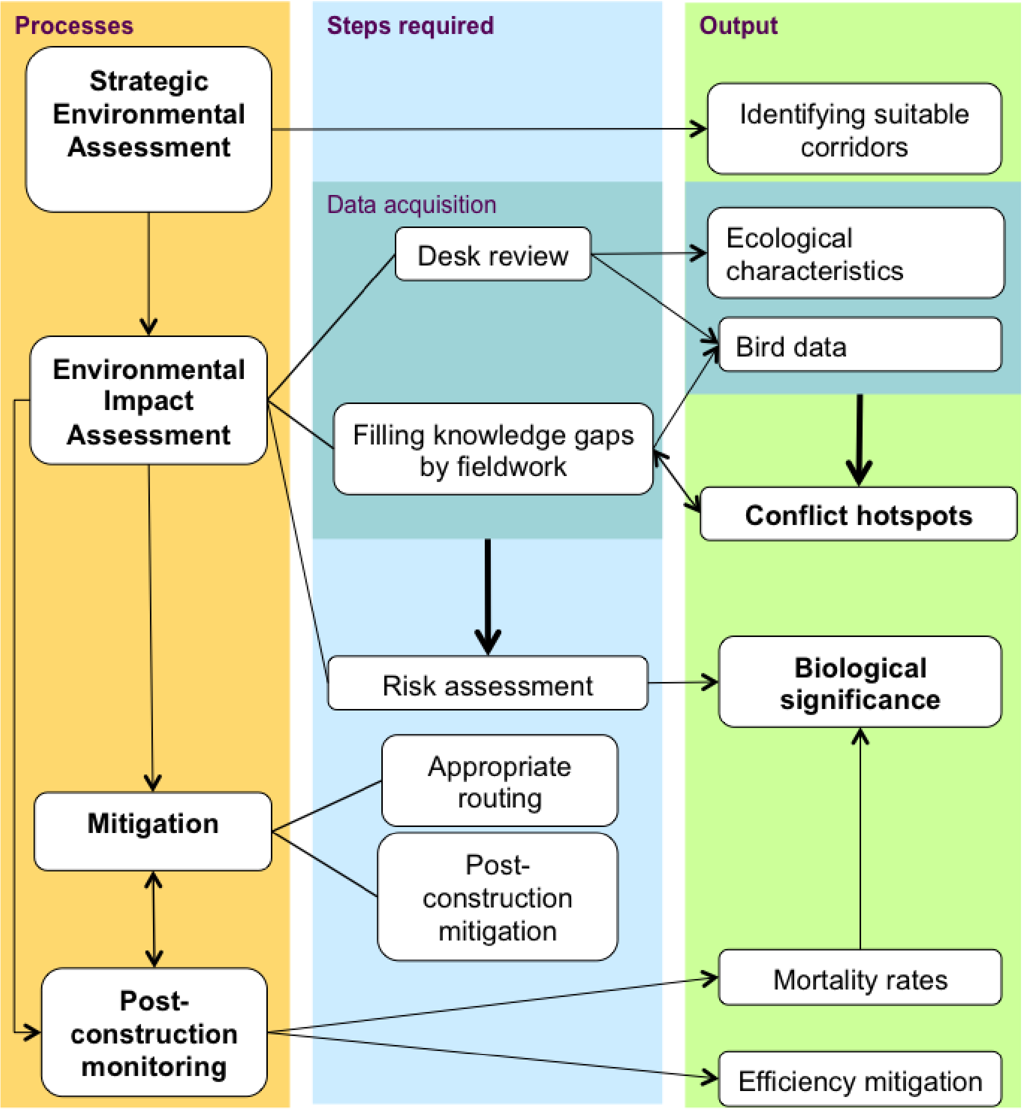

Figure 1.1 Overview of processes on appropriate means of impact assessment, steps required and output as described in this guidance document.

The available information of the hotspot analysis and additional field research should lead to best possible alternatives for network planning and line routing. Nevertheless, even after such preliminary considerations mortality remains to be expected at certain locations. In such cases, mitigation measures can be adapted already during the construction phase. The report provides a brief overview with examples for available mitigation options for electrocution and collisions with reference to available overviews on this topic.

Finally, the first part of the report includes a ‘guide to guidance’ of the most important sources of information and other guidelines relevant to the issue of bird and power line interactions. Previous guidance on general EIA/AA methodology are referenced and completed with recent information.

1.3.2 Guidance on post-construction monitoring techniques

The second part of the guidance document summarises the available monitoring techniques with which to assess post construction mortality and effectiveness of mitigation measures (both for electrocution and collisions). Because of the large scale of the power line network in the study region, techniques are presented that are financially viable when monitoring large lengths of power lines.

Several reviews (e.g, APLIC 2012, Barrientos 2011, Bevanger 1999) conclude that experimental rigour (in terms of spatial and temporal effort) and standards currently in use are insufficient to render statistically and scientific sound data. The development of a standardised and systematic methodology aims to reduce costs to developer. The use of a standardized survey technique will be of value to compare mitigation measures between species and areas or establish the impact of power lines on bird populations at the regional or flyway scale.

2 Guidance on assessment methods

2.1 Introduction

This chapter reviews existing methods of impact assessments of power transmission lines. Careful Strategic Environmental Assessment (SEA) and/or Environmental Impact Assessment (EIA) procedures should be in place and applied. These procedures should look at a large number of possible effects on the environment and ecology of any decision on the construction of infrastructure, including power lines. Predicting the possible effect on bird populations should be an obligation under any SEA and EIA procedure to be described and analysed. According to a recent enquiry among African-European Waterbird Agreement (AEWA) range states, which also covers most of the Rift Valley / Red Sea Flyway, most countries have legislative framework through which EIA procedures are applied (Prinsen *et al*. 2011).

Strategic Environmental Assessment

The Strategic Environmental Assessment (SEA) is an environmental assessment, by which environmental considerations, relative to other constraints within a particular area, are incorporated into policies, plans and programmes, in order to achieve the best possible outcome for all involved. SEA is applied at a higher level of plan or programme than EIA (i.e. it considers why, where and in what form a development is appropriate). It is particularly effective with respect to power line routing and grouping, because suitable corridors for lines can be identified proactively, well before reaching the individual project stage.

Environmental Impact Assessment

The Environmental Impact Assessment (EIA) process allows for the assessment of environmental impacts of plans or proposals at the project level, and considers potential measures to avoid them. In the case of power lines, an important step within the EIA process is defining and assessing alternative routes within the appropriate corridor. EIA processes should explain the consequences of the different alternatives. Although project based and fairly late in the power line planning process, EIA still provides a useful and essential mechanism for minimising the risks for birds. Moreover, EIA procedures also substantially help to avoid any later conflict with national and international conservation legislation, if migratory soaring species are possibly going to be killed by the power lines through electrocution and/or collision. If the EIA reveals that a project or a plan may cause significant effects on protected sites or species, it may be required to carry out an adequate assessment for that specific case. In the EU this may include an *Appropriate Assessment* (AA) if thought to influence Natura 2000 objectives.

2.2 Initial information required for assessments

The necessity of good quantitative bird data for SEA and EIA procedures is very important. Appropriate routing of an above ground power line based on adequate bird data can already substantially reduce the conflict with birds. Here we summarize the data necessary to conduct a robust assessment.

Desk-based review

A thorough search for already available data should focus, and minimise the need for field research, to appropriate areas and/or locations lacking data. Existing bird data and ecologically relevant characteristics of the study area should be reviewed and collated. After a careful desk-based study, a familiarisation visit to the site(s) should be made to validate the collected information, and the need for further field-based assessment can be determined.

Bird data

Reviewing existing bird data of the study area(s) should include the following aspects of the relevant migratory soaring bird species:

- which migratory species occur during migration or staging in the study area;
- maximum and, if applicable, mean numbers present;
- temporal variation in migratory activity;
- location of migration routes;
- local movement patterns;
- habitat requirements for staging;
- foraging habits during staging;
- conservation status of the species concerned;
- sensitivity regarding collisions or electrocution of the species concerned (see table 1.1).

BirdLife International has developed a Sensitivity Tool explicitly for the Migratory Soaring Birds Project, focusing on the Rift Valley / Red Sea Flyway. The tool incorporates known bird data from the region, also providing the locations of Important Bird Areas (IBAs) (see a more detailed description of Sensitivity Tool in Chapter 2.3). It is expected that within large parts of the region the amount of available bird data is very limited or of poor and anecdotal quality. However, evidence for the existence of, for example, important staging areas can be inferred from ecological and landscape characteristics of the areas under concern. It is an important exercise to track the route of the transmission line using this tool to highlight areas of key importance.

Relevant ecological and landscape characteristics of the study area

Reviewing ecologically relevant characteristics of the study area(s) should include the following aspects:

- any nature conservation sites (IBAs, Ramsar sites, national wildlife refuges, etc.) that fall within or in the influence zone of the power line;
- any sites likely to become protected in the near future (proposed sites for protection);
- presence of habitat types associated with high presence of birds, such as coasts, wetlands, major water bodies, fishery ponds, rubbish tips and waste water treatment sites;
- presence of topographical features that may be followed by migratory soaring birds, such as mountain ridges;

- presence of tall vegetation and other likely perches that raptors and storks may use for resting and hunting. In case of a medium voltage power line, absence of these features may indicate a higher risk for electrocution.

Information sources

A number of options exist to collect information on protected sites. National, governmental or non-governmental websites may provide useful information on:

- MSB sensitivity mapping tool for the Rift Valley Red Sea Flyway http://migratorysoaringbirds.undp.birdlife.org/en/sensitivity-map
- Integrated Biodiversity Assessment Tool IBAT (https://www.ibatforbusiness.org/login);
- national parks;
- protected areas;
- Important Bird Areas (e.g. www.birdlife.org);
- Ramsar sites (e.g. www.ramsar.org);
- World Database on Protected Areas (www.wdpa.org);
- Critical Site Network (CSN) Tool: recently updated for the region under the UNEP-GEF Wings Over Wetlands (WOW) African-Eurasian Flyways Project (www.wingsoverwetlands.org), containing information on e.g. Ramsar Sites, IBAs and SPAs.

In addition, based on the ecological and or landscape characteristics provided above, a detailed study of the following maps may further highlight important sites for migratory soaring birds that are currently not protected:

- topographical maps;
- municipality maps;
- aerial photographs or satellite images.

2.3 Identifying conflict hotspots

To enable efficient targeting of potential hotspots and appropriate design and routing of medium and high voltage transmission lines across the landscape, it is important to know and predict key locations for migrating and staging birds along the Rift Valley / Red Sea Flyway. This applies also to the successful design and application of mitigation measures such as isolation of energised parts near the pole top or wire markings (Prinsen *et al*. 2012, see Chapter 2.6 for mitigation measures). Where empirical data are limited, the identification of key areas based on ecological and landscape characteristics may be necessary. Such an approach may be necessary during the SEA or EIA processes, and can enable efficient targeting of potential hotspots and appropriate design and routing of medium and high voltage transmission lines across the landscape.

2.3.1 Geospatial analyses with bird data

Geospatial analyses, currently most often conducted by GIS tools, can facilitate the identification of critical sites. Such an approach has been conducted for existing power lines, for example in Hungary and Switzerland (see below), but can also be applied prior to construction of new power lines. In order to facilitate such preliminary analysis, BirdLife International has developed explicitly for the Migratory Soaring Birds Project an online GIS *"Sensitivity Tool",* focusing on the Rift Valley / Red Sea Flyway.

MSB Sensitivity Tool

The tool incorporates a major amount of bird data from the region, also providing the locations of IBAs. Although primarily developed in relation to wind energy infrastructure, it is also useful for power lines developments, as the basic information requirements for SEA or EIA are similar. After a spatial selection (a certain country, a site with known coordinates, a GIS shapefile or a self-drawn geometrical area) the Sensitivity Tool provides readily available information on:

- observed peak bird numbers per species;
- locations of IBAs for soaring birds;
- locations of IBAs for non-soaring birds;
- protected areas;
- satellite tracks of tagged birds (limited to a few species but with data being updated: mainly data on White Storks, and less on e.g. White Pelicans, Lesser Spotted Eagles, Eleonora's Falcons and Peregrine Falcons).

Subsequently, a sensitivity index per species is provided for the preselected area of concern based on:

- the number of birds per species observed in the area relative to the total population size;
- the vulnerability of the species to collisions and/or electrocution;
- the conservation status of the species.

Finally, the tool adds up the sensitivity indices of all the species concerned, to generate a general sensitivity index for the area as a whole (e.g. low, high, outstandingly sensitive, etc.). The developers of this tool caveat that information is scarce from a lot of areas, and even when data are provided it is not all-inclusive. Consequently, even areas with no data can be categorized as potentially sensitive. Therefore, assessments cannot exclusively be based on this tool and this first step in estimating impacts should always be combined with other data collected during the desk-based review (see Chapter 2.2).

Other examples of geospatial analyses to identify conflict hotspots

BirdLife Hungary has recently produced a "prioritized sensitivity map" for medium voltage power lines. Priority scores were based on the local population sizes of the bird species concerned, their conservation status and vulnerability to electrocution or collision. Based on the distribution of all these species, priority scores were summed for each 5 x 5 km^2 atlas square of the country to a sensitivity score (Horvath *et al.* 2008; Horvath *et al.* 2011). Similarly, the Swiss Ornithological Institute has carried out, a sensitivity mapping for White Storks and Eagle Owls in Switzerland to focus the technical rehabilitation of medium voltage power poles. Based on known breeding sites, as well as large local accumulations of White Storks during the migration period, twelve priority regions have been identified (Heynen & Schmid, 2007).

2.3.2 Geospatial analysis when bird data are lacking

If bird data are not, or only scarcely available, identifying conflict hotspots will mainly rely on *local ecological or landscape characteristics* that importantly influence the number of birds crossing or making use of an area. Generally, the ecological and landscape characteristics listed in Chapter 2.2 are likely to be associated with high numbers of staging or migratory birds. In addition, power lines crossing a known migratory bottleneck are obviously critical locations. Methods to identify conflict hotspots of migrating soaring birds and power lines are, however, different for medium voltage and high voltage power lines.

Medium voltage power lines

Medium voltage or distribution power lines are typically much lower (approximately 5 – 15 m) with smaller structures than high voltage transmission lines and are constructed with poles rather than pylons. Medium voltage power lines form a threat to migratory soaring birds mainly through *electrocution* and to a lesser extent through *collisions*. Due to the higher risk of electrocution for perching and roosting birds, medium voltage power line assessments should concentrate not on flying birds but mainly on *staging* and *roosting sites*.

Identifying staging areas

Staging areas are sites where birds can replenish their energy reserves for migration. Locations of important staging sites are partly known and some of them are designated as IBAs. Other potential staging areas can be identified by the availability of sufficient food and water in the vicinity, such as:

- coastal marshes;
- oases;
- garbage dumps;
- waste water treatment sites.

These areas can be identified to a great extent from maps or aerial photographs.

Identifying roosting sites

In addition to staging areas, migratory soaring birds use roosting sites for the night during their journey. In the case of *electrocution*, topography affects where birds will stop on their migration to roost, and vegetation structure affects the availability of natural perches in the area. A *terrain analysis* can be conducted to highlight areas where raptors and storks are likely to use power line poles as perches. Hotspots for electrocution within or close to roosting and staging sites may occur at *treeless open areas*, where birds commonly use power line poles for perching. Hotspots for collision with medium voltage power lines may occur near locations where migrating soaring birds may fly very low and are at risk to collide with the low hanging distribution lines (i.e. down valleys, at hillsides or near mountain ridges) or during daily commuting flights between staging area (see below).

High voltage power lines

High voltage transmission power lines are typically around 20 – 60 m tall. The energised and non-energised parts are so far separated that birds are not likely to bridge this distance and hence electrocution rarely occurs at these power lines. High voltage power lines mainly pose a risk for flying birds through collisions. Therefore, a spatial analysis to identify conflict hotspots for high voltage power lines needs to include an analysis of high-risk areas for *flying* birds such as:

- migratory bottlenecks;
- potential migration corridors;
- staging areas where birds conduct commuting flights at lower altitudes.

Migratory bottlenecks

Migratory bottlenecks with a concentrated flight intensity of MSBs may occur at:

- land edges;
- mountain passes;
- small crossings of considerable water bodies.

For the Rift Valley / Red Sea Flyway, this latter is obviously the case for birds crossing the Red Sea. Here, migratory bottlenecks are formed either by birds that avoid crossing the sea and follow the land above the Suez Canal, or that cross between the south-western coast of the Sinai Peninsula and the African continent.

Migration corridors

As MSBs mainly rely on thermals, migration corridors often follow:

- mountain ridges*;*
- hill slopes;
- slight depressions in the terrain with strong thermal development.

These are relatively predictable routes, which can give an indication about where a large number of soaring birds may pass by during migration. Placing power lines along or nearby such features may increase collision probability.

Commuting flights at staging areas

While staging, migratory soaring birds may also use regular flight routes during daily commuting flights if resting and feeding sites are spatially separated. Power lines crossing these flight routes pose an increased risk for collisions. Examples of locations where the placing of power lines may cause problems to commuting birds:

- a strip of land separating two water bodies;
- crossing open water bodies;
- close to refuse tips or waste water treatment sites;
- landscape features where thermals occur.

2.4 Filling knowledge gaps through pre-construction field surveys

Based on sensitivity mapping, a qualitative assessment of the study area can be conducted, identifying low and high-risk locations. This approach does not necessarily require detailed field observations, but uses reconnaissance site visits to confirm assumptions. However, sometimes a quantitative risk assessment is required, especially at *conflict hotspots*. As this approach relies on *actual bird count data*, which is scarce or lacking along the Rift Valley / Red Sea Flyway, site-specific field observations may need to be carried out. In addition, the sensitivity mapping may also identify hotspot areas where bird data may exist but the specific field conditions should be investigated in detail, e.g. at known staging sites where birds conduct daily commuting flight, but to an unknown feeding site. Characterising the flight behaviour of birds at such hotspots will help appropriate routing of the power lines and identifying areas where mitigation measures should be carried out. Here we briefly describe survey requirements to collect relevant bird data, specific for MSBs along the Rift Valley / Red Sea Flyway. For basic information on survey design and considerations we suggest referring to relevant literature such as Sutherland 1996 and Morrison *et al*. 2008.

Electrocution hotspots

The identification of electrocution hotspots is generally more straightforward than that of collision hotspots (see also Chapter 2.2). Electrocution hotspots can be identified during preliminary sensitivity mapping and a coupled field visit that focuses on landscape characteristics and the absence/presence of natural perches. As described in Chapter 2.2, power lines and poles close to important feeding sites are likely to be used as perches, especially if tall vegetation is absent in the surroundings. Moreover, an inventory of already existing roosts can help to pinpoint locations where newly erected power poles may also be used for roosting.

Collision hotspots

Because the identification of collision hotspots might be more troublesome, this chapter mainly focuses on carrying out observations on flight movements during bird migration, which is relevant for predicting the number of collisions.

In the case of migratory soaring birds, vantage point surveys conducted by field observers provide the most appropriate field data. Given the large size of most migratory soaring birds, field observers may detect flying birds up to several kilometres distance. Vantage point surveys should be carried out at hotspot locations identified during the sensitivity mapping as requiring additional field data.

For large-scale power line developments, the number of potential collision hotspots will likely be high, and it may be necessary to sub-sample these hotspots. In this case, a *stratified random selection of survey hotspots* should be applied. This should comprise the identification of *different strata* of characteristics identified as potentially important for MSBs within the study area, such as:

- regions;

- topography;
- and vegetation features.

Hotspots should be classified into these strata (e.g. unvegetated mountain ridges and vegetated mountain ridges in the region of Eastern Egypt). Consequently, an adequate sample size of hotspots per stratum (for the most comprehensive results as many as possible but enough to ensure that the range of situations encountered are addressed, particularly with regard to temporal and spatial variation) should be defined for carrying out field research. Finally, the defined number of hotspots should be randomly selected from all the hotspots within the stratum. If a quantitative assessment is required along the entire length of the planned power lines, a sampling design for field research should be developed for the *less sensitive areas* as well. Being sites of less critical value, a simple randomized sample of sections to monitor should be adequate to avoid producing an unnecessarily large sample size. For example, if total length of the power line is 2,000 km, and 4 hotspots are identified with a total length of 200 km, studying about 20% of this section of the line will result in 40 km to be studied randomly. Given an average vantage point with 360 degrees view manned by two surveyors covers 2 km in each direction, equates to an average of circa 10 vantage points to cover 40 km of line.

Primarily, vantage point surveys conducted by field observers should *establish*:

- flight intensity (number of birds/space unit/time interval, e.g. number/crossing a virtual km line/hour; see Figure 2.1);
- flight height (see Figure 2.2) during different weather conditions;
- and flight routes at the local scale (see Appendix 1 for an example of a field form with recorded variables).

Flight intensity can usually be gleaned from detailed flight path maps and cross-referenced recording sheets (see flight routes below). If, for any reason, flight route maps are not used, the data form should still be used to collect data on flight intensity. Data collection should be assigned to 5-minute observation periods (Figure 2.1).

At certain sites high flight intensity does not necessarily lead to high collision risk, as migration often takes place well-above power lines. Nevertheless, during certain weather conditions birds may fly lower, although probably also at a lower intensity. As estimating the exact **flight height** is difficult without reference points, categorization of heights should be sufficient to identify flight intensity:

- at power line height, giving a margin of error to correct for general observer accuracy;
- below the height of the lowest power lines; and
- above power line height.

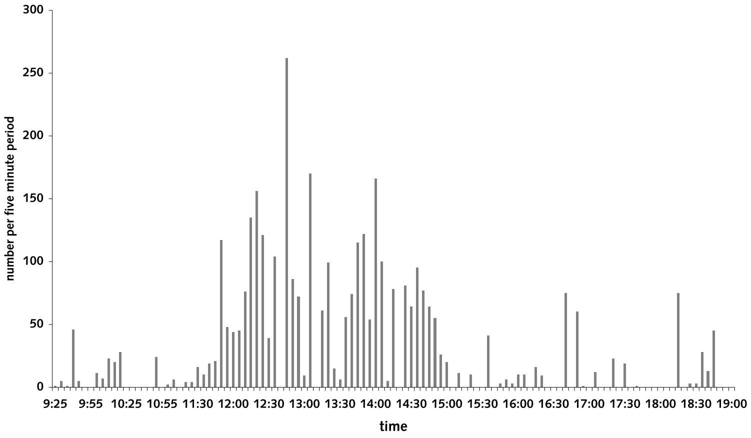

Figure 2.1 Example of temporal pattern of flight intensity (number of birds per five-minute period) of migratory soaring birds recorded by visual observers on one day; Honey Buzzard migration at the Street of Messina, Italy (source: Gyimesi et al. 2010).

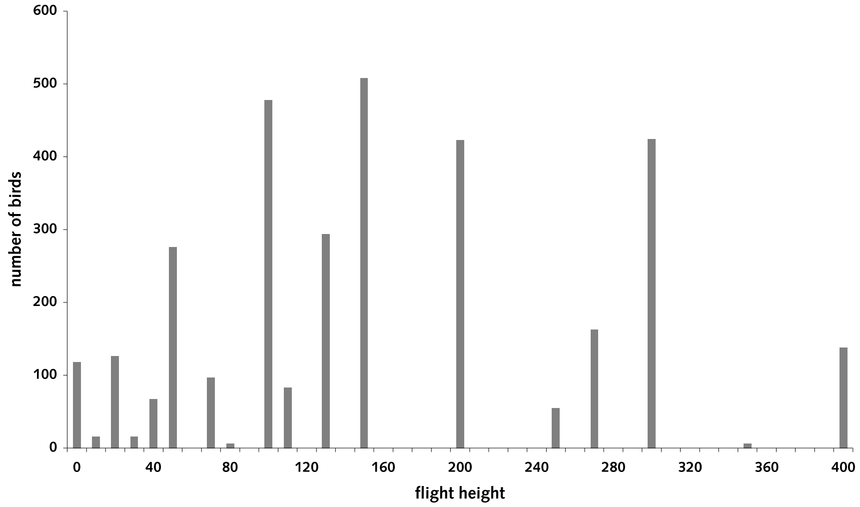

Figure 2.2 The mean flight altitude relative to observer and radar position (1,000 m a.s.l.) of 3,295 Honey Buzzards recorded with radar at May 6th 2010 at Street of Messina, Italy, near the location for a new 380 kV transmission line. The altitude was read from the radar screen when birds passed the radar location. It does not include altitudes that birds gained to when in a thermal above the location or lost to when gliding to the next thermal (from: Gyimesi et al. 2010).

If reference points are available, e.g. already existing power lines, the number of flight height categories could be increased within the power line height band to distinguish flights (see also APLIC 2012 for more detailed classification):

- at the height of phase conductors,
- at the height of earth wires,
- and just above the earth wires.

A considerable fraction of migration (especially in good weather) might take place at an altitude that is difficult to detect for field observers. Although objective measurement of this fraction of the migration is only possible by radars (see below), within the risk height of power lines human observers are well capable of detecting birds and therefore this is not considered to be a limitation. Using electronic range finders might also support the estimation of flight height. These make use of reflection of a laser signal, which might work adequately due to the large reflection surface of migratory soaring birds of the MSB Project, but birds need to be in close range.

Information on **flight routes** will be required to help small-scale design or to adjust alternative routing through hotspot locations in the EIA phase. This can be addressed through vantage point surveys at key locations. A sufficiently detailed topographical map (See Appendix 2 for an example) is needed to record flight routes. In addition, at least the following information should be recorded on a *count sheet* (see Appendix 1 for an example):

- species;
- number of birds;
- flight height;
- type of flight (e.g. locally feeding, going to roost or migrating).

Using a serial ID (route number or letter) the information on the map and on the count sheet can be linked to each other (route number of letter). After entering all information of each registered flight route in a database and digitising all routes, a GIS analysis may result in quantitative maps of the migration of MSBs within the power line corridor around survey locations (for an example see Figure 2.3).

For studies over a **large spatial-scale**, data on flight intensity and flight height can also be collected fully automated with vertical radar (Figure 2.4), and flight paths with horizontal radar (figure 2.3). Radar measurements can provide a more quantitative estimate of flight routes, flight intensity and especially flight height. In case of large soaring birds, radar detection distances of small mobile radars reach approximately 6 km. Radar observations may therefore be more useful when the flight route, flight intensity and flight height of birds over these longer distances has to be defined. For small-scale projects, or at locations where bird movements are concentrated within a corridor that is easy to cover with field observers, radars might not be necessary, especially considering any extra cost.

Further details of the use of radars are discussed in relation to shutdown-on-demand (Collier & Poot 2015). However, some limitations of radar include the potentially high deployment and operational costs and the inability to identify species of species-groups and the possibility of issues from clutter or detection loss. The latter, in particular, leads to a requirement for visual ground-truthing from observers.

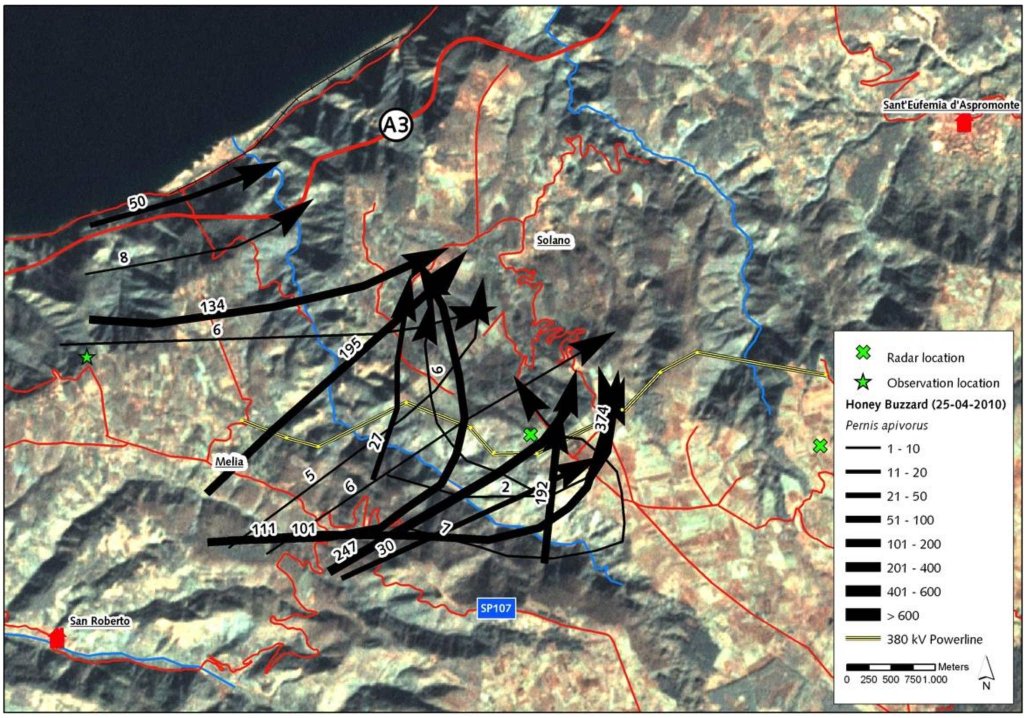

Figure 2.3 Overview of recorded flight patterns of migrating Honey Buzzards in South-Italy on the 25th of April 2010 (source: Gyimesi et al. 2010). The map shows the mountain ridges, the road network (red lines) and river courses (blue lines) for orientation, as well as a part of a planned 380 kV power line through an IBA (yellow line). Arrows indicate flight routes with corresponding bird numbers as observed by radar and visual observations.

At the selected vantage points, a number of surveys (for the most comprehensive results as many as possible but enough to ensure that the range of situations encountered are addressed, particularly with regard to temporal and spatial variation) should be carried out throughout the migration period to have an adequate estimate of the **temporal variation** in flight intensity, also in combination with a variation of weather conditions. In addition, migration routes may show locally some **spatial variance**, due to weather conditions, i.e. mainly changing wind direction and speed. Therefore, it is recommended to conduct counts at more than one vantage point per site, to be able to flexibly adjust counting efforts during the day/season according to the actual migration pattern. However, this should always be mindful of the repeatability of the survey on future visits and during post-construction monitoring. Moreover, surveys should be carried out both during spring and autumn migration, as the migration routes are often different in both seasons. Surveys should be planned to cover the range of conditions when birds are active. Stratified sampling will maximise survey effort at times of peak activity but also ensure that all periods are covered. If times of peak activity are unknown then surveys should be conducted throughout the day during periods of daylight, to account for within-day variation in flight intensity and height.

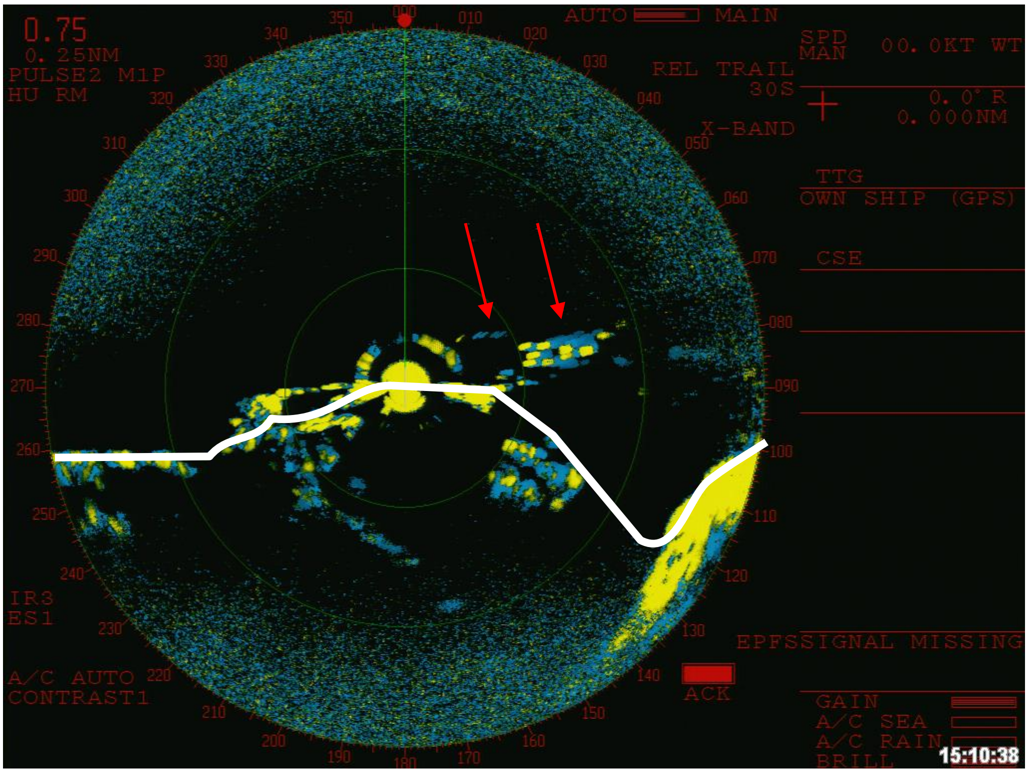

Figure 2.4 Example of migratory Honey Buzzards (indicated by red arrows) on the screen of a vertical radar. The topography (mountain slopes and plateau) is roughly indicated with a white line. The distance around the central radar location is given by three fine green rings at a distance of 450 m, 900 m and 1350 m. Echo signals below the white line are false echoes or clutter.

2.5 Avian risk assessment

Once the sensitivity mapping is conducted and knowledge gaps are filled by newly acquired data, the identification of the affected species and the qualitative level of risk can be identified per power line segment and route alternative, eventually supported by quantitative estimates of flight intensity. Based on the results, an actual risk assessment can be carried out to characterise and estimate the effects of power lines on migratory soaring birds. Risk is normally expressed in terms of biological risk. This process evaluates the potential **electrocution and collision mortality risk** of different segments and assesses these risks at a population level. The outcome can be used to formulate risk management in the form of various mitigation measures, in case the level of electrocution or collision mortality is expected to be biologically significant. In order to come to a pre-construction estimate of possible future mortality, a modelling approach is most suitable (see text box below for examples).

Examples of modelling electrocutions

At new power lines, electrocution should be prevented by installing the appropriate devices or structures during construction instead of post-construction retrofitting, as this latter is more costly. Such proper installations are extensively outlined in existing reviews (see Chapter 2.6 for examples of mitigation and Chapter 2.7 for a list of reviews). The description of modelling mortality by electrocution is mostly limited to already existing power lines, but this knowledge can also be applied to new power lines. Two recent examples of quantitative modelling of electrocution risk have been conducted by Tinto *et al.* (2010) and Dwyer *et al.* (2013). In general, these models give indications on which pylon types within which surroundings have the highest probability to cause electrocutions. However, the models also identify variables that help to quantitatively predict the probability of electrocution. In order to fill the model with appropriate parameters, data should also be collected on:

- the number of jumper wires;
- number of primary conductors;
- presence of grounding;
- and dominance of open, treeless, unpaved areas nearby.

Both references give a clear example on how to apply such parameters to establish electrocution risks for new power lines.

Examples of modelling collisions

Modelling collision risk of large soaring species can be applied both to already existing, as well as new power lines and has, so far, been conducted with various successes. Rollan *et al.* (2010) managed to identify high-risk power line sections for Bonelli's Eagles, based on habitat characteristics. Open habitats, sites far from urban areas and cliff areas used for roosting corresponded to the highest collision risk areas. In Germany, a transmission network (110, 220 and 380 kV power lines of ca. 10,000 km total length) was analysed in order to identify line segments with increased collision risks for birds. In this case, a rating system was developed that took into account the number of birds and species composition within functional areas, as well as the location and lay-out of the power lines in the landscape. The product of both measures was used to qualitatively assess the collision risk for every individual line section (area between two pylons). Using this system, the most problematic areas in the power line network (adding up to 400 km of power lines) could be identified and retrofitted (von Bernshausen *et al.* 2007). In contrast, Shaw *et al.* (2010) failed to predict line segments with high collision risk for Blue Cranes, due to the lack of detailed spatial habitat characteristics and information on crane numbers. Therefore, collision risk modelling should be based on appropriate habitat mapping and empirical bird survey data.

Although reliable modelling of collision mortality is challenging, applying reported mortality rates from other locations is also not straightforward, due to the large site- and study-specific differences, and using site-specific survey data to model predicted mortality will usually be the simplest and most appropriate assessment method. If a modelling approach proves to be unsuitable, the best solution is to monitor mortality at already existing power lines in the vicinity to estimate expected mortality rates at new power lines.

Biological significance

Mortality estimates should be put into context of biological significance, i.e. the effect of mortality on the population of the affected species. The Avian Powerline Interaction Committee (APLIC 1994) defined bird mortalities as biologically significant "….when they affect a bird populations' ability to sustain itself or increase its numbers locally and throughout its range." Some species are more *susceptible to electrocutions and/or collisions*, due to behavioural and morphological differences. Also, most of the MSB species are long-lived, slow reproducing species, for which loss of adults can directly affect populations. Mortality due to power lines will have a larger effect on a bird species with high *conservation status* than a more abundant species. Furthermore, a number of MSB are protected under national or international legislation and memoranda of understanding (MoUs). Additional consideration must be paid to such species with any potential biological significance. Therefore, the protected status of the species should be taken into consideration as well as in relation to the size of the flyway population and the demographic parameters of the species when defining the significance of risks.

Assessing effects at the population level

A range of methods have been proposed in order to assess the effects of additional mortality, such as can occur through interactions with power lines, on a population. The most appropriate method will need to consider a range of factors, such as the size of the population and regeneration potential. Most importantly, a cautious and realistic approach should be adopted to ensure the value of any results. The confidence in the results will depend on the quality of the input data as well as strength of the method. For many species of population there may be insufficient data to carry out an assessment of the potential effects at the population level. The examples below are examples of methods and these can only be carried out where data are sufficient.

Using mortality thresholds

The use of mortality thresholds may be helpful in determining whether power line developments may lead to negative effects on a population. A standard starting point is the use of the 1% of natural mortality threshold. This has been defined by the EU ORNIS Committee in relation to hunting levels and, in some countries, has become widely accepted for assessing bird mortality in relation to human activities. The method compares the predicted annual mortality of the activity (*additional mortality*) in relation to the annual *natural mortality* of the population in question. When this predicted additional mortality is less than 1% of the annual natural mortality it is assumed that there is no effect at the population level. When this value is greater than the 1% threshold, a population level effect cannot be ruled out and further study, such as population modelling, is required.

Population modelling

Population modelling can be used as a basis to which the effects of varying levels of mortality can be assessed. This method requires detailed information on the life-histories of the population concerned, such as survival and fecundity rates (Perrins *et al*. 1991, Akçakaya *et al*. 1999, Newton 1998, Sutherland *et al*. 2004).

Potential Biological Removal approach
A third approach is more suited to species where few data are available. The Potential Biological Removal (PBR) approach assesses the potential level of additional mortality that can be sustained by a population through use of the recovery potential of a population (Lebreton 2005, Niel & Lebreton 2005, Dillingham & Fletcher 2008, Sutherland *et al*. 2004). Poot *el al*. (2011) used this approach for assessing the effects of wind farms on seabird populations.

2.6 Mitigation measures

The outcome of the avian risk assessment should clarify which power line segments or poles potentially pose significant negative effects on bird populations. There are a number of mitigation measures that can be applied to reduce the risk of collision or electrocution at these locations, which will be discussed briefly in this chapter.

Pre-construction considerations
Appropriate routing is the main mechanism to minimise the risk of power line constructions to birds. If power lines must be constructed then burying the power lines underground offers the best solution against electrocution and collisions of birds. For example, placing low voltage utility and medium voltage distribution lines (those that pose the greatest electrocution risk to birds) **underground** is technically possible, and has widely been practiced in Western Europe (see Prinsen *et al.* 2012 and references within). However, putting cables underground is more costly (estimated at 3 to 20 times more expensive; APLIC 1994) and technically difficult in mountainous regions. Furthermore, it can also have greater impacts on terrestrial habitats and ecology in areas of ecological significance. It is, therefore, unlikely to be widely used or contribute significantly to electrocution or collision mitigation within developing countries. It must also be noted that burying power lines may bring with it increased impacts on other components of the environment (mostly at a highly local level).

Therefore, in most cases the construction of an above ground power line will be the more likely outcome. In certain cases, it may be possible to route a new power line *adjacent to an existing* taller power line with safe configuration, partially mitigating for electrocution through the likelihood that birds would naturally tend to perch on the taller power line and partially mitigating for collisions because birds will be more able to see the combined obstruction as well as have a greater likelihood of safely passing a second nearby line if this is of the same or lower height.

Nevertheless, the best mitigation option for the construction of new power lines is to ensure that it is **routed away** from areas that are used by migratory soaring bird species. In order to achieve the optimal routing, it is useful if project planners identify more than one alternative route. However, at certain locations it may be the case that none of the available alternatives for line routing will prevent the predicted MSB casualties exceeding a critical mortality threshold.

Post-construction mitigation

Mitigation may also be implemented once power lines have been built and are operational, but this brings about much higher costs. Post-construction mitigation can be done either *proactively*, whereby the available information on previous fatalities and related factors is used to predict where fatalities could also occur in future. Alternatively, mitigation can be applied *reactively*, whereby action is taken in response to the occurrence of fatalities on existing lines. Mitigation measures are published in numerous reviews on the conflict between birds and power lines. Here, we solely provide a brief overview of examples for available mitigation options for electrocution and collisions. References to available overviews on this topic are provided in Chapter 2.7.

Because mitigation measures can be costly for extensive power line networks, financially realistic measures should be focused on **priority sections**. First of all, these should include conflict hotspots and, when budgets are sufficient, the next-most important stretches. Based on qualitative or modelling assessment and consequent categorization, a priority list of power line segments/poles can be generated. In this way the available budget can be used more efficiently by concentrating on the most dangerous sections/poles. For examples of how such prioritizing can be carried out, see Chapter 2.3 for sensitivity mapping carried out in Hungary and Switzerland (Heynen & Schmid 2007, Horvath *et al.* 2008, Horvath *et al.* 2011).

2.6.1 Mitigating for electrocution

Electrocution mitigation can be more easily achieved than collision mitigation. The problem is at a smaller physical scale, whereby a bird bridges energised wires or wires and grounded hardware on a pole structure. The solution is relatively straightforward and involves ensuring that a bird cannot touch the relevant components using appropriate design. It is cost effective to carry out electrocution mitigation in the building phase of new medium voltage power lines as retrospective fitting (i.e. mitigate for electrocution on an already operational network) of dangerous poles is very expensive. Also the impact upon MSBs in the interim period could be highly significant, especially in terms of cumulative impact if occurring at multiple locations across the flyway. Furthermore, retrofitting normally requires an outage (line switched off) with subsequent customer issues, and is principally changing a previously approved engineering design, with additional materials and complications.

Pole and line design or configuration

This is relatively easily achieved through the technical design of the pole top. The design can take one or a combination of two approaches:

1. ensuring that the likely preferred perching space for a bird on the pole top is well clear of dangerous components;
2. ensuring that the dangerous components are sufficiently separated by space to ensure that the bird cannot touch them.

The second option, whilst more foolproof, can result in significantly larger pole tops with consequent significantly increased costs, which is why a combination of the two approaches is often employed.

Line design modifications for mitigating bird casualties should include sufficient spacing between different conductors and between conductors and grounded wires or hardware. Short distances between conductors often occur at switch towers, at junctions and dead ends of distribution systems.

Insulation

Where poles or pylons or substation hardware pose a risk of electrocution to birds by virtue of the insufficient clearances between critical hardware, it is possible to adjust the situation with add-on mitigation. This usually takes the form of insulating materials that are fitted onto critical components of the structure, in order to render those components neutral. In some cases this insulation takes the form of custom designed products for insulating certain components, and in other cases more universal, generic material is used, which can be adapted on site to insulate varying components. A feature of most of these products is that they often do not provide full insulation, and should not be considered safe for humans. In fact, these materials often only cover the dangerous components, reducing the likelihood of electrocution but not fully eliminating it.

Perch management techniques

Cross-arms, insulators and other parts of the power lines can be constructed so that there is no space for birds to perch where they can be proximate to energised wires. For this often *exclusion devices* or *perch discouragers* are installed on the top of the pole, but these may cause more problems than benefits. Because the birds still try to perch on the constructions where the space is even more limited, they have a higher chance to contact the energised wires.

On the other hand, there has been considerable success achieved by providing *artificial bird safe perches* and *nesting platforms*, which are placed at a safe distance from the energised parts (See examples in Prinsen *et al*. 2012). A recent application in Portugal to prevent White Storks from nesting on utility poles uses a device with rotating cups and an attached metal bar that sweeps across the top of the pole (Figure 2.5) (Prinsen per comm.). This might be a cheap and efficient method to prevent larger birds from landing on a pole, but at least some wind is needed (or alternatively a low-power (solar) motor) to rotate the sweeping bar.

Figure 2.5 Perching dissuasion devices to prevent White Storks from nesting on utility poles in Portugal (Photo: H. Prinsen).

Deterring birds from power lines

Visual deterrents have been trialled in the past (such as the use of raptor silhouettes placed on pylons as deterrents to reduce bird flights over lines) but have proven to be ineffective. These devices almost certainly suffer from bird habituation. Audio or *acoustic deterrents* have potential, although no proof on their effectiveness is available. It is anticipated that habituation could be a challenge also with this approach. None of these techniques can be applied over long distances other than at high costs and over time may lose their effect. Permanent solutions (line design or isolation and insulation) as illustrated above are much better and much more cost effective.

Habitat modification

Habitat modification can be used in various ways, including:

- shielding of the line by trees;
- altering the attractiveness of the habitat close to the line;
- and changing the disturbance levels close to the line.

However, with all of these options there are often challenges of spatial scale. Habitat modification would therefore need to be implemented on a large scale in order to manipulate bird movement successfully. In addition, in some cases long sections of line may pose a risk, thereby requiring a significant level of habitat modification, with potentially high environmental and financial costs.

2.6.2 Mitigating for collisions

Employing mitigation measures already during the development of new lines is more cost-effective and may ensure a substantially reduced number of casualties from the onset of the operation of the power line. Once infrastructure exists, line modification in various forms is the most widely used approach. Modification of existing lines can be broadly divided into measures that:

- make power lines less of an 'obstacle' for birds to collide with;
- keep birds away from the power line (for such solutions see the section 'deterring birds from power lines' in Chapter 2.6.1);
- make the power lines more visible.

Line design or configuration

Although different bird species fly at different heights above the ground, there is general consensus that:

- power line cables lower to the ground are better for preventing bird collision;
- less vertical separation of cables is preferred, as it poses less of an 'obstacle' for birds to collide with. Horizontal separation of conductors is therefore preferred;
- construction of self-supporting towers, which do not require stay wires, is preferred, as bird collisions have been recorded with the guy or stay wires of towers;
- removing or designing power lines without earth or shield wire (the thinnest wire at the top of the power line structure) can take away the obstacle birds most often collide with.

Line marking

Since the assumption is that birds collide with overhead cables because they cannot see them, fitting the cables with devices in order to make them more visible to birds in flight has become the preferred mitigation option worldwide. Besides thickening, coating or colouring the often least visible thin ground wires, a wide range of potential 'line marking' devices has evolved over the years, including: spheres, swinging plates, spiral vibration dampers, strips, swan flight diverters, Firefly Bird Flight Diverters, bird flappers, aerial marker spheres, ribbons, tapes, flags, fishing floats, aviation balls and crossed bands (See Prinsen *et al*. 2012, Barrientos *et al*. 2011, Jenkins *et al*. 2010).

Devices should be installed on the earth wire (also-called ground or shield wire) wherever possible. On lines without an earth wire devices should be installed on the conductors. Although installation of these devices on higher voltage conductors is problematic, lines of higher voltage would typically have an earth wire anyway. Guidance is available on spacing between line markers (Prinsen *et al*. 2012).

2.7 A guide to guidance

This chapter provides the most important sources of information and other guidelines relevant to the issue of bird and power line interactions. Appendix 4 provides a list as a 'guide to guidance' of the most important sources of information and guidelines relevant to the issue of bird and power lines interactions. In addition, general guidance on EIA/AA methodology are referenced and completed with recent information. For a more complete overview of published and non-published references on this topic, we refer to the AEWA/CMS International Review on Bird-Power Line Interactions (Prinsen *et al*. 2011) and references in the back of the guidelines report at hand.

3 Guidance for post-construction monitoring

This chapter summarises monitoring techniques that can be used to assess post-construction mortality and the effectiveness of mitigation measures (both for electrocution and collisions). The evaluation of mitigation is an essential, but often overlooked, component of the approach to reduce bird electrocutions and collisions. Ground-truthing the effect of mitigation measures is crucial in future refinement of measures. Therefore, the measurement of the effectiveness of any mitigation measure must be carried out through systematic monitoring.

There are two broad types of effects to monitor: mortality and flight behaviour. For mortality monitoring, because of the large scale of the power line network in the study region, we present **monitoring techniques** that are cost-effective when monitoring large lengths of power lines. Such techniques include monitoring by foot for small-scale projects and by car for larger distances. This latter is especially a viable option when the vegetation cover is minimal and large birds are involved.

Flight behaviour monitoring is important to establish how MSBs respond to power lines both with and without mitigation measures, allowing MSB avoidance rates to be calculated for mitigated and unmitigated lines, building the evidence-base for future guidance.

Finally, for large-scale projects remote sensing techniques (bird strike indicators, aerial line surveys using high definition cameras and survey cameras in masts and on aerial surveillance vehicles) should be considered. For medium and large lengths of power line, it might be costly to monitor the full length of the line. In order to select an **appropriate number of line segments to monitor** for mortality or post-construction flight behaviour, the same approach could be followed as described in Chapter 2.4. Examples of survey protocols are given in Appendix 3. Indeed wherever possible such monitoring should use the same, or a sub-sample of vantage point locations and other survey protocols used for pre-development assessment.

3.1 Measuring mortality rates

Below we present technical descriptions on the design of standardised and systematic line searches by researchers, including experiments to control for searcher detection bias and scavenger removal bias. Because factors that affect the search efficiency, scavenger rate, accessibility of terrain, etc., vary greatly between study locations, it is not possible to present a method that is applicable in all situations and study outlines may need to be developed on a case-by-case basis (Bevanger 1999). Nevertheless, the following topics are of importance to be considered and incorporated in a study protocol, in order to make studies more comparable. Examples of survey protocols are given in Appendix 3. Methods for calculating mortality rates are discussed in relation to post-construction monitoring in Costa *et al*. (2014).

3.1.1 Spatial and temporal coverage

Search area

Line searches for power line bird victims (both for identifying impacts as well as evaluation of *mitigation measures*) should be sufficiently extensive, both spatially and temporally. Most collision victims are found within 50 metres distance from the power line. Therefore, the search area**,** in case of *collision victims*, should include the complete area up to at least 50 metres, on both sides, measured from the centre of the line. If feasible, or identified as necessary on a site or species specific basis, larger distances from the line should be incorporated in the search protocol to ensure that those victims that have fallen to the ground farther away are also included (see also next section).

Because most *electrocution victims* fall close to the base of the pole, in the case of electrocution monitoring a search radius of 10 metres around poles and pylons will suffice. The use of dogs to locate carcasses has sometimes improved searching efficiency. However, the success rate was not everywhere overwhelming (Goudie 2006).

Search intensity

Depending on the size of the victims (small falcons to large eagles), the type of terrain (irregular surface, hollows, rocks, etc.), and vegetation cover (size and structure), the search intensity needs to be adjusted. An observer should be able to find medium sized birds (e.g., buzzards) in flat terrain with low vegetation within a radius of 10 metres around him. Therefore, within the search area of 50 metres from the centre of the line, at least three transects need to be included to cover the full area at each side of the line. E.g. collisions for medium-sized MSBs need to search in line transect 10, 30 and 50 metres parallel to line centre, covering a search area up to 60 metres from the line centre. For smaller species at least four transects are needed at each side of the line with 5, 15, 25 and 35 metres transects (i.e. up to 40 metres from line). For very large species two transects at 15 and 45 metres at each side of the line suffices. When more than one size class is at risk, one should always search to a maximum distance and frequency required, such that the search area for all sized target species includes transects at 5, 15, 25, 35 and 50 metres from the line. Preferably, the terrain is covered on foot, but for large, open, bare areas, searches can be carried out by car.

Temporal aspects

The **frequency of searches** should be adjusted to prevent too many victims being lost to scavengers. The smaller the expected bird victims are, the more often searches have to be carried out. For birds larger than a pigeon, in most cases sufficient feathers remain in the field after a week to establish an electrocution or collision incident and identify the species concerned, even with high predation pressure. Therefore, for most soaring birds a search intensity of once a week is likely to render good results. When only large conspicuous birds (storks, vultures, eagles and cranes) are searched for, fortnightly searches may be sufficient. Sufficient breaks should be planned during searches to ensure observer concentration is maintained and collision victims are not overlooked.

In order to control for temporal variance in migration intensity, the **time period** of carcass searches must cover the whole migration period, both in spring and autumn, unless site-specific circumstances dictate otherwise. Although this often concerns several months of observations, such approach should be feasible due to the low frequency of searches required for migratory soaring birds.

3.1.2 Experiments to correct for bias

Dedicated line searches and evaluation of mitigation measures must include experiments to correct for searcher detection bias (the percentage of dead birds that are not found during searches, which varies with habitat and topography) and scavenger removal bias (the percentage of birds that die from power lines, but are removed by scavengers). Rates to correct for both biases should be established with experiments, in which carcasses are laid out within the search area under and near the studied power line sections. Preferably such ‘test’ carcasses are similar in size and colour of the species normally encountered in the impact study.

Searcher detection efficiency experiments

In searcher detection experiments searchers are not aware that ‘test’ carcasses have been placed in the study area. Based on the percentage of carcasses found from the known number of test carcasses laid out, the searcher detection bias can be determined. Trial administrators should be careful not to put out too many carcasses at once or leave traces, such as footprints or tags on trial carcasses, otherwise they may influence search intensity. In cases where a broad range of electrocution or collision victims are involved, the test carcasses should be of various sizes (of the whole body-size range of soaring birds) and colours. Use of chicken or feral pigeon carcasses as surrogates is discouraged, as these are often more rapidly removed by scavengers than migratory soaring bird species. They will also notify the searchers of the on-going experiment.

Scavenger removal experiments

Scavenger removal experiments are conducted to correct for the number of victims that are removed by scavengers before searchers could find them. In practice, this means following the fate of carcasses, to record the length of period that searchers can still detect a carcass. This can take place with carcasses found during the regular searches, but also with carcasses used for the searcher detection experiments. As by this latter approach the exact date is known when a carcass is laid in the field, this can be a useful method for quickly disappearing carcasses. However, the disappearance rate of large soaring birds could be low, and therefore carcasses can persist for weeks or months (Brown & Drewien 1995, APLIC 2012). Nevertheless, scavenger rate could largely vary greatly among different regions and habitats as well as between seasons and species. Therefore, scavenger removal experiments should always be a part of a carcass search protocol, and preferably carried out per habitat type at each search period.

It is of importance not to put out too many carcasses at once, because this may give scavengers more than they can remove and process, and carcasses may become unattractive as food because of rotting or mummification processes. This again may strongly bias mortality estimates. In addition, if vegetation cover is highly variable along the monitored power line segment, bias control experiments (especially searcher detection experiments) should ideally be conducted in all these different habitats. Due to such habitats and surveyor variance, the extrapolation of results of searcher detection- and scavenger removal experiments carried out elsewhere should be avoided.

Crippling bias

In addition to the above-described biases, researchers should be aware of the existence of the so-called crippling bias. This accounts for birds that get injured due to collision or electrocution but can still move on, eventually to die outside the search zone of the carcass searches. This bias is extremely difficult to estimate and would require a great effort of monitoring bird flights and behaviour, with the corresponding recording of collisions and electrocution, which often will not be feasible in post-construction studies of extensive power line segments. Due to the large variance in reported crippling biases (APLIC 2012), using results from other studies is not a reliable method. Therefore, possibly the most appropriate approach is to accept that the estimated mortality rates are minimally expected rates.

Few examples of estimating mortality rates in studies along power lines are widely available; therefore we present below examples from studies at wind farms. Although both of these examples relate to studies at wind turbines the principles of search efficiency and carcass persistence apply to searches along power lines. Differences most likely come from the habitat (both these studies were in vegetated temporal habitats where search efficiency may be lower than for open and unvegetated areas) and involved small birds and bats, which are more difficult to find, have a greater chance of being removed and lower persistence than larger birds of prey.

Examples of estimating mortality rates from studies with wind energy:

Estimating Wind Turbine-Caused Bird Mortality: Smallwood (2007) presents a comprehensive description of the methods that can be used to assess collision-related bird mortality with wind turbines. Although this does mention power lines, the approach and methods used can be applied as the processes involved in finding and estimating numbers of victims are similar. The methods describe a model for estimating the errors due to search efficiency, scavenger removal as well as due to other biases such as crippling bias and size of search area.

A new method to determine bird and bat fatality at wind energy turbines from carcass searches: An alternative model is described in Korner-Nievergelt *et al*. (2011) and also takes into account bias from the searching, search area and carcass removal.

3.1.3 Data registration

It is important to establish the *species* involved. Often this may be difficult when few parts of the carcass remain. There are, however, several web sites and books detailing the identification of birds by its individual feathers (See Chapter 2.7). If possible, the *position* of a carcass should be recorded using a GPS and printed on a map or a form to later identify the most problematic line sections or poles, and to identify the type of line (conductors or ground wires) the bird has collided with. If possible, the *age and sex* of the bird should be noted to analyse their effect on susceptibility for electrocution and collision.

Finally, it is important to establish the *cause of death.* Mortality may be due to reasons other than power line impact, and this is important to establish if possible. For example, shot birds often show shattered bones, spattered blood, contusions and bullet wounds. Evidence of electrocution can include burn marks on feathers, feet, or bill, visible as *e.g.*, small well-defined burn holes in the plumage, scorched areas at current entry and exit points, or large necrotic areas on the limbs. Evidence of collision can include fractured bones of the extremities (wings, legs and shoulder bones), broken vertebrae and skull fractures, torn off wings and limbs, flesh wounds and impact wounds on head or body where the bird hit the wire.

3.1.4 Qualification of searchers

The parameters described above in Chapter 3.1.3 can be directly recorded in the field. However, this requires the field searches to be conducted by qualified researchers, which could be a costly option for long running post-construction monitoring. Basically, conducting systematic searches and recording bird victims with appropriate documentation, marking the position on a map or digitally, taking photos and collecting feather material in labelled bags requires little ornithological knowledge. Therefore, costs can be reduced whilst maintaining data quality by training locals in conducting this part of the work. Subsequently, the identification of the victims based on the collected photos and feathers can reduce the time input demanded by qualified personnel. In addition, utility companies could give attention to raise awareness of the utility staff to collect and report relevant information on power line victims along remote or difficult to access line segments.

3.1.5 Remote sensing to record fatalities

One of the challenges of estimating bird mortality at power lines is the sheer volume of time taken by field searches, particularly if line patrols are done reasonably frequently and/or for extensive line segments. A means to overcome this is the use of remote data collection.

Bird Strike Indicator

An available and tested remote sensing device for collision studies is the Bird Strike Indicator (Figure 3.1) that records bird collisions through sensing vibrations along the cable (Arun *et al.* 2008, Murphy *et al.* 2009). Although their precision has been questioned, they are likely valuable in measuring collisions of large soaring birds (Murphy *et al.* 2009). Nevertheless, this device measures collisions without providing information on the species concerned. This could be checked by a field visit, initiated after a signal from the Bird Strike Indicator. Moreover, future developments are intended to couple an image-based recording tool, which would enable both sensing and imaging of a bird collision (Harness *et al.* 2003, APLIC 2012).

Figure 3.1 Bird Strike Indicator (BSI) attached to a power line. BSIs are relatively small devices that can be attached to a single wire of a power line and automatically register bird collisions based on the vibration of the wire.

Aerial Surveying

Developments in the resolution of digital imagery may provide remote sensing possibilities in detecting bird carcasses over large spatial segments. For instance, there are existing methods using high definition camera systems mounted on aircraft and is already in use to inspect existing power lines for line failures (See http://www.hidefsurveying.co.uk). This and similar approaches may provide a reasonable alternative to time–consuming line searches, especially in the case of large soaring birds in combination with habitats with bare vegetation.

3.2 Monitoring bird movements

The monitoring of live bird movement is less commonly conducted than carcass searches for power lines. Without estimates of how many birds actually crossed the power line in flight, the collision rates calculated through carcass searches are less meaningful. Moreover, estimating the effects of habitat alteration or habitat loss due to the construction of power lines on migratory flight routes or the use of stopover sites, is only possible if pre-construction monitoring results can be compared with post-construction results. Examples of survey protocols are given in Appendix 3.

Post-construction monitoring of bird movements should follow the same principles as that of pre-construction monitoring. Therefore, the approach described in Chapter 2.4 should largely be followed, comparing flight heights and routes before and after construction to help elucidate avoidance rates. Additional recording of micro-route deviation will elucidate bird avoidance behaviour in close proximity to power line segments. This can be set in the context of the effectiveness of mitigation measures, such as flight diverters. The following are possible reaction categories and definitions (after: APLIC 2012, Hartman *et al*. 2010):

- No reaction: birds maintain constant altitude and unaltered flight;
- Slow over/under: birds gradually increase or decrease flight height and cross over or under;
- Swerve and over/under: birds turn from course and/or react close to line (<50 m), flying up and over or under line;
- Dip: birds cross low over line and swerve immediately after crossing;
- Turn and leave: birds turn and retreat from the line;
- Collide: birds in flight hit a line and drop to the ground or continue flight;
- Land on line: birds land on line or pole.

The outcome of the post-construction monitoring should reveal particular line segments that continue to pose a high collision *risk* and a high level of *mortality.*

As described in Chapter 2.4, direct observations of live bird movements are time consuming. **Remote techniques** such as radar, however, can be used in order to obtain data with less human resources needed, although observations to ground truth the radar data are still required. In some countries the assistance of volunteers of bird conservation and research organisations is a welcome source of manpower, but in the majority of countries along the Rift Valley / Red Sea Flyway this source of manpower may be scarce. The most demanding part of the fieldwork may be the identification of migrating soaring birds, which requires extensive experience. However, training of local personnel to support qualified personnel by administration of observations or controlling bird movements on the radar could in the long-term mean a considerable reduction in project costs. As for pre-construction monitoring, the use of electronic range finders might also support the estimation of flight height.

3.3 Database structure and analysis

All the data collected during post-construction monitoring should be entered in a digital database or spreadsheet to enable analysis of the data. Utility companies should supplement this database with information on collisions and carcasses discovered outside the regular monitoring, during visits by maintenance workers, locals or birdwatchers, but such information should be explicitly separated from the monitoring results to aid unbiased analyses. It may be useful to provide the utility company with a standard file that is compatible with your main data storage system. For standard monitoring protocols it is necessary to record effort alongside any data. For example, the area searched and time taken. Field visits where no collisions/birds are recorded must also be recorded in the standard manor, as null observations are essential for correct analysis.

The collection of these data should allow the identification of hotspots for collisions and electrocutions, which should consequently help to focus mitigation measures on the most important sections. On the other hand, the effectiveness of existing mitigation measures can also be tested. Especially for evaluating mitigation measures, a Before-After-Control-Impact analysis is most suitable. Nevertheless, the success of such analysis largely relies on the setup of the field research and the structure of the database. Namely, data on power line fatalities should be available from the same sections/poles before, as well as after a mitigation measure is applied. Moreover, in order to control for temporal differences in occurrence of birds, control sections/poles should be monitored simultaneously before and after the treatment. Use of control sites/sections is a key component of effective, unbiased monitoring, and description of how and when to do this for all pre and post-construction methods need to be clearly described in all relevant sections of this report, not just in this analyses section. A single control area can be used for several experimental survey areas, assuming other conditions, such as habitats, are constant and comparable. If all these requirements are met, statistical analysis can be used to examine any patterns or differences in these data. For example, Two-way Analysis of Variance (ANOVA) can be applied, where a significant interaction term between time (before and after treatment) and treatment (mitigated or control) indicates a positive effect of the mitigation measure. Generalized Linear Models (GLM) or Generalized Additive Models (GAM) may also be appropriate alternatives for use in data analysis.

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Appendix 1 Field form examples

An example of a form to record flight patterns in the field, to be used simultaneously with a field map (see Appendix 2). When entered in a digital database, information on specific flights can be coupled to a flight route on the map via route nr.

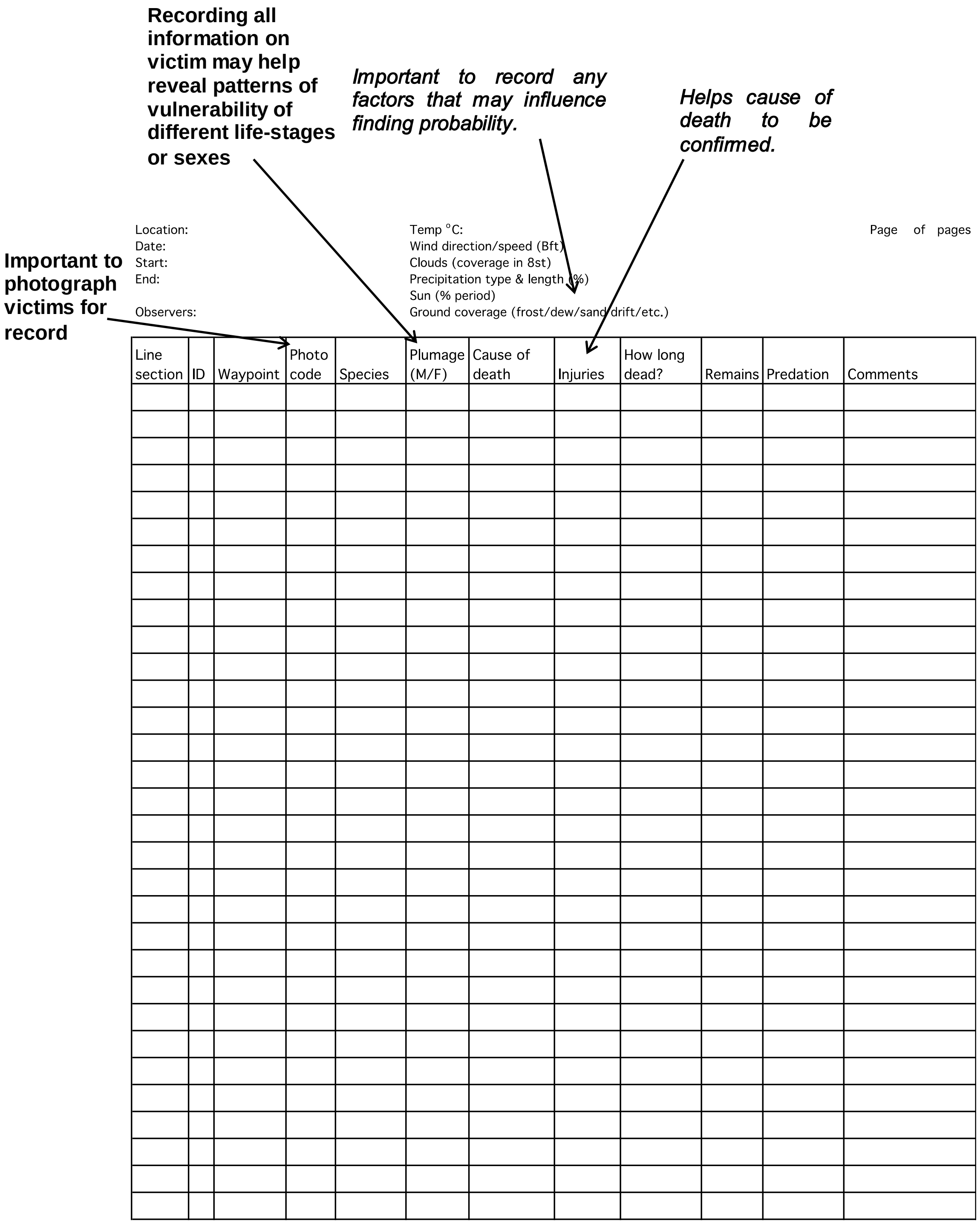
page of page

Location:
Date:
Place of observation (symbol on map):
Start:
End:
Sunrise/sunset:
Observers:

Temperature:
Wind direction/speed (Bft):
Clouds (coverage in 8st):
Precipitation type & length (%):
Sun (% visible of obs.period):
Visibility (km):
Time of darkness:

time (per 5 min)	species	number birds	routenr. on map	landed ?	flew on via routenr.	flight altitude	remarks e.g. flight type, weather change, disturbance

An example of a form to record collision victims in the field. Remains of dead birds should be photographed and collected to allow later confirmation of identification and cause of death, and to prevent re-counting in consecutive visits.



Recording all information on victim may help reveal patterns of vulnerability of different life-stages or sexes

Important to record any factors that may influence finding probability.

Helps cause of death to be confirmed.

Important to photograph victims for record

Location:
Date:
Start:
End:

Observers:

Temp °C:
Wind direction/speed (Bft)
Clouds (coverage in 8st)
Precipitation type & length (%)
Sun (% period)
Ground coverage (frost/dew/sand drift/etc.)

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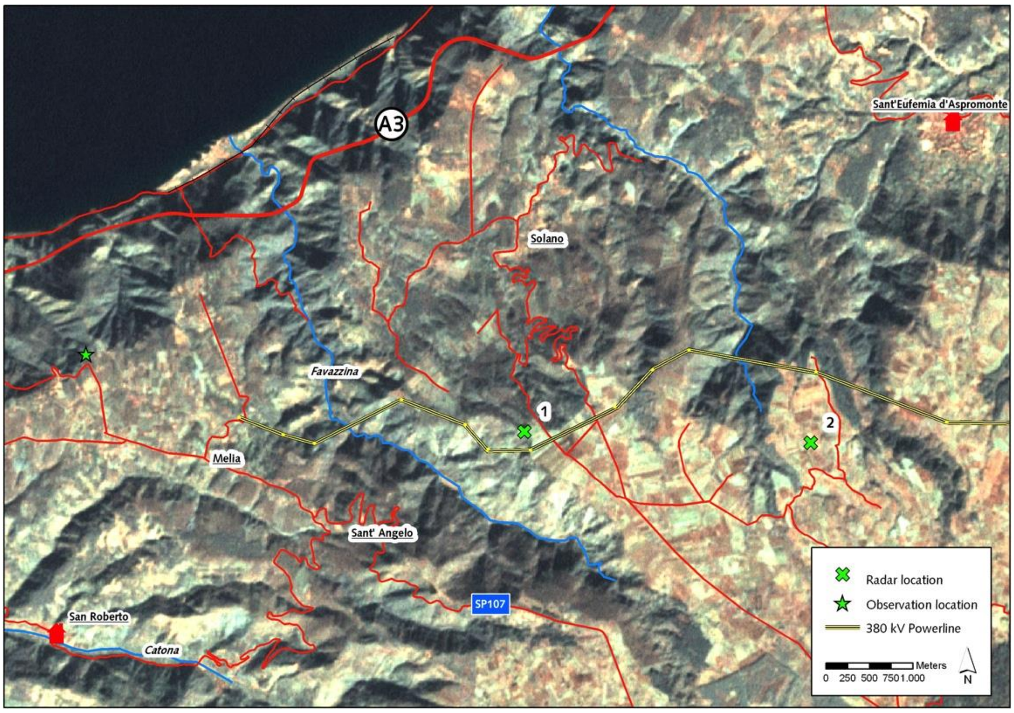
Line section	ID	Waypoint	Photo code	Species	Plumage (M/F)	Cause of death	Injuries	How long dead?	Remains	Predation	Comments

Appendix 2 Field map example

An example of a detailed topographical map to record flight routes in the field, to be used simultaneously with a field form (see Appendix 1). The map shows the mountain ridges, the road network (red lines) and river courses (blue lines) for orientation, as well as a part of a planned 380 kV power line through an IBA (yellow line) in an Italian field situation. In this example, radar and visual observations were used to quantify Honey Buzzard migration through this conflict hotspot near the Street of Messina in Southern Italy (Gyimesi et al. 2010) (See also Figure 2.3).



Appendix 3 Field work protocol guidance

The following table provides examples of protocols for fieldwork aimed at gathering information on collision rates. For more information on the methods used see chapters 3.1.

Protocol **Measuring mortality rates**	**Standard**	**Possible variation**
Search area	40-50 m both sides of line 10 m around poles.	For extremely high lines, this may need to be increased to cover extent of area where birds could land. Similarly, for extremely low lines this area could be reduced.
Search intensity	Carried out on foot.	Searches in open, flat terrain with sparse vegetation and for large species can be from car or motorbike.
Search frequency	1 x per week.	For areas with high predation, high carcass removal or small species search two or three times a week. For large species and no carcass removal, every two weeks may be sufficient.
Searcher efficiency experiments	1x per season/period.	Not more than every month to reduce predator attraction.
Scavenger removal experiments	1x per season/period.	Not more than every month to reduce predator attraction.

Appendix 4 Guide to guidance

Information on EIA and other assessment procedures

Detailed information on SEA, EIA and ecological impact assessment processes and their general benefits for birds can be obtained in:

- AEWA Conservation Guidelines No. 11, 'Guidelines on how to avoid minimise or mitigate the impact of infrastructure developments and related disturbance affecting waterbirds' (Tucker & Treweek, 2008);
- Ecology Guidelines for Electricity Transmission Projects (EirGrid 2012);
- Guidelines for ecological impact assessment in the United Kingdom (Institute of Ecology and Environmental Management 2006).

Mitigating electrocution and collision impact

AEWA documents (available at www.unep-aewa.org, www.cms.int or www.buwa.nl)

- Review on the conflict between migratory birds and power lines and guidelines (Prinsen *et al.* 2011);
- Guidelines on avoidance and mitigation of impacts (Prinsen *et al.* 2012).

Avian Powerline Interaction Committee (APLIC United States)

For information and ordering reports see www.aplic.org

- Avian Protection Plan (APP) Guidelines (APLIC & USFWS 2005);
- Suggested Practices for Avian Protection on Power Lines (2006): document detailing state-of-the-art in electrocution mitigation from a North American perspective;
- Reducing Avian Collisions with Power Lines (2012).

International Conference on Power Lines and Bird Mortality, Budapest, Hungary, 2011

Posters and presentations can be downloaded from: http://www.mme.hu/termeszetvedelem/budapest-conference-13-04-2011/presentations.html

BirdLife Germany (NABU) Working Group on Electrocution:

General website of NABU presenting information on electrocution and links to several important papers and documents, including background documents to Recommendation No. 110 on minimising adverse effects of above ground power lines adopted by the Bern Convention Standing Committee in 2004 and NABU Guidelines on electrocution in several languages:

http://www.nabu.de/tiereundpflanzen/voegel/forschung/stromtod/05166.html

Product descriptions:

Information on Bird Flappers Bird Flight Diverters:

www.rwerheinruhrnetzservice.com

Information on FireFly Bird Flight Diverters:

www.hammarprodukter.com

Information on Avian Deflector Flight Diverters

www.aviandeflector.co.uk

Comparison of efficiency of wire marking devices to mitigate for collision
Recent reviews of collision causes and mitigation measures are given by Jenkins *et al.* (2010) as well as Barrientos *et al*. (2011).

Bird Survey and monitoring techniques
Specific power line search and monitoring protocols are not readily available and will probably contain site-specific guidance. The following references may be helpful when setting up a more general monitoring scheme and protocol and may be of help to prepare site inventories of birds.

AEWA Guidelines
(downloadable from www.unep-aewa.org/publications/technical_series.htm)

- AEWA Conservation Guidelines No. 9, 'Guidelines for a waterbird monitoring protocol'
- AEWA Conservation Guidelines No. 3, 'Guidelines on the preparation of site inventories for migratory waterbirds'
- AEWA Conservation Guidelines No. 11, 'Guidelines on how to avoid minimise or mitigate the impact of infrastructure developments and related disturbance affecting birds' lists useful publications on the subject.

The following web sites and book may be helpful in identifying remains of bird carcasses found during the monitoring of electrocutions and collisions:

- http://www.gefiederkunde.de/index.html
- http://www.vogelfedern.de/
- http://www.javierblasco.arrakis.es/families.htm
- Brown, R., J. Ferguson, M. Lawrence & D. Lees, 2002. Tracks and signs of the Birds of Britain and Europe. Helm Identification Guides. Christopher Helm Publishers Ltd, London.

Data on important bird sites
Wings Over Wetlands' Critical Site Network (CSN) Tool:
www.wingsoverwetlands.org/csntool
This website provides species and site data on important sites along the Rift Valley / Red Sea Flyway. It includes also the information on Ramsar sites and Important Bird Areas listed below.

Ramsar Convention on Wetlands: www.ramsar.org
For a worldwide overview of the Ramsar sites: http://ramsar.wetlands.org/

BirdLife International's Important Bird Area data:
http://www.birdlife.org/datazone/home