BEST PRACTICE GUIDE

Innovative solution to reduce bird mortality in medium-voltage power lines: the Horizontal Eco Cross Arms

LIFE LINES
Rede de Infraestruturas Lineares com Soluções Ecológicas

Coordination of the edition

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Estimates indicate that tens of thousands of birds are killed in Portugal every year by collision with cables or electrocution on the utility poles of medium-voltage power lines. Some studies indicate that this effect led to the local decline of several threatened species, such as the Bonelli's eagle or the little bustard. The severity of such impact justified the search of solutions to minimize the risk of bird mortality in power lines.

This guide aims to disclose an innovative solution to reduce bird mortality by collision and electrocution in medium-voltage power lines – the Horizontal Eco Cross Arms (ECO-HAL A25). This structure was implemented for the first time in the framework of the LIFE LINES project (LIFE14 NAT/PT/001081), coordinated by University of Évora, in close partnership with QUERCUS – A.N.C.N., responsible for the evaluation and monitoring of the impacts of power lines on avifauna, and with EDP Distribuição (now E-REDES -Distribuição de Eletricidade, SA), responsible for the management and maintenance of the infrastructures of medium-voltage electric power distribution.

The primary objective of this guide is to present the characteristics and technical requirements of this structure, as well as the effectiveness and cost-benefit of its implementation in the structure of the electric poles, based on the analysis of the results obtained during the LIFE LINES project.

It is thus intended to contribute with an effective alternative for mitigation of bird mortality in medium-voltage power lines, by making it known to the various agencies dealing with electric power distribution, the public authorities concerned with nature conservation, and associations engaged in environmental protection.

Bonelli's eagle (*Aquila fasciata*) | SI

Short-toed Snake Eagle (*Circaetus gallicus*) | SI

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The LIFE LINES project

Thousands of animals die every year in linear infrastructures of transport and energy, by road- or rail-kill, or by collision and electrocution with medium- and high-voltage power lines. These deaths impact on the preservation of biological diversity, but there are solutions to lessen these effects.

The **LIFE LINES project – Linear Infrastructure Networks with Ecological Solutions** (LIFE14NAT/PT/001081) was developed to contribute to the creation of a **Green Infrastructure** that promotes **refugia for plants and animals**, and their **safe movement along the linear infrastructures**, ensuring ecosystem services and thus mitigating the negative impacts of those structures on biodiversity.

The project was coordinated by the Universidade of Évora and involves the following partners: Universidade de Aveiro, Faculdade de Ciências da Universidade do Porto, Municipalities of Évora (CME – Câmara Municipal de Évora) and Montemor-o-Novo (CMMN – Câmara Municipal de Montemor-o-Novo), Infraestruturas de Portugal S.A., MARCA – Associação de Desenvolvimento Local, and QUERCUS – A.N.C.N.. LIFE LINES is also in close collaboration with E-REDES, REN – Redes Energéticas Nacionais SGPS S.A. and GNR (Guarda Nacional Republicana). The project focused on the promotion and recovery of biodiversity in an area that is still well preserved but where a number of linear infrastructures might endanger some local populations of animals and plants.

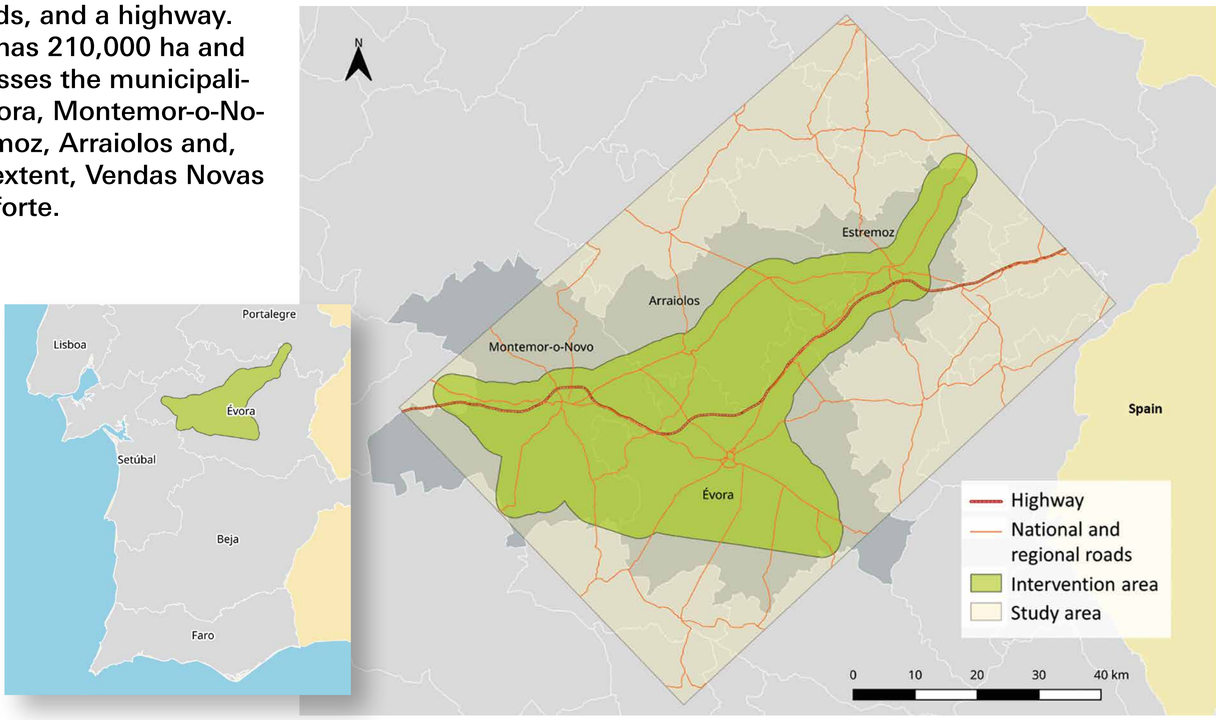
The search of solutions with a demonstrative and innovative character to solve a series of problems identified in linear infrastructures such as the power lines was one of the purposes of the project. In the framework of LIFE LINES, a new pole structure design was developed and tested that was subsequently adopted by E-REDES. This structure – the Horizontal Eco Cross Arms (ECO-HAL A25) –, based on horizontal cross arms, presents a hanging plane of collision and a larger distance between phases, thus contributing to reduce bird mortality by electrocution as well as by collision, and being more effective than the solutions previously implemented.

LOOK FOR FURTHER INFORMATION AT LIFELINES.UEVORA.PT

The intervention area of LIFE LINES is crossed by the main land transport corridor between Lisbon and Madrid. There is a high density of power lines, roads, and a highway. The area has 210,000 ha and encompasses the municipalities of Évora, Montemor-o-Novo, Estremoz, Arraiolos and, to some extent, Vendas Novas and Monforte.

2015-2021

Alentejo Central



Objectives of the Project:

- Create corridors and refugia for biodiversity
- Reduce mortality by electrocution, collision, and roadkill
- Promote landscape connectivity
- Inform and raise public awareness about the impacts of linear infrastructures on biodiversity
- Implement a national database on wildlife roadkill
- Detect and control invasive vegetation

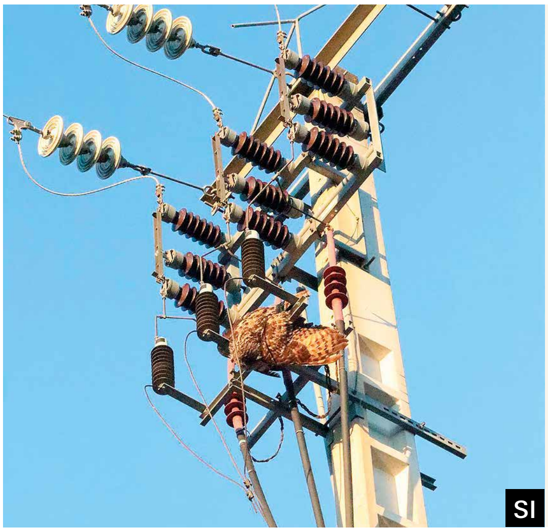
LIFE LINES
Linear Infrastructure Networks with Ecological Solutions

Context

The relation between birds and overhead power lines has been the subject of a large number of systematic studies over the last decades, both at the national level and in almost all the world (e.g., 1, 2, 3). The present state of the art, accepted by several electric power agencies, authorities concerned with nature conservation and associations for environmental protection, points to the possibility of significant and localized mortalities in time and space. Whenever certain habitat conditions favour species occurrence, there are species vulnerable to collision, unfavourable weather occurs and power lines are present, an increased mortality rate should be expected.

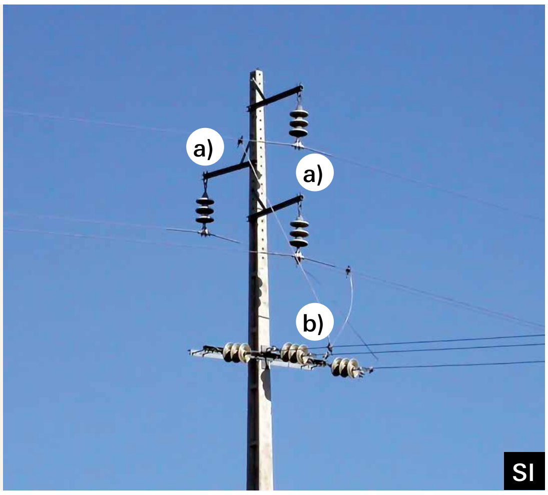
Different types of electric pole structures affect bird mortality rates differently. In Portugal, there are several pole types, and some of the most common and studied ones will be briefly described below, namely the horizontal type cross arms, the PT type vertical cut module, the GAL-HDR, the Vertical isolated rigid triangle (TAL), the GAL, and the vertical cut module with insulated arches.

Horizontal type cross arms. This is the type associated with the highest mortality by electrocution in Portugal (0.53 birds/pole/year). This type of pole provides a cut-out function. The installation of Horizontal type cross arms is no longer allowed, however thousands of them are still in use all over the country.



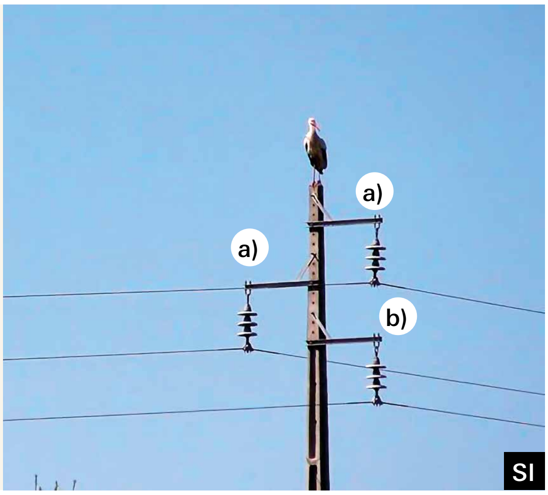
PT type vertical cut module, with an electrocuted Eurasian eagle-owl (*Bubo bubo*). This type of pole is associated with the second largest mortality rate caused by electrocution in Portugal (0.31 birds/pole/year).

GAL-HDR (Power line cables in suspension with triple arms - structure of horizontal cross arms for derivation). This is one of the most frequently used type of cross arms nowadays for the distribution of medium-voltage electric power, and it represents the third highest risk of electrocution for medium- to large-sized birds, such as storks, eagles and vultures. Adding to the risk of a GAL, there is a risk associated with the fact that the HDR derivation arches between the bird perched on the cross arm and one of the upper two phases (a) or when the bird rests on the lower cross arm (b). For this type of poles, the associated mortality in Portugal is of 0.28 birds/pole/year.



TAL (Vertical isolated rigid triangle) with anti-electrocution measures. This is found in an old type of power lines, still very frequent in Portugal and associated with high risk of mortality by electrocution. It is the fourth greatest cause of death by electrocution in Portugal (0.25 birds/pole/year). The photo shows a perched Short-toed snake-eagle (*Circaetus gallicus*).

GAL (Power line cables in suspension with triple arms). This is one of the most frequent type of cross arms used nowadays to distribute medium-voltage electric power. It represents a medium/high risk of electrocution for medium- and large-size birds (such as storks, eagles or vultures) as it arches between the bird perched on the top of the pole and the two upper phases (a) or when the bird sits on the lower cross arm (b). The mortality by electrocution associated with this kind of structure in Portugal is of 0.06 birds/pole/year.



Vertical cut module with insulated arches. The new cut module replaced the horizontal-type; they are vertically installed and can have insulated arches. The vertical cut module do not represent an electrocution hazard for birds.

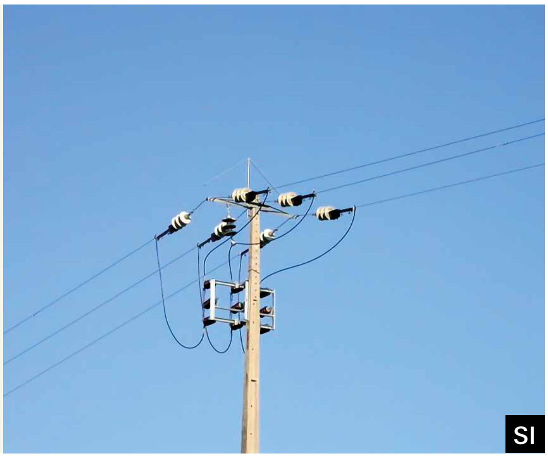


Table I – Number (sample size), average mortality (birds /pole/year) and standard error by studied pole type (adapted from Infante et al., 2005 [4]).

Type	Electrocution			Collision		
	Sample	Average Mortality	Standard Error	Sample	Average Mortality	Standard Error
Horizontal type cross arms *	984	0.53	0.08			
PT with vertical cut module **	296	0.31	0.11			
GAL **	330	0.28	0.09			
TAL	8574	0.25	0.02	832	2.60	0.13
GAL-HDR	4722	0.06	0.01	572	4.22	0.22
Vertical cut module	984	0.53	0.08			

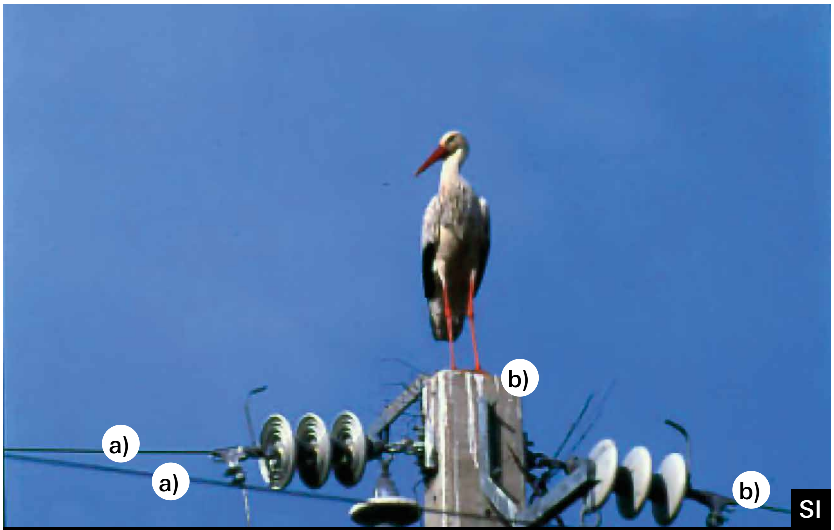
* No collision data are shown for the horizontal cross arms because it is not applicable; this type of line does not exist for cross arms and the analysis is plane-based.
** For this type, no data is available for bird collisions.

Several studies on this subject show that a significant extent of the power lines regularly cause bird mortality. Some segments even contributed to the regression of threatened populations such as those of great bustard (2), little bustard (5), Iberian imperial eagle (6) or Bonelli's eagle (7). Avian mortality due to power lines occurs by electrocution or by collision, each way having with specific impacts on birds and on field sampling approaches (8). As already mentioned, bird mortality in power lines has been studied worldwide and been promoting many efforts to minimize it. Several authorities, including electric power agencies, research centres and nature conservationists, are involved in these searches for solutions.

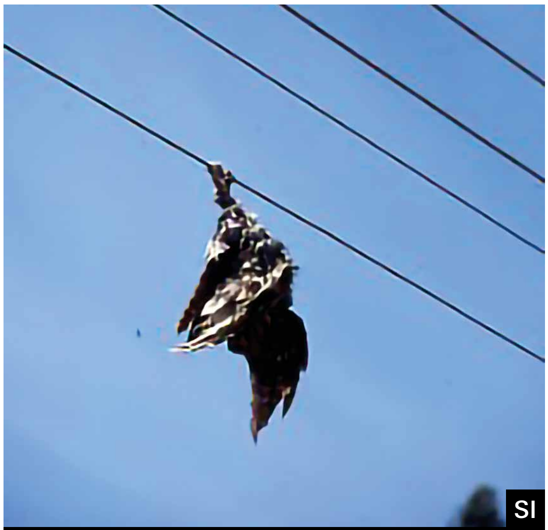
In Portugal, and according to the Avifauna Protocol I (4), the estimated average mortality associated with medium-voltage power lines was 0.18 birds /pole/ year, by electrocution, and 3.4 birds /km/ year, by collision. So, **about 100,000 wild birds are estimated to be killed every year by electrocution or collision in protected areas in Portugal, and about 300,000 across the whole territory.**

How does electrocution occur?

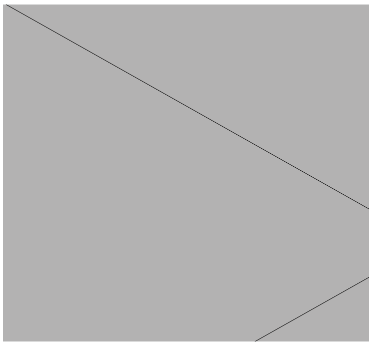
The electrocution takes place when the bird contacts with two conducting elements, of different potentials, allowing the passage of a significant electric flow through its body which might be fatal. It occurs through the contact with two aerial conductors, or between a conductor and any other element connected to the ground (for example a metallic bar on top of a pole), which might create a conducting line. This problem occurs mainly associated with medium-voltage power lines and affects birds that regularly sit on the poles (e.g., storks, diurnal birds-of-prey and/or corvids).

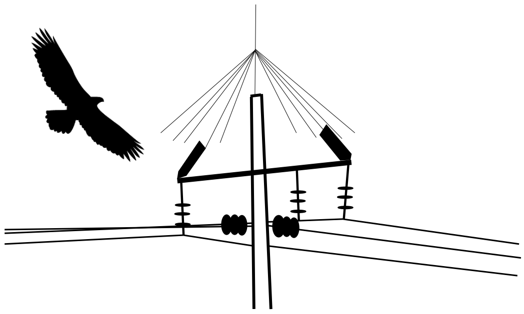


White stork (*Ciconia ciconia*) perched on a GAN pole. The risk of electrocution is due to the contact between phases (a) or between phase and neutral elements of the pole (b).



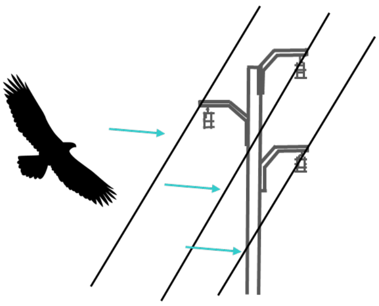
Electrocuted tawny owl (*Strix aluco*) caught between two phases of low-voltage power lines.

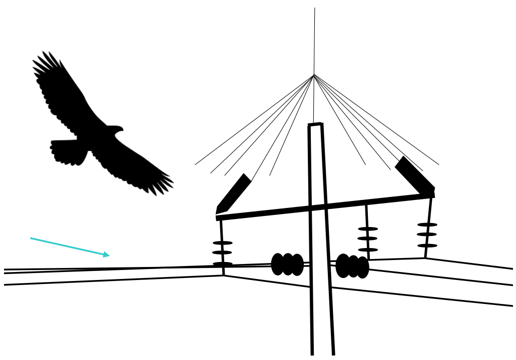




How does collision occur?

The collision results from the impact of the bird with the overhead conductors of medium- and high-voltage electric power, as well as with ground cables or guard cables of the high- and very high-voltage power lines. All species can collide with these components of power lines, but the particular characteristics of some species, such as poor flying agility and gregarious behaviour, make some groups of birds more vulnerable, as is the case of stepparian and aquatic birds. The probability of collision is particularly high in places where great numbers of birds gather.





Design and conception of the Horizontal Eco Cross Arms

Technical considerations

As previously mentioned, the main negative direct effects of power lines are the mortality caused by collision and electrocution. The solution to reduce these effects lays in the development of a type of equipment different from the technology available so far and generally used for electric power distribution. Considering the increasing levels of investment made by the agencies managing power lines to implement additional devices meant to reduce these problems, experience shows, or even demands, that innovative solutions are studied and evaluated for more effective lines and goals. In the framework of this project, a horizontal cross-armed structure for aligned cement poles – the Horizontal Eco Cross Arms (ECO-HAL A2S) – was developed.

The above described conventional types present several planes of collision (corresponding to the power cables), as is the case of the GAL, with three power cables at different heights. Studies about this issue indicate that the risk of collision increases with the number of planes (9). Therefore, a type of construction was developed to present a reduced number of possible collision planes (only one). To reduce collisions, the middle cross arm and the corresponding cable were also lowered (about 80 cm, relative to the position in the conventional type HAL A2S), to the same level as the outer cables. The risk of electrocution could also be decreased by modifying the design of the structure. This was achieved by increasing the safety distances between the cables (min. 1.40 m) and through a design of the pole top that discourages the birds from sitting there, with the installation of anti-nesting (umbrella-type) devices and anti-perching EVD plates.

MAINTENANCE REQUIREMENTS

Hardly any. Degradation occurs at the same speed as for the poles, so their maintenance is included in the actions of maintenance concerning cross arms and insulators. The maintenance costs are lower than in the case of the GAL and GAN type and others because it does not include materials that deteriorate and need to be replaced every 10 years. The expected durability of the Horizontal Eco Cross Arms is 30/40 years, unless they are damaged by extreme weather conditions.

COMPLEMENTARITY WITH OTHER INTERVENTIONS

This type of cross arm can be combined with bird anti-collision devices (BFD, Fire-flys). With just one plane of collision, less of these devices need to be applied: it is only necessary to mark the two outer cables, not the all three as in the conventional situations.

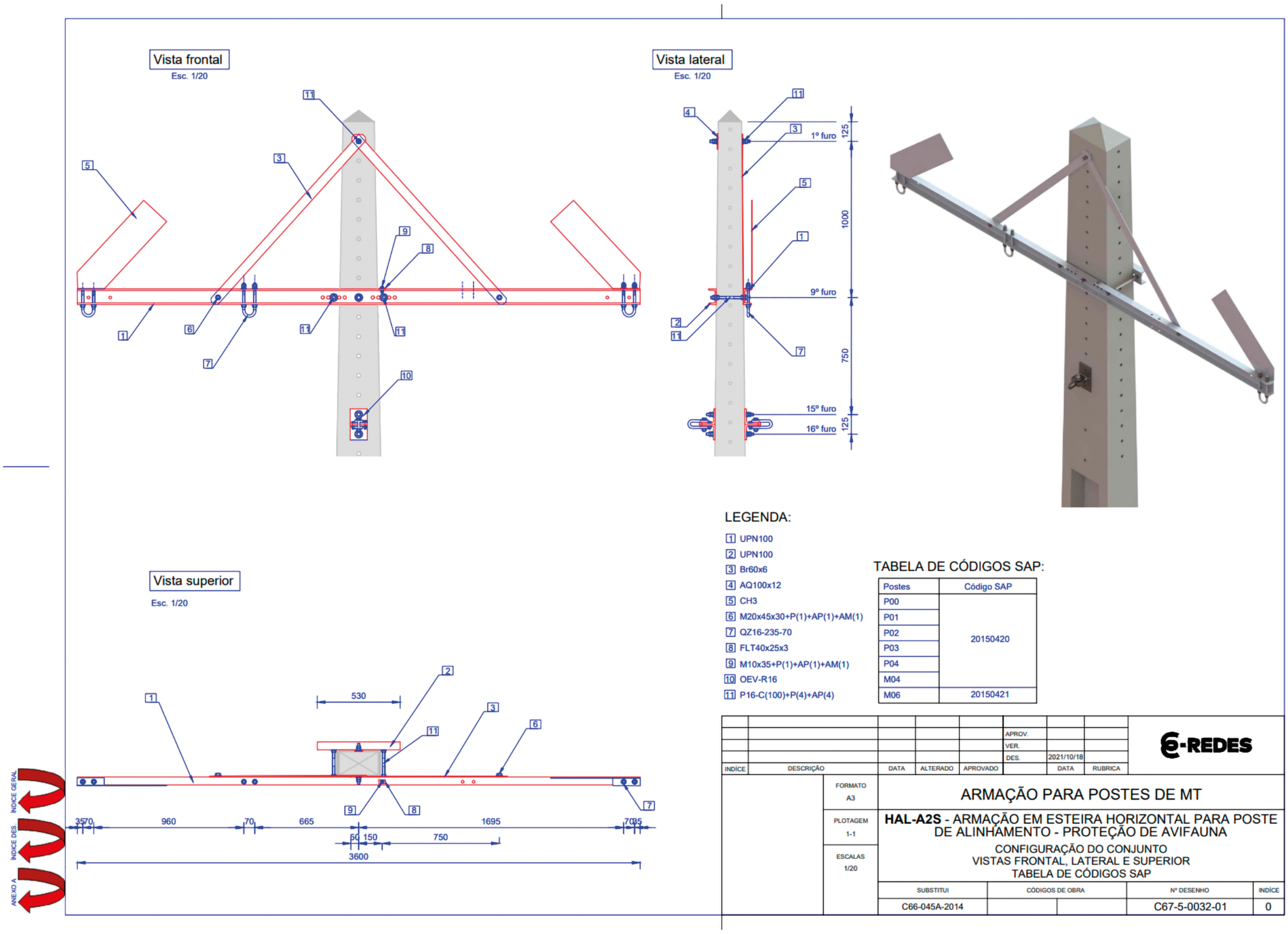
ALTERNATIVES

Before the construction of ECO-HAL A2S in the framework of this project, which introduces an innovative design of the pole top, and its approval for medium-voltage power lines, there was no electrocution risk-free solution presenting only one plane of collision for aligned overhead lines and in Portugal. Therefore, this is the first solution that simultaneously reduces collision and electrocution, thus decreasing avian mortality and encouraging its general application in the construction of new power distribution grids in Protected Areas.

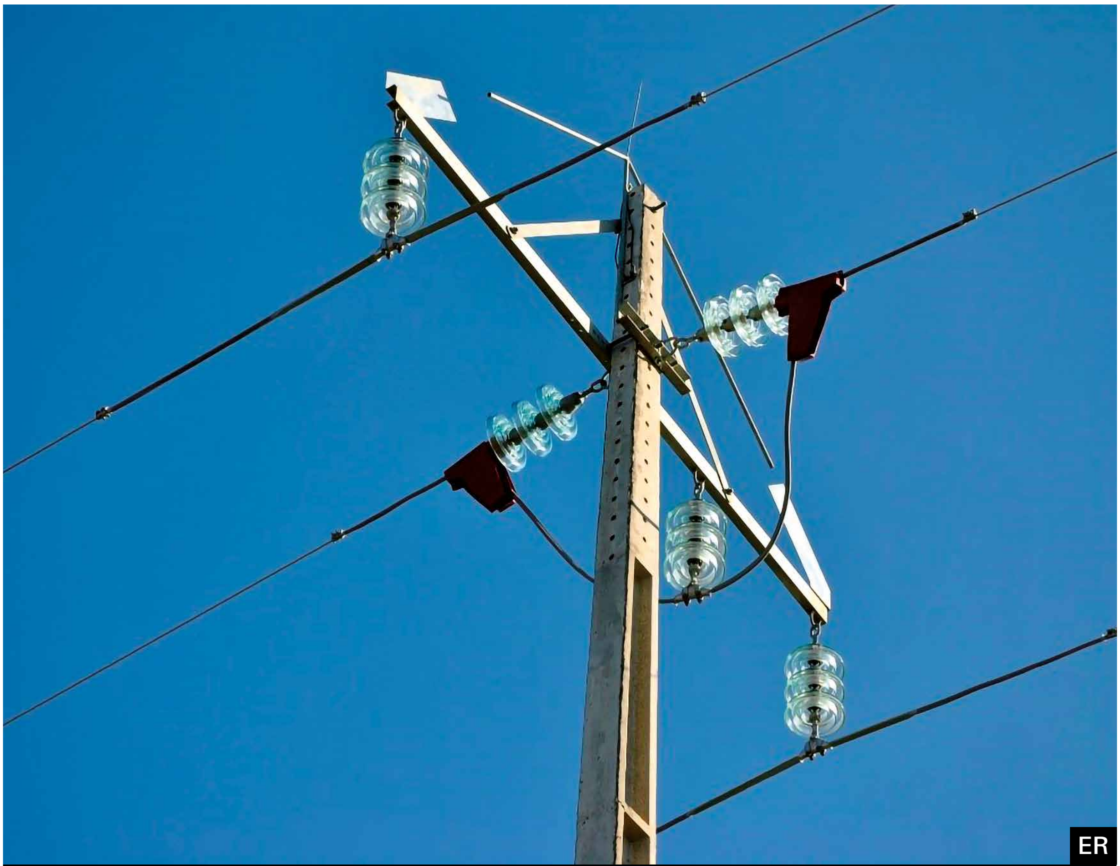
LIMITATIONS

The Horizontal Eco Cross Arms are specific for overhead power lines, and can be applied to upgrade existing lines with the GAL type (3 planes of collision), which represent a high mortality risk for birds. It is worth mentioning that, in these cases, some limitations to the application of ECO-HAL A2S might exist due to degradation of some poles and/or poles with technical characteristics that are unsuitable. In these cases, such poles should be replaced by new ones, with adequate characteristics.

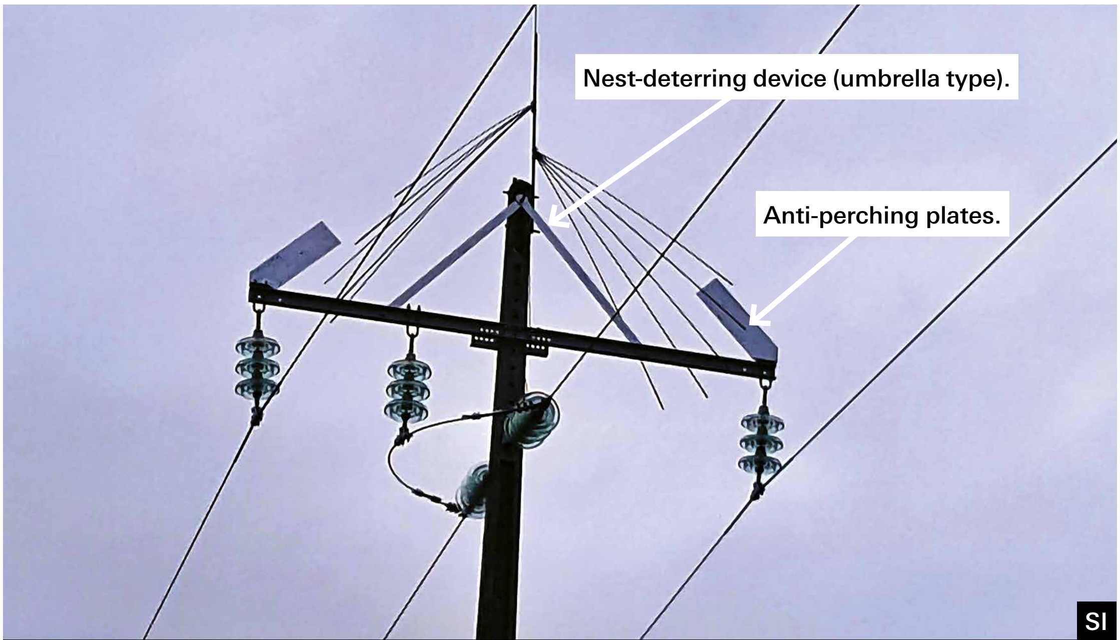
SCHEMATIC REPRESENTATION OF THE HORIZONTAL ECO CROSS ARMS:



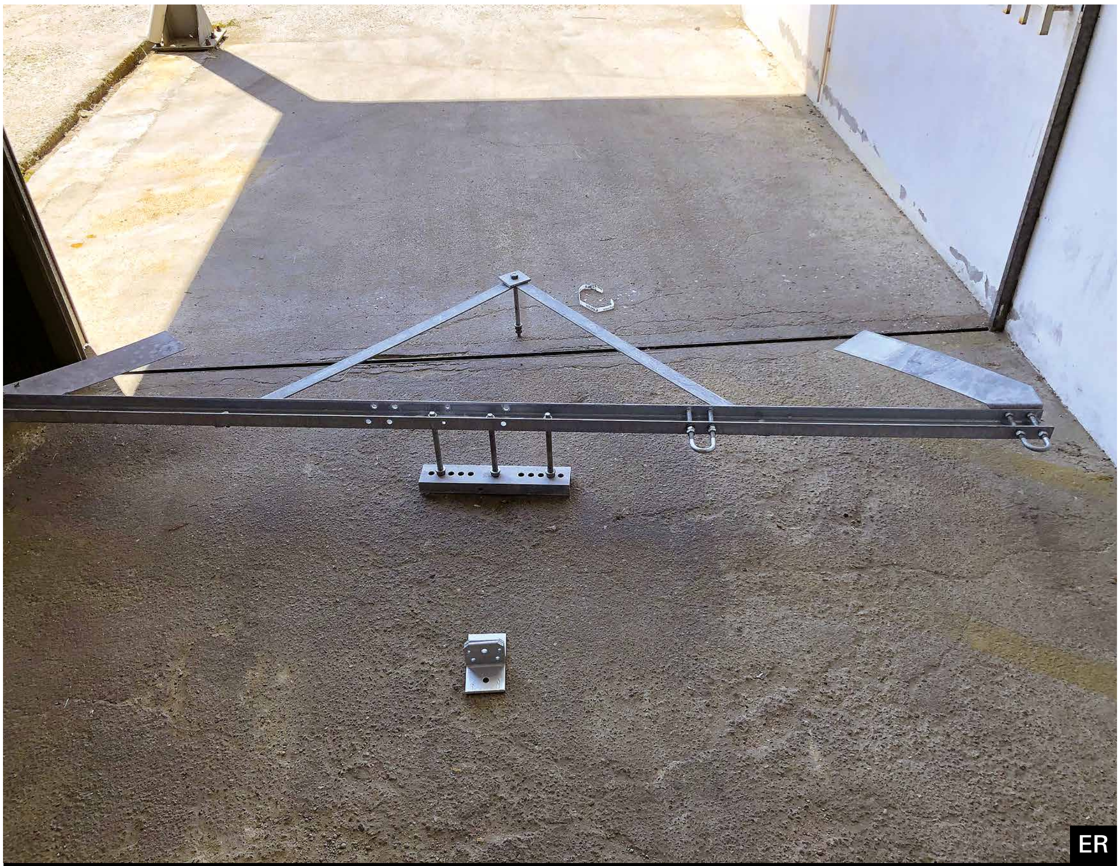
COMPARISON BETWEEN PREVIOUSLY HORIZONTAL CROSS ARMS TYPE AND ECO CROSS ARMS:



Horizontal cross arms, previous typology of the ECO-HAL A2S
Collision - 2 planes of collision; the central phase is attached above the outer conductors; signaling of the 3 conductors is needed, if applicable.
Electrocution – Distances between phases require insulation of the cables close to the pole, if applicable.



Horizontal Eco Cross Arms Advantages:
Collision – By lowering the central phase, only 1 plane of collision is presented; if applicable, signaling is only necessary for the outer conductors.
Electrocution – The previous operation promoted a larger distance between phases, thus avoiding the need of some anti-electrocution device, if applicable.



Metallic components of the Eco Cross Arms.

Eco Cross Arms installed in a pole.

Steps of the installation and evaluation of the Horizontal Eco Cross Arms

1. Identify priority sites for implementation, according to the potential or confirmed mortality, based on:

- Mortality records;
- Maps of occurrence of sensitive / threatened species;
- Maps of connectivity / migration routes between nesting and overwintering places;
- Specific situations: protected areas, special protection areas (SPA), important bird areas (IBA).

2. Identify site characteristics that might constrain the interventions:

- Existence of trees close to the pole;
- Presence of nearby crops;
- Need of permissions by landowners.

Design and planning

1. Design and plan the intervention, taking the site characteristics into consideration:

- Evaluation of poles (age, type);
- Evaluation of the possibility to adapt and / or replace existing poles.

Implementation

1. Select the most appropriate height for the intervention, considering:

- seasonal weather conditions;
- species ecology;
- types of land use;
- permissions of landowners.

Maintenance

1. Establish the frequency of maintenance, according to:

- need of maintenance of cross arms and pole insulators;
- vulnerability to extreme weather events (rain, flooding, wind).

Monitoring / Adjustments

1. Monitoring of effects:

- on mortality (change of patterns);
- on the abundance of fauna;
- on the movements of fauna.

2. Evaluation of the effectiveness of the intervention.

3. Adjustment of the measures:

- Identification of the problem;
- Reversal or improvement of the implemented solution.

INSTALLATION OF THE HORIZONTAL ECO CROSS ARMS: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Evaluation of the effectiveness of the Horizontal Eco Cross Arms to reduce bird mortality

In the framework of this project, 49 Horizontal Eco Cross Arms (ECO-HAL A2S) were installed along 9 km of medium-voltage power lines in the Évora municipality. This area, as well as a similar one where no intervention took place (control area), were surveyed in the same way, for subsequent comparison. The evaluation of effectiveness was based on an experimental design called BACI (Before-After-Control-Impact). This approach allows to evaluate the real effectiveness of the Horizontal Eco Cross Arms since it compares the situations before and after the interventions in both areas. In this way, the methodology allows to isolate the bird mortality reduction due to the installation of ECO-HAL A2S from other external factors, such as weather conditions.

The basic survey method consisted of travelling along pre-defined segments of the power lines, to locate and count dead birds (e.g. 10; 11). The lines were monitored in different times of the life cycles of the species – reproduction: March-April, juvenile dispersion: May-August; migration: September-November, and winter: December-February; one year before, and one year after the interventions. The observers surveyed the soil or the low vegetation, within 5 m around each pole. During the displacements between poles, a route of about 10 m away from the central axis of the line was made, whenever the topography and the vegetation allowed. To confirm the death by electrocution or collision, the necropsies of the dead birds were performed by a vet at CERAS (*Centro de Estudos e Recuperação de Animais Selvagens*) from Castelo Branco.

The observed mortality rate (OMR) was expressed as the number of dead birds by distance unit and by time unit. So, the number of birds/pole/year in the case of electrocution, and the number of birds /km/year in the case of collision were calculated. However, the final total numbers were estimated taking the real values of mortality into account, using correction factors. The real mortality rate (RMR) was obtained from OMR, corrected for the four factors of bias associated with studies of power lines based on the collection of dead birds. The first factor describes the percentage of birds that die within the surveyed area (MAP), the second factor accounts for the percentage of effectively surveyed segment (TPE), the third accounts for dead birds removed by scavengers (RPN) and the fourth accounts for the percentage of birds that are not detected by the observers (NEO).

The actual mortality rate (RMR) was calculated as:

$$RMR = OMR \times 1/ TPE \times MAP \times (1-NEO) \times (1-RPN)$$

Samplings of bird mortality by collision and electrocution.

Main results

A total of 110 dead birds were recorded, of which 85 were used in data analyses; the remaining 25 could not be unequivocally attributed to collision or electrocution after necropsy. Twenty different species of dead birds were identified regardless of the type of impact (Figure 1).

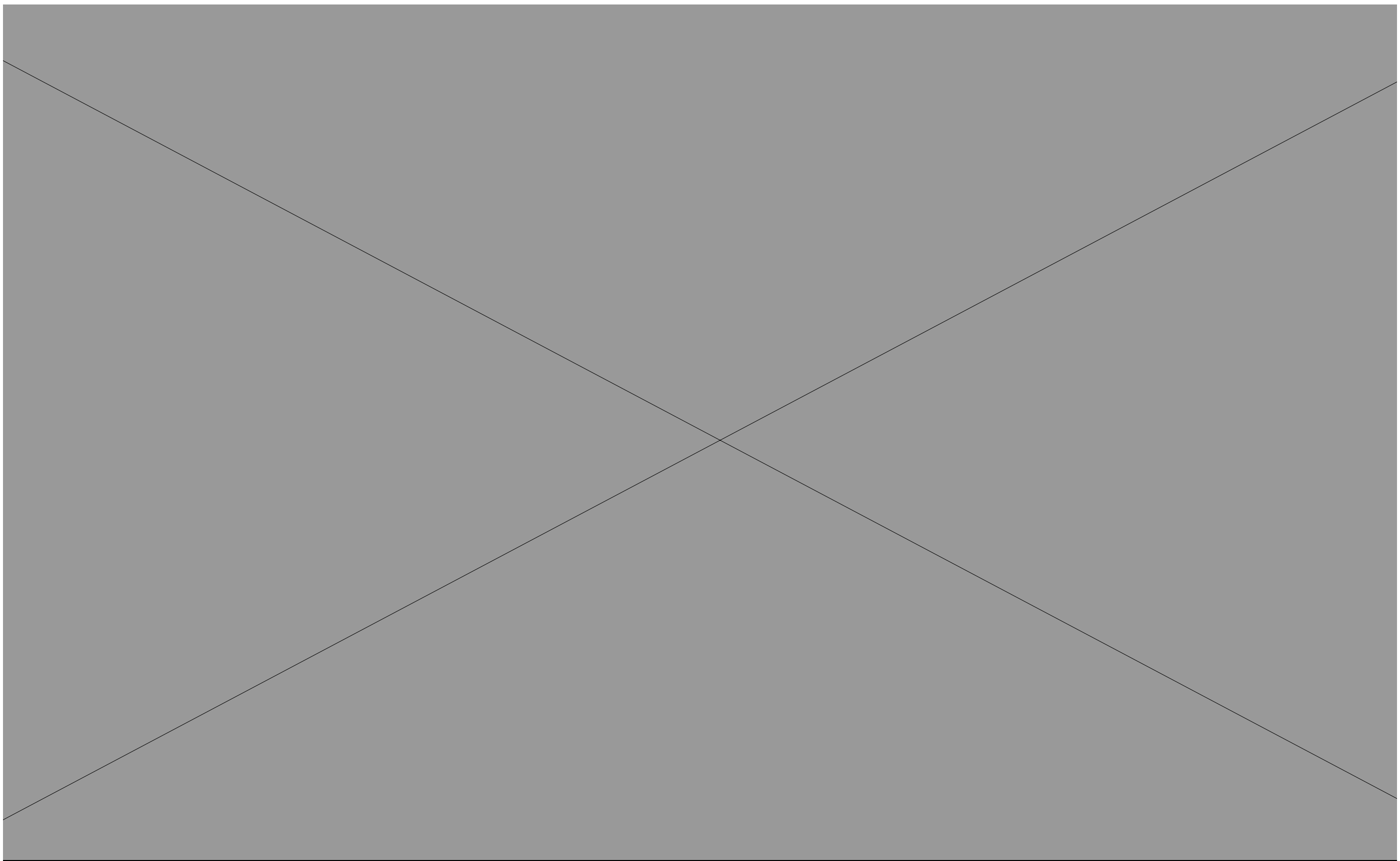


Figure 1 – Species of birds killed by collision or electrocution during the monitoring, and their absolute frequency.

ELECTROCUTION

The results show a 100% reduction of mortality by electrocution after the installation of the Horizontal Eco Cross Arms. The observed mortality rate decreased from 0.14 birds/pole/year to zero in the area of intervention, while 0.14 birds/pole/year were recorded in the control area in the previous year and 0.12 birds/pole/year in the subsequent year (Figure 2 and Table 2).

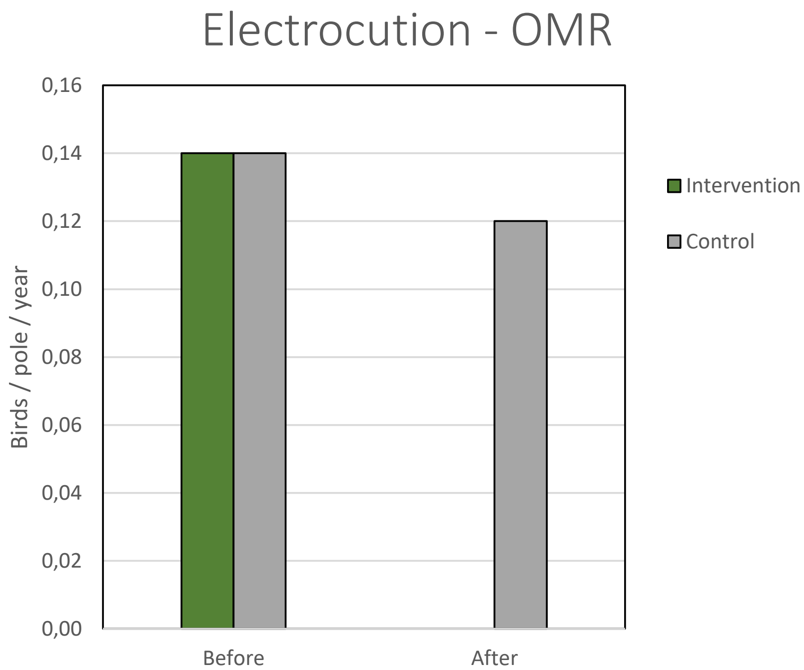


Figure 2 – Observed mortality rate by electrocution in the area of intervention and in the control area, before and after the installation of the Horizontal Eco Cross Arms.

Table 2 – Observed mortality rate (OMR) and real mortality rate (RMR) due to electrocution associated with power lines, in the area of intervention and in the control area, before and after the installation of the Horizontal Eco Cross Arms.

Electrocution					
Horizontal Eco Cross Arms			Control		
	Before installation	After installation		Before installation	After installation
OMR (birds/pole/year)	0.14	0.00	OMR (birds/pole/year)	0.14	0.12
RMR (birds/pole/year)	0.33	0.00	RMR (birds/pole/year)	0.33	0.28

COLLISION

The observed mortality rate due to collision decreased from 2 birds/km/year to 1.67 birds/km/year in the intervention area (Figure 3); however, this difference was not statistically significant (t-test: P = 0.7> 0.05) (Table 3). In the control area, the observed mortality rate also decreased, from 1.44 to 0.89 birds/km/year (t-test: P = 0.4> 0.05). In this case, despite the reduction of mortality after the installation of the Horizontal Eco Cross Arms, the results are inconclusive, since no significant differences between the two areas were found (t-test: P = 0.4> 0.05); however, the reduction of mortality in the control area might be associated with changes in land use that occurred during the monitoring periods.

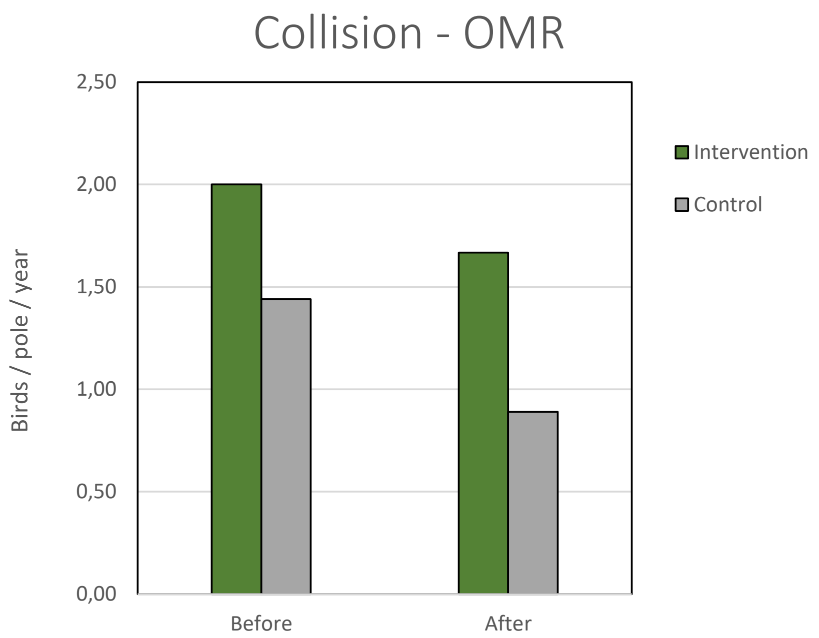


Figure 3 - Observed mortality rate by collision in the area of intervention and in the control area, before and after the installation of the Horizontal Eco Cross Arms.

Table 3 – Observed mortality rate (OMR) and real mortality rate (RMR) due to collision associated with power lines, in the area of intervention and in the control area, before and after the installation of the Horizontal Eco Cross Arms.

Collision					
Horizontal Eco Cross Arms			Control lines		
	Before installation	After installation		Before installation	After installation
OMR (birds/km/year)	2.00	1.67	OMR (birds/km/year)	1.44	0.89
RMR (birds/km/year)	13.05	10.22	RMR (birds/km/year)	8.22	6.05

Cost-benefit

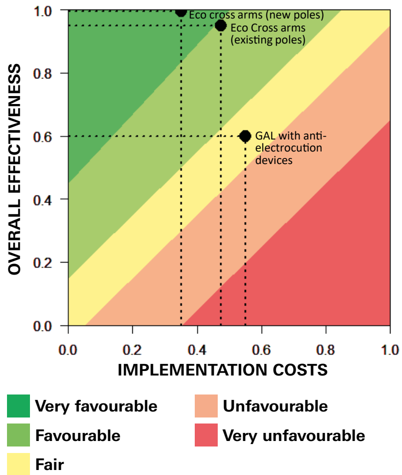
The cost-benefit of each solution was evaluated taking the following parameters into consideration:

- **Difficulty of implementation** in terms of human and logistics resources. The evaluation ranges from 1 (the intervention is localized and does not require qualified human resources) and 5 (the solution requires a project, qualified human resources and/or heavy machinery).
- **Maintenance costs** associated with after the intervention. The evaluation varies between 1 (infrequent and non-specialized maintenance) and 5 (specialized maintenance and/or frequent maintenance required).
- **Need of repair**, determined by the period during which it remains functional. The evaluation varies between 1 (durable and functional solution on the long-term, with scarce need of repair) and 5 (short-term solution, requiring very frequent repair).
- **General cost** of implementation, including the design process when applicable. The evaluation varies between 1 (relatively low costs) and 5 (high costs).
- **Effectiveness to mitigating** mortality on fauna. The evaluation varies between 1 (poorly effective, with low impact on the reduction of mortality or on fauna movements) and 5 (direct impacts on the short-term, on the reduction of mortality or promoting fauna movements).
- **General cost-benefit** of the solution, the weighted analysis of the above parameters. The evaluation can be Very Unfavourable (high technical and/or financial requirements and low effectiveness), Unfavourable, Fair, Favourable or Very Favourable (low levels of technical and/or financial requirements and effective results).

SOLUTION EVALUATION:

Intervention	Fauna group	Difficulty to implement	Maintenance costs	Need for repair	General cost	Effectiveness	Cost-benefit
Eco Cross arms New poles	Birds	●●●●○	●○○○○	●○○○○	●○○○○	●●●●●	Very favourable
Eco Cross arms Existing poles	Birds	●●●●●	●○○○○	●○○○○	●●●○○	●●●●●	Favourable
GAL with anti-electrocution devices	Birds	●●●●○	●●○○○	●●○○○	●●●○○	●●●○○	Fair

COST-BENEFIT:



The innovative solution ECO-HAL A2S showed an excellent cost-benefit relation; although the costs can be high when adapting existing poles, their effectiveness to reduce bird mortality has been demonstrated. Actually, the costs are not different from those of other structures, such as the GAL, and the effectiveness is higher; moreover, no extra costs are involved, in the case of new lines. ECO-HAL A2S is a more enduring solution than those complemented with anti-electrocution devices, with low maintenance costs or none at all. To reduce bird mortality in the case of the GAL-type it is necessary to add anti-collision and anti-electrocution measures, made of materials that rapidly deteriorate and need to be replaced every 10 years, thus increasing the costs of maintenance and repair when compared with ECO HAL2S. The Horizontal Eco Cross Arms were approved for use in zones of wild bird occurrence, Natura 2000 network, Protected Areas and even across the whole national territory.

TECHNICAL GLOSSARY

BACI (Before-After-Control-Impact) – Experimental design that compares the situations before and after the intervention between the intervention area and the control area.

BFD – Bird flight diverter or double spirals – anti-collision device for birds, to decrease possible collisions with the cables.

ECO-HAL A2S, Horizontal Eco Cross Arms – Structure of horizontal cross arms for concrete poles.

Fire-flys – ribbon-like or rotary anti-collision devices, implemented aiming to increase the cables visibility, in order to decrease possible collisions with the cables.

GAL – Power line cables in suspension with triple arms, for attachment of the conductors to the aligned pole.

GAN – Straight cross arms -like structure to attach the conductors to the angled (or aligned) pole.

HDR - Structure of horizontal cross arms for derivation.

IBA – Important Bird Area

OMR – Observed Mortality Rate

PT with vertical cut module – Transformation module.

RMR – Real Mortality Rate

SPA – Special Protection Area

TAL – Straight cross arms with vertical isolated rigid triangle structure to attach the conductors to the aligned pole.

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