

Power line routing and configuration as major drivers of collision risk in two bustard species

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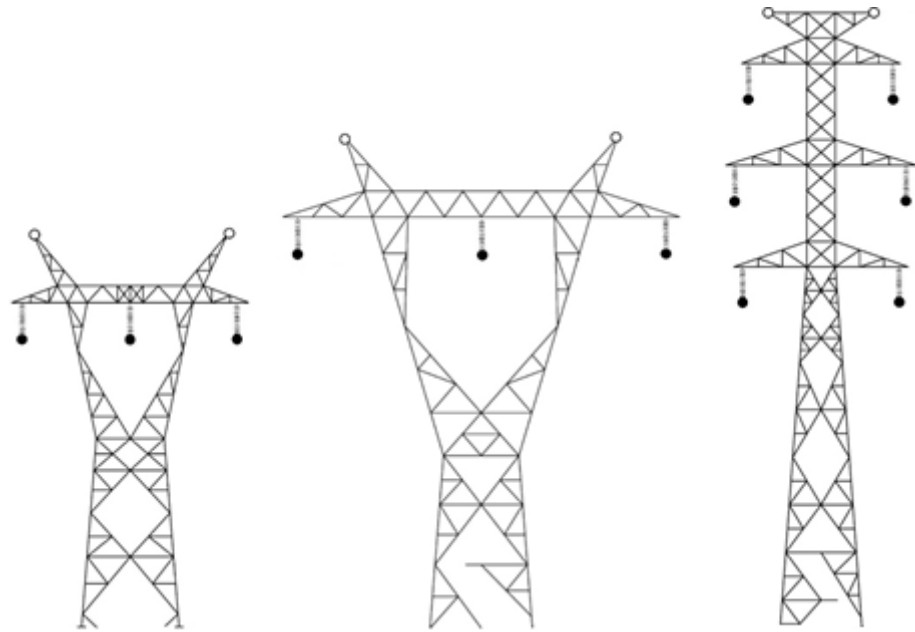
SUPPLEMENTARY TABLE 1 List of studies on collisions of the great bustard *Otis tarda* and little bustard *Tetrax tetrax* with transmission power lines in Alentejo region used in this analysis. The Table indicates the number of 2 km power line sections surveyed, the power line configuration (see Supplementary Fig. 1), the total length of surveyed power lines, the study duration, the interval between consecutive surveys, and the total number of great and little bustard carcasses registered.

Source	No. of power line sections surveyed	Power line configuration	Survey length (km)	Study duration (months)	Survey interval (days)	No. of carcasses	
						Great bustard	Little bustard
Neves et al., 2005 ¹	61	Small, Large	139.0	12	30 / 90	14	40
Marques et al., 2007 ²	6	Small	11.2	29	15	32	30
Marques et al., 2007 ²	3	Small	5.7	29	30	8	1
Marques pers. data ²	1	Large	2.7	12	30	3	2
Ecosistema 2007 ³	15	Small, Medium	41.0	12	30	0	11
Procesl 2007, 2010 ³	12	Large	25.0	67	15 / 30	2	6
Agripro Ambiente 2007, 2008, 2009 ³	2		2.8	36	90	0	0
Ecosativa 2009 ³	15	Medium	26.5	24	30 / 90	0	5
Infante et al. 2011 ²	25	Small	61.3	24	30	0	2
Procesl 2012 ³	10	Large	22.5	24	15	0	0
Procesl 2015 ³	5	Large	7.9	24	30	0	0

¹National assessment.

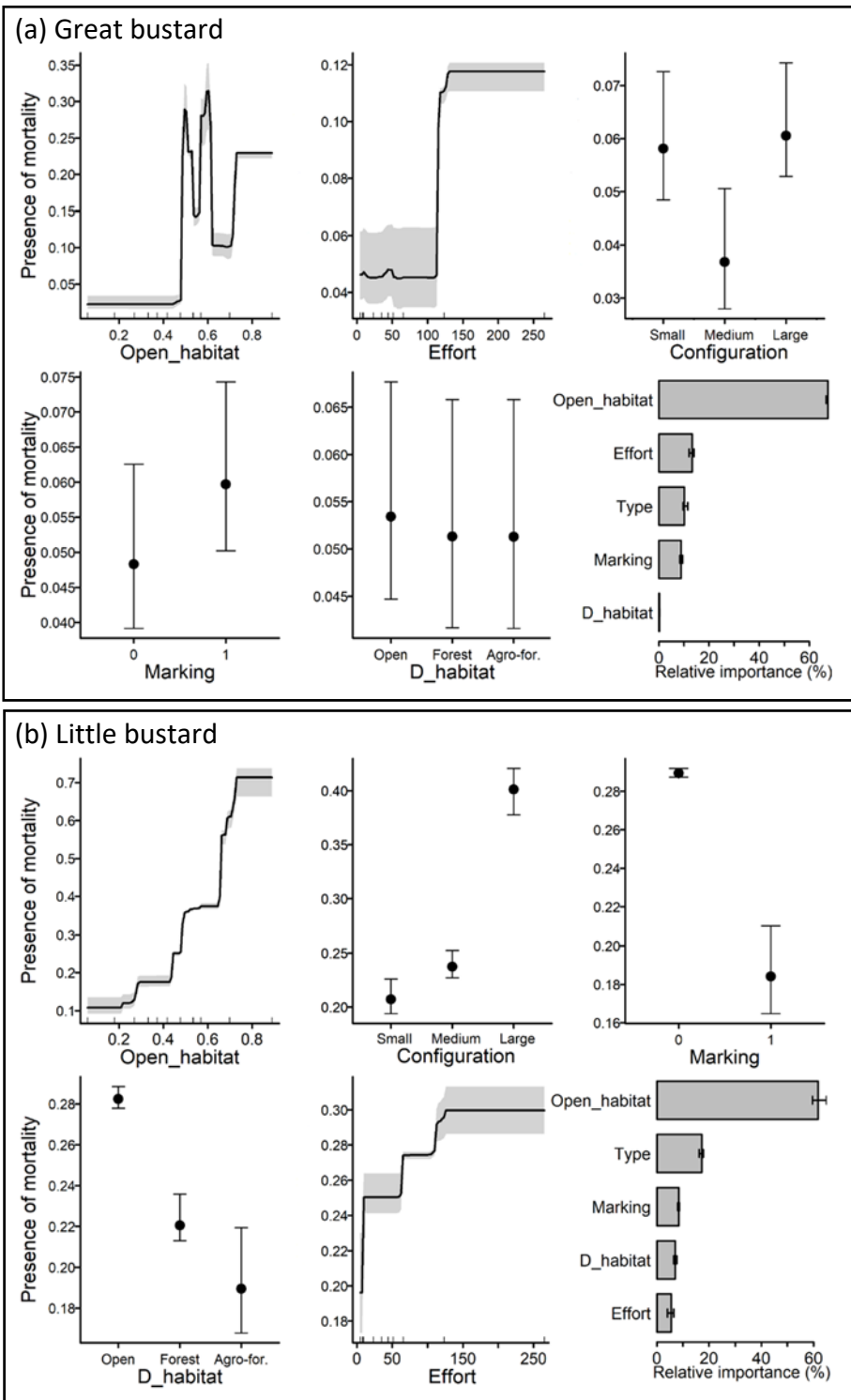
²Wire-marking effectiveness study.

³Monitoring programme (from environmental impact assessment process).

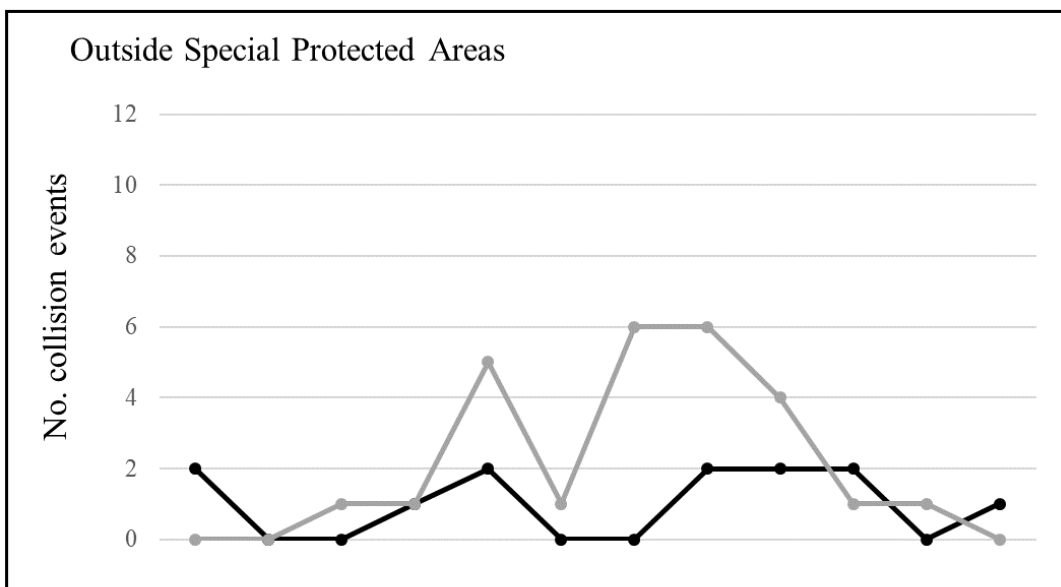
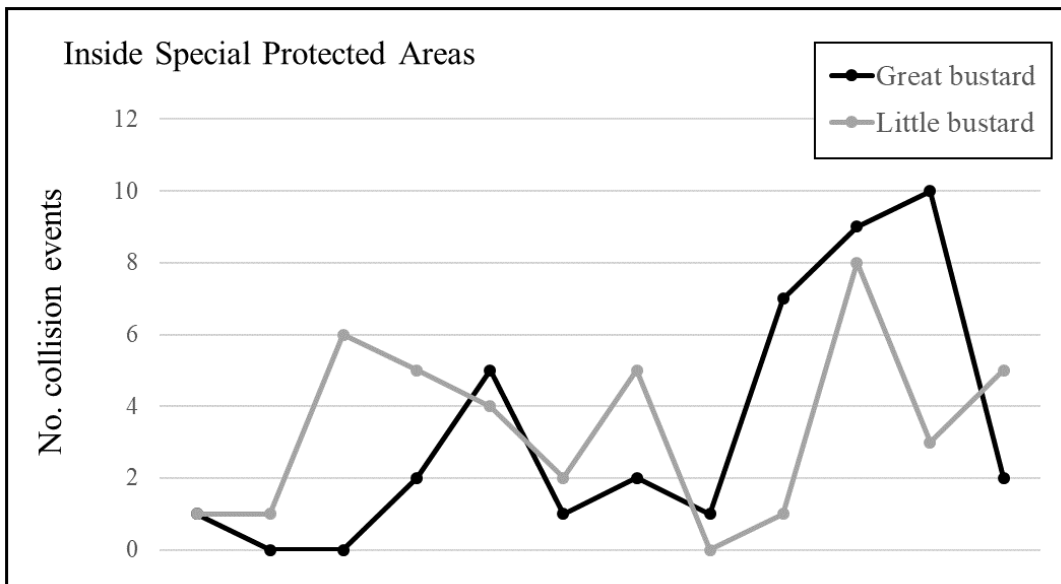


	Small configuration, horizontal (single circuit) at 150 kV	Medium configuration, horizontal (single circuit) at 400 kV	Large configuration, vertical (double circuit) at 150 or 400 kV
No. of vertical wire levels	2	2	4
Mean \pm SD pylon height (m)	30.2 \pm 4.7	38.0 \pm 7.1	47.3 \pm 8.1
Mean \pm SD distance between top and bottom wires (m)	5.7 \pm 0.5	8.3 \pm 0.7	22.3 \pm 3.2

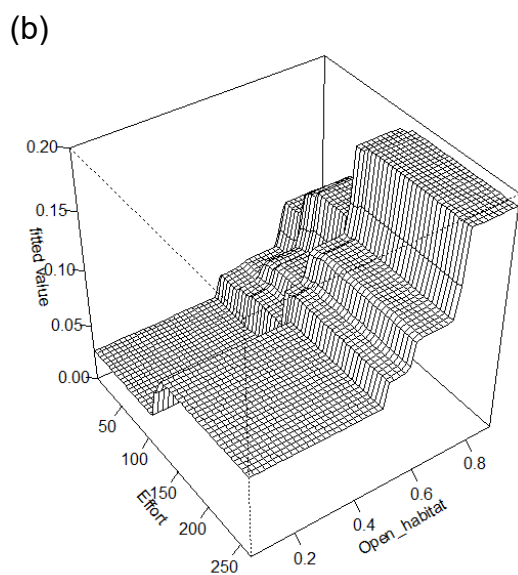
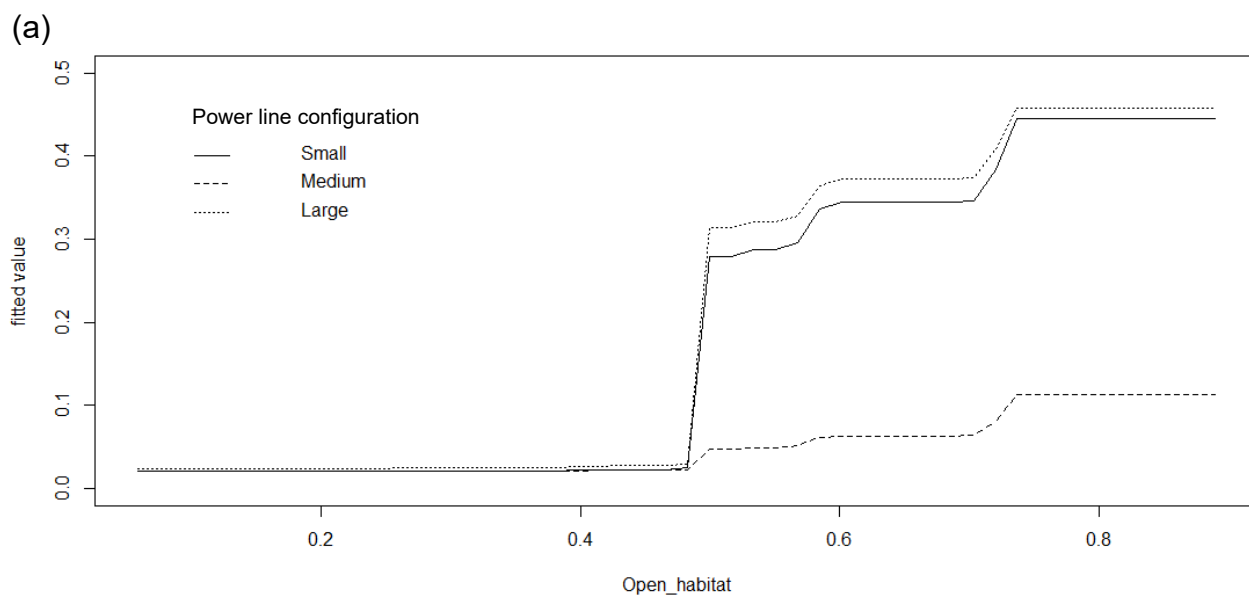
SUPPLEMENTARY FIG. 1 Characterization of the three main configurations of transmission power line pylons in Alentejo, Portugal. The solid dots represent the position of the conductor wires, while the open dots represent the earth wires.



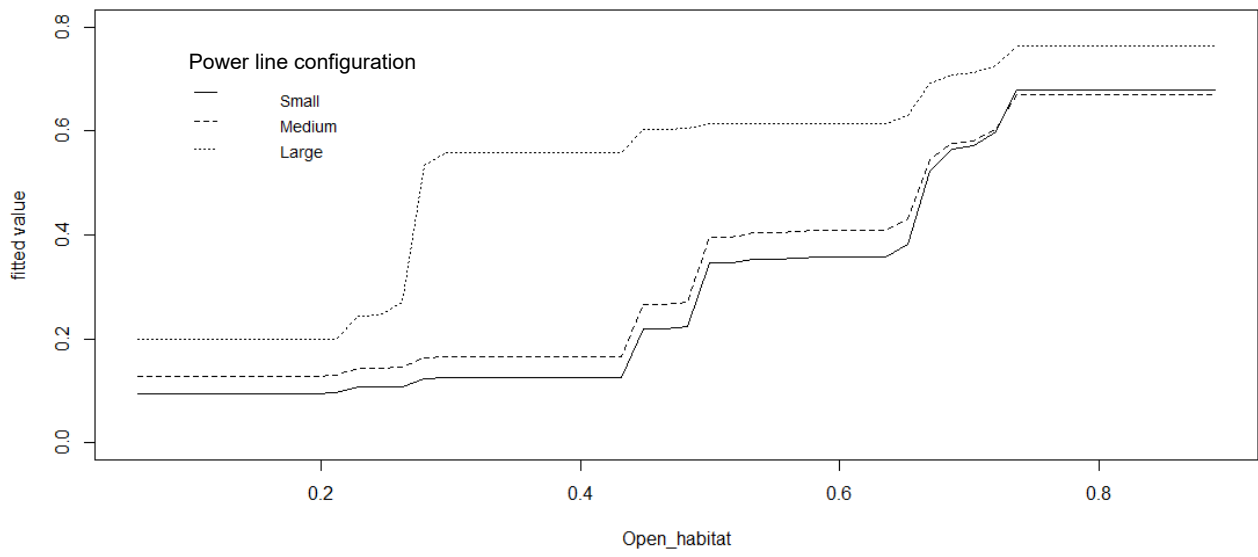
SUPPLEMENTARY FIG. 2 Partial dependence plots (means and 95% confidence intervals) and relative importance (%; means and 95% confidence intervals) for the predictor variables influencing the presence of mortality of (a) great bustards and (b) little bustards by collision with transmission power lines in Alentejo, Portugal. These models were fitted without imposing monotonic variations to the variables. See Supplementary Fig. 1 for details on small, medium and large configuration. Ticks along the x-axis of a plot show the distribution of sites across the continuous variables, in deciles. Intervals for fitted functions and relative importance represent the range (minimum and maximum values) for a set of 100 runs. Great bustard model: $20.4 \pm 1.9\%$ explained deviance; $AUC = 0.849 \pm 0.02$ and Pearson's correlation of 0.42 ± 0.03 . Little bustard model: $15.5 \pm 1.6\%$ explained deviance; $AUC = 0.778 \pm 0.01$ and Pearson's correlation of 0.46 ± 0.02 .



SUPPLEMENTARY FIG. 3 Seasonal variation in great bustard and little bustard collisions with transmission power lines (number of carcasses or remains) inside Special Protected Areas (n = 40 great bustards; n = 41 little bustards) and outside Special Protected Areas (n = 12 great bustards; n = 26 little bustards).

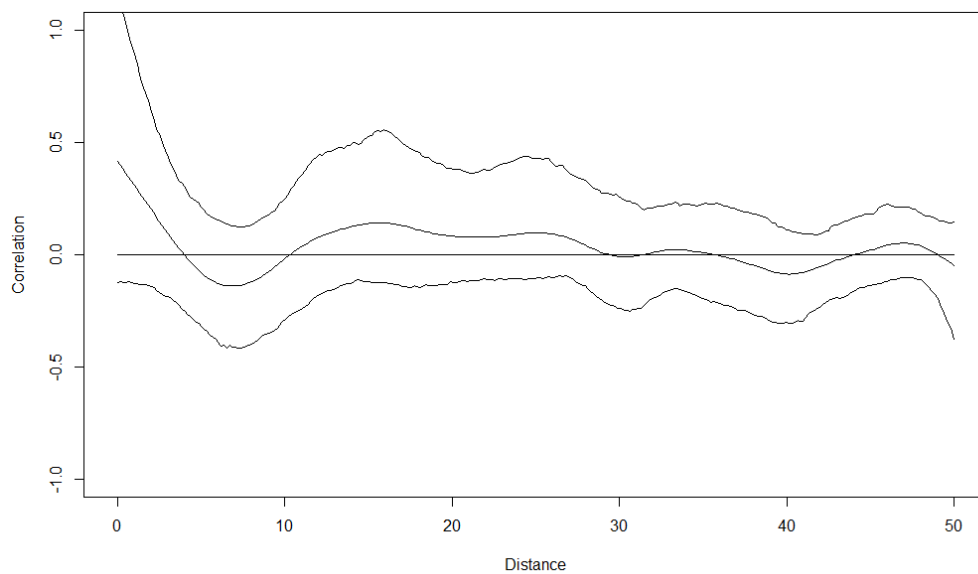


SUPPLEMENTARY FIG. 4 Interaction between the predictor variables in the great bustard model:
(a) proportion of open habitat in a 5 km buffer and power line configuration (Supplementary Fig. 1);
(b) sampling effort and proportion of open habitat.

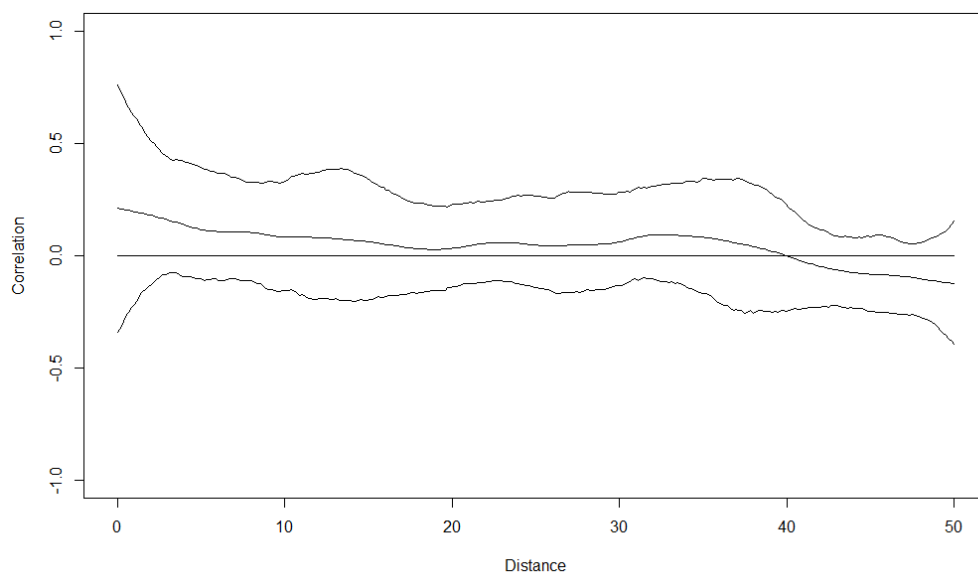


SUPPLEMENTARY FIG. 5 Interaction between the predictor variables in the little bustard model: proportion of open habitat in a 5 km buffer and power line configuration (see Supplementary Fig. 1).

(a) Great bustard



(b) Little bustard



SUPPLEMENTARY FIG. 6 Spline correlograms describing spatial autocorrelation for the boosted regression trees residuals for models describing the presence of mortality of (a) great bustards and (b) little bustards in transmission power lines in Alentejo, Portugal. Lines represent the estimate (in the middle) and the 95% confidence envelopes (external lines) using 1000 bootstrap resamples (Bjørnstad and Falck, 2001).

References

- AGRIPRO AMBIENTE (2007) *Monitorização do Impacte da Linha de ligação do Parque Eólico do Pinhal Interior à Subestação da Falagueira (150 kV) nos Vertebrados Voadores – 1º Relatório Anual*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Lisbon, Portugal.
- AGRIPRO AMBIENTE (2008) *Monitorização do Impacte da Linha de ligação do Parque Eólico do Pinhal Interior à Subestação da Falagueira (150 kV) nos Vertebrados Voadores – 2º Relatório Anual*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Lisbon, Portugal.
- AGRIPRO AMBIENTE (2009) *Monitorização do Impacte da Linha de ligação do Parque Eólico do Pinhal Interior à Subestação da Falagueira (150 kV) nos Vertebrados Voadores – 3º Relatório Anual*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Lisbon, Portugal.
- BJØRNSTAD, O.N. & FALCK, W. (2001) Nonparametric spatial covariance functions: estimation and testing. *Environmental and Ecological Statistics*, 8, 53–70.
- ECOSSISTEMA (2007) *Linhas de alta tensão Alqueva – Ferreira do Alentejo e Ferreira do Alentejo – Sines 2, a 400kV. Monitorização de impactes na avifauna*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Lisbon, Portugal.
- ECOSATIVA (2009) *Monitorização de Vertebrados Voadores – Linha Sines-Portimão 3, a 400 kV. Relatório Final*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). São Teotónio, Portugal.
- INFANTE, S. (Coord) (2011) *Estudo de avaliação da eficácia de dispositivos anti colisão. Relatório Final*. Unpublished report, Quercus Associação Nacional de Conservação da Natureza. Castelo Branco, Portugal.
- MARQUES, A.T., ROCHA, P. & SILVA, J.P. (2007) *Monitorização dos Efeitos da Linha de Muito Alta Tensão Ferreira do Alentejo/Ourique sobre Espécies Prioritárias, Mortalidade e Taxas de Voo*. Instituto para a Conservação da Natureza, Lisbon, Portugal.
- NEVES, J., INFANTE, S., MINISTRO, J. & BRANDÃO, R. (2005) *Estudo sobre o Impacto das Linhas Eléctricas de Muito Alta Tensão na Avifauna em Portugal*. Quercus Associação Nacional de Conservação da Natureza e SPEA Sociedade Portuguesa para o Estudo das Aves. Castelo Branco, Portugal.
- PROCESL (2007) *Linha de transporte de energia Alqueva – Fronteira Espanhola, a 400kV. Relatório bianual de monitorização 2005-2006*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Alfragide, Portugal.
- PROCESL (2010) *Linha de transporte de energia Alqueva – Fronteira Espanhola, a 400kV. Relatório final de monitorização*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.). Alfragide, Portugal.
- PROCESL (2012) *Linha Falagueira-Estremoz, a 400 kV – Monitorização de Vertebrados Voadores. Relatório Final (Maio de 2010 a Abril de 2012)*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.), Alfragide, Portugal.
- PROCESL (2015) *Ramal da Linha Palmela-Sines 3, a 400 kV, para Fanhões – Monitorização de Avifauna e Quirópteros – Relatório Final, 2013/2015*. Unpublished report (prepared for REN – Rede Eléctrica Nacional, S. A.), Alfragide, Portugal.