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Better utilisation and transparency of bird data collected by powerline companies

Esther F. Kettel[1,2]*, Chris Thaxter[1], Steffen Oppel[3], Andrew Carryer[4,5], Liam Innis[5], James W. Pearce-Higgins[1,6]

Corresponding author email: esther.kettel02@ntu.ac.uk

[1]British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU, United Kingdom

[2]Nottingham Trent University, School of Animal, Rural & Environmental Sciences, Southwell, Nottinghamshire, NG25 0QF, United Kingdom.

[3]Royal Society for the Protection for Birds Centre of Conservation Science, The David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, United Kingdom.

[4]Climate Analytics, Ritterstraße 3, 10969 Berlin, Germany.

[5]Renewables Grid Initiative, Manfred-von-Richthofen-Straße 4, 12101 Berlin, Germany.

[6]Department of Zoology, University of Cambridge, The David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, United Kingdom.

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Highlights

- Powerline companies collect a range of data on bird mortalities and mitigation.
- The value of such data is widely recognised among stakeholders.
- Sharing of bird data among stakeholders will inform best mitigation practices.

Abstract

There is in an ongoing expansion of powerlines as a result of an increasing global demand for energy. Powerlines have the potential to negatively impact wild bird populations through collisions and/or electrocution, and reducing bird powerline collision and electrocution risk is a priority for companies running high-voltage powerlines (known as Transmission System Operators (TSOs)). Most TSOs are legally required to assess any potentially significant impacts via Enivronmental Impact Assessments, and so potentially collect a significant amount of data on the presence of species, species behaviour, and observed mortality rates. The value of such data, if available, for reducing and preventing bird casualties could be enhanced by increasing availability across TSOs and other decision-makers. We review the extent to which the sharing of data is happening, and how the quality, scope and availability of bird data collected by European TSOs could be improved, through use of a questionnaire and workshop with TSOs, conservationists and academics. Sixteen European TSOs responded to the questionnaire and 30 stakeholders attended the workshop. There was wide recognition of the value of different types of data on birds at powerlines, and a positive attitude to working together to share and enhance data across stakeholders to achieve the shared goal of reducing bird mortalities. Key barriers to the sharing of data included a lack of a centralised database, the lack of standardised methods to collect bird data and concerns over the confidentiality of data and reports. In order to overcome these barriers and develop a collaborative approach to data sharing, and ultimately inform best practice to reduce significant negative impacts on bird populations, we suggest a stepwise approach that (1) develops guidance around the field methods and data to be collected for mitigation effectiveness and (2) shares meta-data / bibliography of studies of powerline impacts / mitigation effectiveness for birds. In time, a more structured approach to the sharing of data and information could be developed, to make data findable, accessible, interoperable and reusable.

Keywords: Environmental Impact Assessment; bird electrocution; bird collision; human-wildlife conflict; mitigation; Transmission System Operators

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1. Introduction

Worldwide there are thousands of kilometres of powerlines transporting generated energy from both traditional (e.g. coal) and renewable sources (e.g. wind, solar, hydropower) to the end user. The global demand of electricity is predicted to grow at 2.1% per year to 2040, and so powerline networks are expanding globally (International Energy Agency, 2019). When inappropriately designed, overhead powerlines pose a collision and electrocution risk to certain bird species, leading to potentially detrimental effects on some avian populations (e.g. Schaub et al., 2010; Boshoff et al., 2011; Jenkins et al., 2011). The likelihood of powerline-related mortality is dependent on species-specific factors such as flight behaviour, aerodynamic capability, life-history strategies, sensory perception and morphological features (Bevanger, 1994; Bernardino et al., 2018), with large-bodied species such as raptors, cranes and storks particularly vulnerable to collision and electrocution (Janss, 2000; Rubolini et al., 2005). Placement of powerlines on migratory pathways (Kirby et al., 2008) and in areas with important habitat features (Garrido & Fernández-Cruz, 2003; Oppel et al., 2021a), as well as a number of powerline-specific factors such as the number of vertical wire levels, wire height (Bernardino et al., 2018) and the design of pylons and poles (Lehman et al., 2007; Hernández-Lambraño et al., 2018) are also important factors in the rate of bird mortalities.

In light of the dangers of poorly sited and/or designed powerlines to some avian populations, there is a recognised need to mitigate against powerline collisions and electrocutions for conservation purposes and to meet legislative requirements. Strategic Environment Assessments (SEA) and Environmental Impact Assessments (EIA) are processes that aim to identify and mitigate any significant negative impacts on the environment and are legislative requirements in most countries. Mitigation to reduce significant negative impacts on birds can be through careful planning of line design, burying powerlines underground, the installation of wire insulation, perching deterrents and line-marking devices to reduce bird collisions and electrocutions (Prinsen et al., 2012). Indeed, careful route planning and underground cabling are thought to be the most effective solutions in reducing or completely eliminating bird collisions and electrocutions altogether, whilst line marking and other mitigation measures that are usually implemented post-construction have shown to reduce mortalities in most cases (Bernadino et al., 2018).

Bird collisions and electrocutions can have financial consequences for energy companies due to disruptions to power supplies and costs associated with repairs, as well as financial costs and interruptions to the consumers (Küfeoğlu and Lehtonen, 2015). As well as complying with national and international legislation (European Commission, 2018), it is therefore in the company’s interest to adopt the best mitigation practices to maintain reputation and public acceptance.

A number of studies have examined mitigation design and effectiveness (e.g. Janss & Ferrer, 2001; Barrientos et al., 2011; Barrientos et al., 2012; Sutherland et al., 2020) and a review of bird collisions with powerlines found that research on this issue has advanced in recent decades (Bernardino et al., 2018). However, the authors of the review conclude that more scientific evidence is needed on what powerline-specific factors are affecting bird collisions, to support recommendations of good practice to reduce bird collisions, and to understand the population-level impacts of induced mortality. Furthermore, improved understanding of mitigation effectiveness and the scale of impacts is hampered by much of the data on bird collisions being either unavailable and/or inaccessible to different stakeholders making decisions on mitigation measures (Prinsen et al., 2012).

It is vital to engage the energy industry, including Transmission System Operators (TSOs; companies responsible for controlling and operating transmission grids), in these issues to identify hotspots of high avian mortality for mitigation and to understand the effectiveness of different mitigation options. However, there is a danger that progress in this regard could be hampered by conflict - real or perceive - between conservation NGOs, eager to highlight and reduce the risk of bird mortality, and industry concerned about public perception and the cost of mitigation. Instead, approaches are required that encourage dialogue between different interest groups (Redpath et al., 2013). One potential approach to achieve this, whilst also informing decision making on mitigation measures, could be to bring together data collected on bird presence, bird mortality and effectiveness of mitigation techniques by energy companies in a systematic fashion, and through a single resource, so that best practices can be shared widely between different stakeholders. Given the common goal of conservation organisations and electricity companies, sharing of data and subsequent application of measures is likely to be more effective if stakeholders work collaboratively (D’Amico et al., 2018).

The power of such large-scale data collation is shown by work on collision risk vulnerability for birds and bats at wind farms, where a global literature review and subsequent meta-analysis of collision mortality rates of species identified the most vulnerable species, revealed hotspots of their occurrence and made recommendations for mitigation at a global level (Thaxter et al., 2017). Whilst similar collision risk approaches have been taken for powerlines at a regional or country level (e.g. Pérez-García et al., 2017; Hernández-Lambraño et al., 2018; D’Amico et al., 2019), it could be valuable to undertake such assessments across a wider, continental scale, particularly to inform decision-making in areas where existing data and monitoring of birds and mitigation measures is low or inaccessible (Oppel et al. 2021b). Furthermore, issues of variable data quality, lack of standardisation of methods and reporting, lack of availability of grey literature and lack of general sharing of information have been identified as limitations in the context of wind energy mitigation (Fernández-Bellon, 2020) and are likely to show

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parallels with the powerline sector. In order for such an international effort of data sharing to succeed, companies that have access to bird data associated with powerlines must first be willing to collect and share such data.

Here, through use of a questionnaire and workshop, we aim to assess (i) the type of bird data (e.g. fatalities, abundance, distribution etc.) collected by TSOs in Europe and (ii) the potential for wider sharing of data among TSOs, and between non-governmental organisations (NGOs) and researchers. Given the legislative requirements associated with the construction of powerlines, we expect to find that most TSOs collect at least some data related to bird adundance, mortalities and mitigation effectiveness, but are unsure of the scale and type of data collected. Due to the common goal of reducing impacts of powerlines on birds that likely exists between different stakeholders, we expect to find a willingness to share data on risks and effective mitigation approaches, but recognise that there could be a number of barriers to doing so, which we seek to identify to inform future work. Our study provides a first insight into the potential for data and information sharing among TSOs and with other stakeholders on a continental scale, to inform the development of future collaborative approaches to reduce the conflict between bird conservation and energy transmission.

2. Methods

We used a combined questionnaire and workshop approach to undertake the audit in which a questionnaire was circulated to a wide-range of participants and analysed, prior to a workshop at which the results of the questionnaire analysis was presented and refined / discussed in more detail (Pearce-Higgins et al. 2017).

2.1 Questionnaire design

A questionnaire aimed at TSOs in Europe was designed to obtain information on the bird data collected by the company or external contractors (e.g. ecological consultants). It was circulated in December 2018 and January 2019 to all 11 TSO members of the Renewable Grids Initiative (a collaboration between TSOs and NGOs across Europe), as well as five other TSOs that have mutual partnerships and contacts with the authors. The questionnaire contained 26 questions (see Supplementary Material 1) divided into five sections: (1) reasons for data collection and partnerships with organisations, (2) collection of bird collision/electrocution data, (3) collection of bird presence/abundance data, (4) making use of the data, and (5) sharing the data.

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The number of TSOs providing an answer to a specific option per question are presented and any comments made by the respondents are summarised for each question. Respondents could often choose more than one option for each question, so answers do not always sum up to the maximum number of respondents answering each question.

2.2 Workshop

In April 2019 we held an interactive two-hour workshop in Brussels, Belgium, to gain further understanding on the value of bird data and information, and potential ways of effectively sharing such data. The participants were selected to include a mix of stakeholders (TSOs, NGOs and Others (academic researchers and consultants)). The results from the questionnaire were presented at the workshop before attendees were split into three mixed groups of 10 participants each and asked to undertake the following tasks: (i) to review the value of collecting bird data, (ii) to understand the benefits of sharing data to different stakeholders and (iii) to discuss potential ways of improving effective sharing of data. Feedback from the workshop groups contributed to the ideas captured in the discussion, and more quantitative results were derived from task two when each participant was asked to identify the importance of different data types and topics both for them as stakeholders, and for sharing amongst the wider community (Supplementary Table 1).

To test the extent that different stakeholders ranked the importance of data differently, we performed statistical analyses on the responses for the second aim of the workshop (understanding the benefits of data sharing). Generalised Linear Models (GLM) were fitted with binomial error structures to test for differences in what TSOs, NGOs and Others (as three stakeholder groups) thought were the most important data / information types and topics, in which the number of stickers placed by each stakeholder type for each combination of data was modelled as a function of the total number of stakeholders in each group. We tested for differences among the three groups of the workshop (which contained a mix of stakeholders) to control for potential ‘group’ effects. We also tested for any interactions between the terms (for example, if there was an observed difference in the importance of data types, the interactive term would test if this depended on the topic, such as electrocution or abundance). Analyses were conducted in the statistical package SAS 9.4 (SAS Institute Inc., 2016).

3. Results

3.1 Questionnaire

Sixteen TSOs from across Europe responded to the questionnaire (Table 1), although four TSOs that operate in Germany answered the questionnaire jointly, so there was a total of 13 questionnaire responses.

Table 1 *Transmissions system operators, and the countries in which they operate, that responded to the questionnaire.*

Transmissions System Operator (abbrv.)	**Country of operation**
Austrian Power Grid (APG)	Austria
Elia	Belgium
Fingrid Oyj (Fingrid)	Finland
Réseau de Transport d'Électricité (RTE)	France
Amprion*	Germany
50Hertz*	Germany
Transnet BW*	Germany
TenneT*	Germany
Mavir	Hungary
Terna Rete Italia S.p.A. (Terna)	Italy
AS "Augstsprieguma tikls" (AST)	Latvia
TenneT	The Netherlands
Polskie Sieci Elektroenergetyczne S.A. (PSE)	Poland
Redes Energéticas Nacionais (REN)	Portugal
EirGrid	Republic of Ireland
Swissgrid	Switzerland

*answered jointly.

3.2 Reasons for bird data collection and partnerships with organisations

Two of the TSOs stated that they have no legal requirement to collect bird data by regional, national or other authorities pre-construction of powerlines, and four stated that they have no legal obligation post-construction. All others stated that they have some legal obligation to collect bird data (Fig. 1). Two comments explained that the legal requirements for bird data collection depended on the scale (and potential impact) of each project.

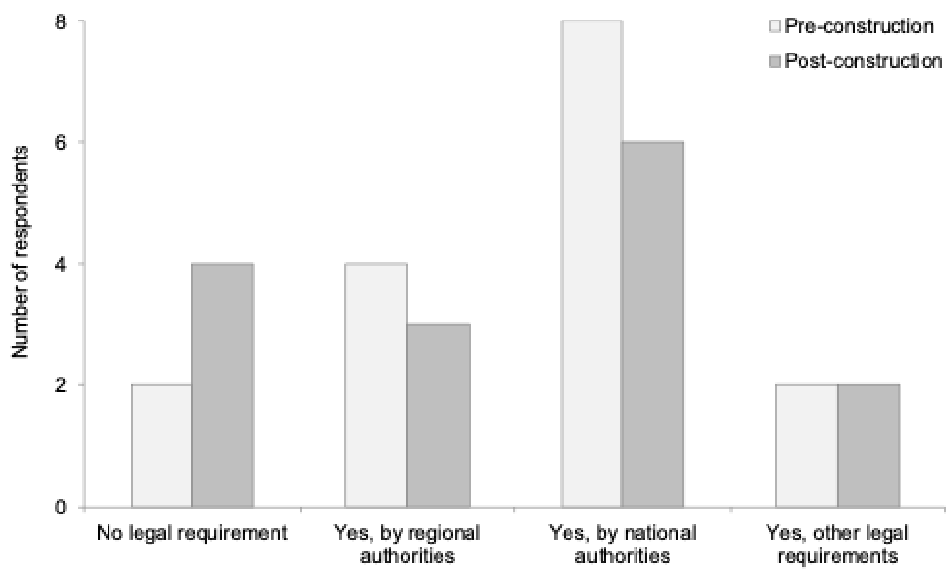

Fig. 1 *The number of Transmission System Operators that had legal requirements to collect bird data pre- or post-construction of powerlines at a regional, national or other level, and the number of TSOs that had no legal requirements to collect bird data (total n = 13 TSOs). Note that some TSOs provided multiple answers.*

All but three TSOs stated that they have partnerships with NGOs to some capacity; over half (*n* = 7) had partnerships on a national level; two TSOs worked with NGOs at some sites on the ground, two involved NGOs as key stakeholders in decision-making and two work with NGOs in another capacity. Some TSOs appeared to have strong partnerships with multiple NGOs; for example, collaborating with different NGOs to develop collision-risk maps and to develop good-practice guidance. Some usually involved local and national NGOs when planning infrastructure and have worked with NGOs on specific scientific projects. One of the TSOs who said they have no involvement with NGOs stated that they plan on doing in the future and another stated that they involve NGOs if there are specific questions they may be able to advise on.

3.3 The range of bird data collected by TSOs

Nine TSOs stated that they collect at least some bird mortality / injury data; four of these collected both systematic (i.e. using a specific method as part of a monitoring programme) and opportunistic (e.g. when there is a power outage) data, four collected data only systematically and one collected bird mortality data only opportunistically.

One TSO stated that they have not collected data on bird presence/abundance but relied on existing external data sources on bird presence/abundance for pre-construction consent. Nine TSOs used external contractors to collect presence data for pre-construction consent and six for post-construction monitoring.

Seven TSOs stated that they had specific methods for observing birds during presence surveys. A variety of methods were listed by the TSOs including line transects, point counts, vantage point counts, car transects for specific bird groups (e.g. bustards), nest box observations and radar-monitoring.

3.4 Making use of bird data

The majority (*n* = 11) of the 13 TSOs stated that they have modified, replaced or re-designed infrastructure in some way based on their bird data, with nine stating that they deployed bird diverters on existing lines, and two that they placed markers on lines based on predictions of where there will be higher collision risks. Five TSOs stated that, before construction, route planning might be adjusted in higher risk areas. Eight of the 11 TSOs that answered the question have an inventory of their modifications and all knew how many pylons or km of powerlines have been modified.

3.5 Sharing of bird data

Just over half of TSOs that answered stated that they have not shared bird mortality/injury, bird presence, or data on location of bird deflectors with NGOs (Table 2). Four TSOs stated that they shared mortality data and data on location of bird deflectors with NGOs, and five stated that they shared bird presence data. Over half of TSOs stated that they have not shared any of the types of data with other power companies. Most sharing was not to fulfil legal requirements (Table 2). One TSO has in the past shared large amounts of bird presence data to the ‘open data’ section on their website – the data were collected as part of a project with a local NGO and the data are now publicly available. This TSO is moving towards an open-data approach in relation to their bird presence data. Another TSO shared their data as part of a collaborative programme with a university.

Table 2 *The number of Transmission Systems Operators to share bird and/or mitigation data with NGOs, other power companies, government-run databases, or others, such as academics.*

	Type of data shared								
	Bird mortality/injury data			**Bird presence/abundance data**			**Where insulators, markers or bird deflectors have been installed**		
	No	Yes, as a legal requirement	Yes, but it is not a legal requirement	No	Yes, as a legal requirement	Yes, but it is not a legal requirement	No	Yes, as a legal requirement	Yes, but it is not a legal requirement
NGOs	5	0	4	5	0	5	6	0	4
Other power companies	7	0	1	6	0	2	6	0	3
Government-run centralised database	7	2	0	5	3	2	5	2	1
Other	0	0	1	1	0	2	2	0	1

Two of the 12 TSOs that answered the question stated that effective sharing of bird data is already simple. The most common concerns about effective data sharing were that there is no centralised database (*n* = 7), the lack of resources to do so (*n* = 6), and it is unclear who to share the data with (*n* = 5), or what data to share (*n* = 4; Fig. 2). Some TSOs also stated that their data are confidential (*n* = 4), with one particularly emphasising this point in relation to endangered species. Two TSOs voiced concerns about commercial interest or other reasons to prevent effective data sharing. For example, one respondent said that few birds are affected by their powerlines, so sharing collision/electrocution data might be damaging for public relationships.

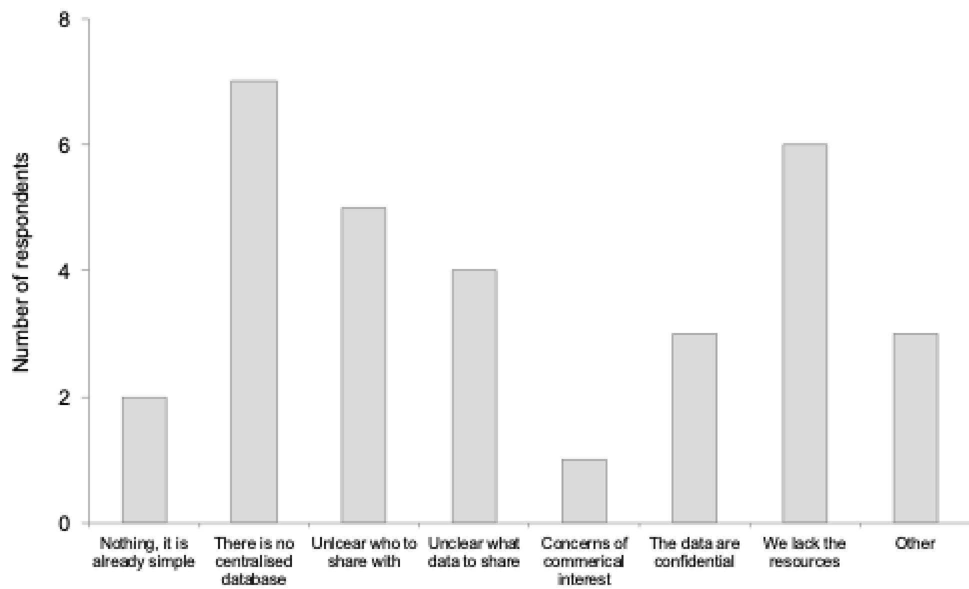

Fig. 2 *The number of Transmission System Operators that provided different reasons for the prevention of effective sharing of bird data (total n = 12, note that multiple reasons could be provided by each respondent).*

Seven of the 12 TSOs that answered the question said that a centralised database would help to inform their decision making on reducing bird interactions with powerlines, whilst the other five said such a database would not. Five respondents suggested that a centralised database would not be useful because data concerning bird-powerline interactions are localised and/or may not be relevant to other countries, although one TSO suggested that sharing would be useful for the most vulnerable species. A common requirement suggested in the comments was that methods should be standardised in order for the data to be comparable.

Two TSOs said they would be willing, and six potentially willing, to share their data with a centralised database. The five TSOs that said they would not be willing justified this with a range of reasons; they have no data to share, data on sensitive species are confidential, there is no recognisable benefit or need, or that data are already shared with a national database.

Six of the 10 TSOs that answered the question about financing a centralised database said that industry should finance such a database; six said that government agencies should and two said that NGOs should.

3.6 Workshop

The importance of different data types varied significantly between stakeholders and whether they considered the data important for sharing, or for their own operations (significant 3-way interaction χ^2_8 =

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23.17, P = 0.003; Fig. 3). Raw field-collected data from specific studies were most important to NGOs in order to understand the impacts on particular species. Most other types of data were less important, although the importance of peer-reviewed studies did not differ significantly from field-collected data (Fig. 3a). More than 50% of NGO representatives found it important to share study data, but also found unpublished reports, peer-reviewed literature and meta-analyses important to share, albeit significantly less so (Fig. 3b). Raw field-collected data from specific studies and peer-reviewed studies were significantly more important to TSOs than other forms of data, although at least 40% also wanted access to the results of literature reviews and meta-analysis to understand the best available evidence on impacts and mitigation potential (Fig. 3a). Similar preferences were expressed by TSOs for data sharing (Fig. 3b). Other stakeholders also wanted access to study data more than other forms of data (Fig. 3a), but thought it important to share all forms of data and information, particularly meta-analses and literature reviews, recognising the value of the overall synthesis they provide (Fig. 3b).

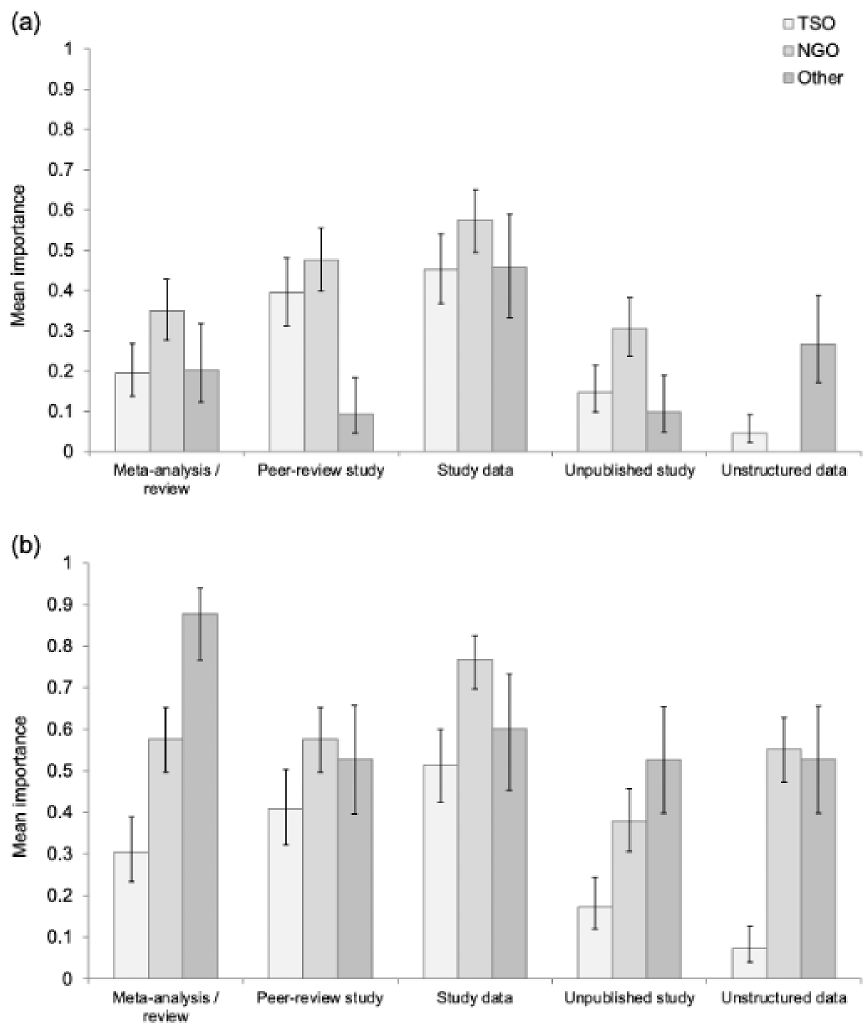

__Fig. 3__ Predicted importance (proportion of each stakeholder listing data type as important) of different data types to different stakholders for (a) themselves and (b) for sharing. Predicted importance ± SE derived from binomial error GLM (see methods).

There was however no significant difference between stakeholders and the importance of different topics of data for the stakeholder or for sharing (2-way interaction $\chi^2_6 = 6.66$, $P = 0.35$). However, there was significant variation between the types of data and the topic of data (significant 2-way interaction $\chi^2_{12} = 30.60$, $P = 0.002$; Fig.4). Thus, there was consistency between stakeholders, and between sharing and importance to them, in terms of the types of data that are important. The most important data (supported by more than 50% of individuals) were, therefore: (i) study data on the impacts of powerlines on abundance, collision and electrocution, (ii) published studies on the impacts of powerlines on abundance, electrocution and mitigation effectiveness and (iii) the results of literature reviews and meta-analysis on the success of mitigation (Fig. 4). The greatest interest in study data was to document impacts of powerlines on the abundance, collision and electrocution of birds, which significantly contrasted with a keenness in other forms of data for these impacts. Conversely, the greatest interest in the data on mitigation was from meta-analyses and reviews, demonstrating a lack of knowledge about the likely effectiveness of mitigation which all stakeholders would value robust evidence about.

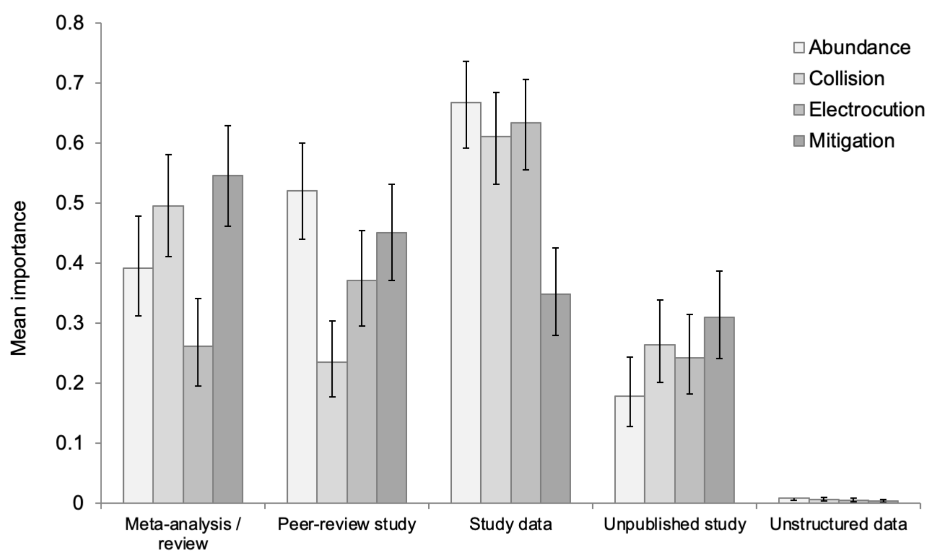

__Fig. 4__ Predicted importance of different data sources (meta-analysis, peer-review etc) for the different types of data (bird abundance, collision, etc.). Predicted importance ± SE derived from binomial error GLM (see methods).

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4. Discussion

Through use of a questionnaire and workshop, we assessed the scope and quality of bird data and the potential for wider sharing of data among TSOs, non-governmental organisations (NGOs) and researchers to inform environmental management decisions around powerline infrastructure across Europe.

Whilst the majority of European TSOs collect at least some data on bird presence and/or mortalities at powerlines to inform environmental management decisions, it is clear from our results that the amount of data and frequency of collection differs among companies. Unless the data are collected for a specific scientific purpose (e.g. as part of a specific study) or where powerlines are situated in a particularly bird-sensitive location, monitoring is undertaken relatively infrequently. Most TSOs have some form of partnerships with NGOs, with some already collaborating in academic research through data collection, financial support and/or guidance, leading to peer-reviewed publication (e.g. Panuccio et al., 2018; D'Amico et al., 2019; Moreira, 2019), and this tends to be where the most intensive data are collected.

4.1 Importance of certain data

Our results demonstrate that there was interest in the results of peer-reviewed studies being made more available and accessible (Fig. 3), particularly recognising the particular stamp of quality assurance that peer-review provides. Lack of access to peer-reviewed scientific articles by environmental management decision makers is not a new issue (e.g. Pullin et al., 2004) and may be addressed by collating only the summaries and key messages from papers, as has been achieved more broadly by Sutherland et al. (2020).

The provision of raw data and unpublished reports (or 'grey literature'), such as EIA reports, was particularly valued by NGOs and discussions suggested that making such unpublished reports available could provide an important forum to identify and address particular issues and to build trust between environmental management decision makers. Indeed, data from some internal reports provided by TSOs have already been utilised in peer-reviewed meta-analyses (e.g. Barrientos et al., 2018) and may therefore provide an important source of information to prioritise and inform future conservation efforts around powerlines, if made more widely available. The high value associated with the provision of study data, particularly for NGOs (Fig. 3), was to identify areas where powerlines were having high impacts on bird populations. Many TSOs collect such data, although much of these data are not systematic. TSOs are concerned about the reputational risk from making data and results of studies of powerline impacts more available, whilst NGOs are keen that such data are used to inform conservation solutions. This poses an apparent dilemma, which is not surprising given the plethora of human and environmental factors concerned with environmental management. However, the fact that many TSOs already collaborate effectively with NGOs and academic groups provides evidence that effective collaboration and working between different stakeholders to address the issues of avian mortality associated with transmission lines is possible.

There was a particular need for access to studies on mitigation effectiveness, with agreement that one of the critical uncertainties that remains is over the effectiveness of different line-marking approaches. Whilst evidence is accumulating that line-marking is effective, the relative efficacy of different approaches is not well understood (Bernardino et al., 2018). Data/articles used to inform the effectiveness of different mitigation techniques was therefore flagged as one of the most important to capture, alongside meta-analysis and review of the results of multiple studies to guide industry in the most effective approaches to use.

SEAs and EIAs should ensure appropriate siting of powerlines in the early planning stages, which is one of the most effective measures to reduce bird collisions (Bernadino et al., 2018). For a robust assessment, these processes require quality information about the location and abundance of potentially vulnerable species and habitats, as well as information on the movements and behaviour of birds, in order to identify the most sensitive geographical areas. Sensitivity approaches, first developed in relation to wind energy (e.g. Bright et al., 2008) are increasingly being applied to the environmental management of powerlines (e.g. Pérez-García et al., 2017; Hernández-Lambraño et al., 2018; D'Amico et al., 2019). Not only do such sensitivity maps inform SEAs, potentially minimising the cost and difficulty of securing consent for transmission line construction by avoiding the most sensitive areas, but they can also be used to prioritise the monitoring and marking of existing transmission lines. Improving access to data on the occurrence, abundance and movements of birds to inform SEAs and EIAs was identified as a high priority by the stakeholders at the workshop and should be one of the main foci of potential data sharing. This would include increasing the availability of data from NGOs and other organisations involved in wider bird monitoring, and also improve the flow of abundance and distribution data collected as part of EIAs and other surveys, to more centralised data repositories to make them more openly available (see Pearce-Higgins et al. 2018).

These conclusions reflect the results of a recent review of renewable energy and biodiversity conservation that the use of spatial decision support tools, improved understanding on the impact of renewable energy and testing mitigation systems were required to evaluate different future scenarios (Agha et al., 2020). The availability of spatial data, particularly to inform multi-criteria decision-making, can be an important tool for achieving consensus in where renewable energy infrastructure should be sited (Hanssen et al., 2018), and is an important pre-requisite to minimise the conflict associated with renewable energy development (Bright et al., 2008); low rates of avian mortalities at UK wind farms probably result from their avoidance of areas of high bird activity (Warren & Birnie, 2009). The monitoring of birds and their interactions with renewable energy infrastructure is required to support meta-analyses of the cumulative impacts of renewable energy infrastructure, regarded as a priority (Smith & Dwyer, 2016). The recommendations of our workshop provide a way forward to fill these data gaps, which is especially urgent in areas with rapidly increasing power networks (Puig et al., 2021).

4.2 Sharing of data and the creation of a centralised database

Although the idea of a centralised database for bird data was welcomed by around half of the TSOs, in order for this to be effective, the aims of data sharing should be made explicit and data sharing needs to be made simple and cost-effective. We found that the most common barrier to effective data sharing was that there is currently no centralised database (Fig. 2), suggesting that there would be support for such a system if created and properly resourced. Although potentially slight, contributing to a centralised database would take time and cost money, and these factors would need to be considered by TSOs. However, for companies not already collecting large amounts of data and/or in partnership with other organisations that store data, such as NGOs, a centralised database has the potential to archive data that are not currently being stored in an accessible format.

For others, there is a stronger need for the development of more model-based products such as a repository of sensitivity maps (e.g., Pérez-García et al., 2017; Hernández-Lambraño et al., 2018; D'Amico et al., 2019), including interactive online mapping tools that identify sensitive areas on an international scale as has been done for the wind energy sector (Migratory Soaring Birds Project, 2021). Stakeholders could see the value developing tools like this, which would reduce the conflict between bird conservation and transmission-line deployment. The two priorities are linked, as having a centralised system where TSOs can input data that can be included in modelling studies might be an important avenue to aid scientific research and ultimately reduce risk of population-level impacts on birds.

The lack of standardisation of methods to collect bird data was flagged as a key barrier in the collection and sharing of data by the stakeholders. To address this deficiency, improved standardisation and guidance of methods is suggested, as has been highlighted in the wind farm industry (e.g. Bernardino et al., 2013; Fernández-Bellon, 2020). This would also help TSOs that are not yet sharing data with the design of studies and database formats to ensure that they are transferable. We suggest that the FAIR principles for scientific data management and stewardship (data being Findable, Accessible, Interoperable and Resusable) could form a useful guide for development in this area (Wilkinson et al., 2016). The

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standardisation of methods, or at least appreciation that methods across studies are not standardised, should be recognised before attempted collation of data and information.

Confidentiality concerns were also highlighted as a barrier to sharing data, particularly in relation to data on sensitive species as well as locations of pylons and lines. Similar concerns also applied to making unpublished reports available, given the potential risk of misrepresentation and adverse publicity relating the environmental management decisions. A potential way forward would be to share meta-information about studies and data that could be available across a trusted network of organisations. Similarly, a bibliography of unpublished reports could be an alternative or complementary solution, with the potential for those reports to then be requested within the network. This would enable data to be findable, accessible, and if supported with sufficient meta-data, reusable (Wilkinson et al., 2016). The main cost to those contributing studies and data would be in ensuring that the meta-data were accurate and that studies were properly archived. As well as improving information exchange and therefore increasing the knowledge and information to inform the development of solutions to this conflict, this system would provide a relatively limited and safe space within which trust could grow among stakeholders. Such a model of a centralised hub providing information about data and studies which could be made available on request, is similar to one of the potential models by which citizen science biodiversity recording data, which are also associated with challenges of data ownership and confidentiality, may be made more openly available (Pearce-Higgins et al. 2018).

4.3 Summary and Conclusions

In summary, there is wide recognition of the value of different types of data and information on birds at powerlines, and a positive attitude to working together across TSOs, NGOs and other stakeholders, such as academic researchers. Indeed, involving of a range of stakeholders when making environmental management decsisons, such as implementing best mitigation measures, is critical to ensure success (Haddaway et al. 2017). There is a shared goal among stakeholders to reduce bird mortalities, whether it be for conservation or economic reasons, which is a good foundation for addressing a significant human-wildlife conflict. The collection of a range of data related to bird ecology and demography, mitigation measures and environmental data is imperative to inform what impacts powerlines have on populations and how these impacts can be reduced, as conceptualised in Figure 5. Ultimately, sharing standardised high-quality data may help to inform best mitigation practices, for example adopting the FAIR principles. However, in order for this to be achievable, a stepwise approach might be required to foster increased data sharing and collaboration through time. This would require: (i) the development of guidance around the field methods and data to be collected for EIAs and studies of impact and mitigation effectiveness, (ii) the sharing of meta-data / bibliography of studies of powerline impacts / mitigation effectiveness to increase the visibility of relevant studies being conducted, and (iii) a scoping study of the structure of data and information already being collected and shared, as a first step to developing a cost- and time-effective way of sharing data / information on a wide scale.

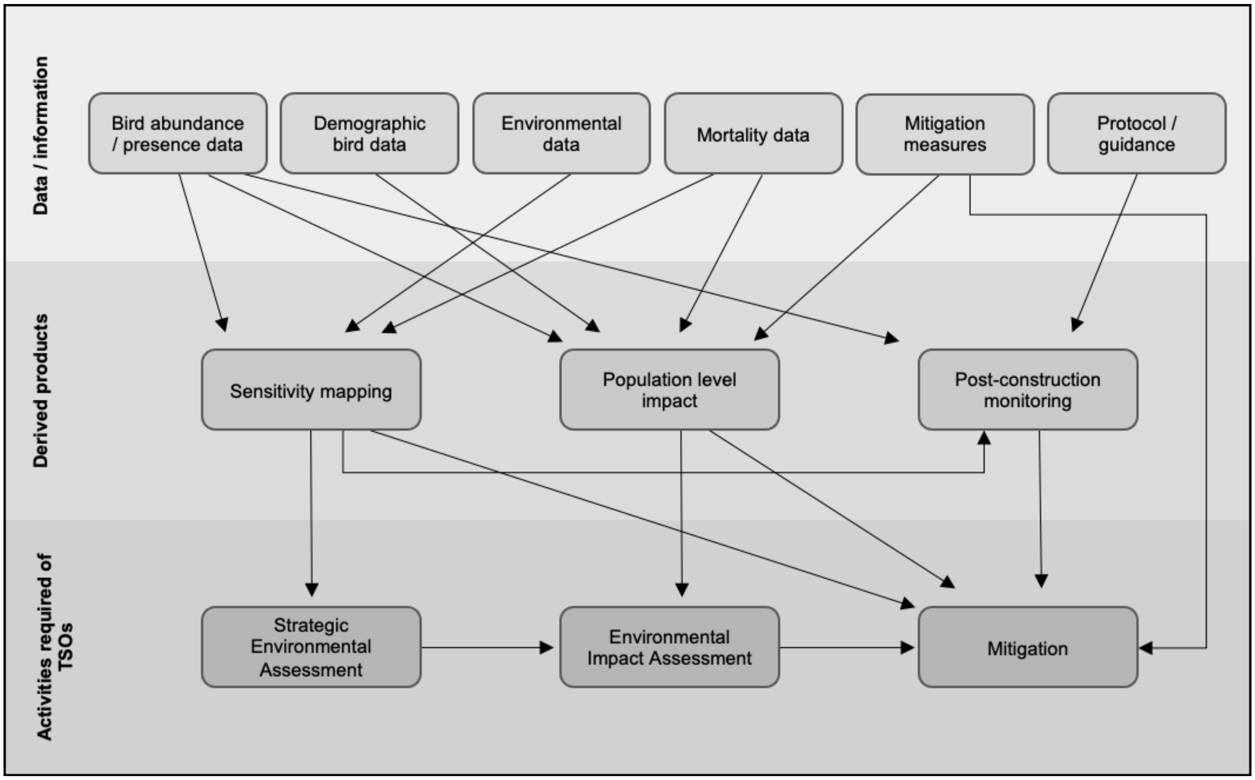

Fig. 5 *Conceptual framework for how data / information (top) informs derived products (middle) and activities required of TSOs (bottom).*

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Author contributions

Esther Kettel: methodology, formal analysis, investigation, writing – orginal draft, writing – review and editing, visualisation; **Chris Thaxter**: methodlogy, investigation, writing – orginal draft, writing – review and editing; **Steffen Oppel:** methodology, writing – review and editing**; Andrew Carryer:** conceptualization, methodology, project administration, funding aquistition**; Liam Innis:** writing – review and editing; **James Pearce-Higgins:** conceptualisation, methodology, formal analysis, investigation, writing – orginal draft, writing – review and editing, visualisation, supervision, project administration, funding acquisition.

Declaration of competing interests

The authors declare no competing financial interests or personal relationships that could influence the work reported in this paper.

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